CONFERENCE PROCEEDINGS

Pan African Society for Agricultural Engineering
&
The Nigerian Institution of Agricultural Engineers
(A Division of the Nigerian Society of Engineers)

2021

VIRTUAL
INTERNATIONAL
CONFERENCE

"Africa's Agenda 2063: The Africa We Want"

Theme:
Engineering Africa's Agro-Industrial Transformation for Economic Prosperity and Sustainable Development

Date: 19-22 April, 2021
Venue: Zoom

AfroAgEng
PAN AFRICAN SOCIETY FOR AGRICULTURAL ENGINEERING

Pan African Society for Agricultural Engineering
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2021 VIRTUAL INTERNATIONAL CONFERENCE



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Title:
The Conference Plenary And Workshop Presentations

PAN AFRICAN SOCIETY FOR AGRICULTURAL ENGINEERING

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d) Farm Structures, Environment And Emerging Technologies

CONFERENCE REPORT

Pan African Society for Agricultural Engineering
&
The Nigerian Institution of Agricultural Engineers
PASAE-NIAE 2021 INTERNATIONAL CONFERENCE

"Africa's Agenda 2063: The Africa We Want"
Engineering Africa's Agro-Industrial
Transformation for Economic Prosperity and Sustainable Development
Date: 19-22 April 2021

Background:

The conference was jointly organized by the AfroAgEng — the Pan African Society for Agricultural Engineering (PASAE) and the Nigerian Institution of Agricultural Engineers (NIAE), and was focused on adequately apprehending the wide dimensions, the multi-faceted challenges, the abundant emerging opportunities andprospects for agricultural and rural transformation in Africa, in line with the Africa Agenda 2063 — The Africa We Want. Thus, the conference was essentially aimed at harnessing an emerging global movement for Africa's renaissance through knowledge and practice-driven agriculture and agriculture-led industrialization. It was noted that Africa's potentials in human, agricultural and natural resources is significant but largely under exploited and underutilized, hence there was the need to create a new momentum for concerted action. The critical role and the need for agricultural engineering in achieving these goals does not seem to have been adequately appreciated in the policies and actions designed for them. Hence, the conference was aimed at securing the understanding and buy-in of critical stakeholders, policy makers, development and financial institutions in the potentials and prospects for agricultural engineering interventions in attaining the set goals for transforming Africa into a productive, competitive and sustainable "global economic power house", where people live in prosperity.

Conference Theme:

Theme: Engineering Africa's Agro - Industrial Transformation for Sustainable Development and Economic Prosperity

Sub Theme:

1.Towards 2063 — Strategies for exploiting Africa's demographic dividend, encouraging the youths in agri- business, and attaining key SDGs; infrastructure development, food security, poverty reduction and creation of decent jobs.

2. Sustainable pathways to Africa's structural transformation through agro-equipment development, driven by local capacity and content, agro industrialization and thriving agricultural value chains.

"Agricultural, Biosystems and Environmental Engineers have a responsibility to drive the modernisation of Africa's agriculture and to create the foundation for its commercialisation. New technologies are critical in expanding hectarage; improving farm productivity not only in crops, but also livestock, aquaculture, marine and forestry products; ensuring efficiency in resource use and protecting the environment. Agricultural, Biosystems and Environmental engineers must also support the introduction of efficient and least-cost technologies and farming practices that will enhance productivity growth, eliminate post-harvest losses, and enhance the overall quality and acceptability of agricultural products on the African and global markets"

3. Boosting agricultural productivity and economic diversification through mechanization, precision farming soil conservation, irrigation, and livestock transformation.
4. Development and application of appropriate technologies to reduce post-harvest losses, sustainable energy development and value engineering in the agricultural value chains.
5. Agriculture, smart farming and the 4" industrial revolution — exploiting modern intelligent technologies (Drones, AI, Robotics and Machine Learning, etc) in farming and rural transformation.
6. Human capital for modern agriculture - transforming tertiary institution curricula/programmes and pedagogies to meet the challenges of Agenda 2063.
7. Mobilising global partnerships for climate action/climate-smart farming, conservation of Africa's agro-ecology, biodiversity, forestry and for dryland farming.

CONFERENCE FORMAT

The conference, earlier scheduled to hold in Abuja, Nigeria from September 21-24 2020, became a victim of COVID-19, and was postponed indefinitely, but subsequently rescheduled to hold virtually from April 19-22, 2021. Two of the earlier envisaged six high-level workshops were held on Day 1, Monday April 19 (Workshop E on Growing Agricultural Engineering in Africa, was held virtually on September 21, 202 – see pp75-79 of the brochure). The Plenary sessions, formal conference opening and the technical sessions followed on April 20 and 21. The last day, April 22, was set aside for the participation of students and the Annual General Meeting (AGM) of the Nigerian Institution (NIAE).

Professional Development Workshops and Master classes

To harness the momentum of the conference, Six High-Level Professional Training Workshops/ Masterclasses running concurrently were planned for the first day of the Conference, Monday April 19th. However, only two (A & F) were run from 9.00am to 3.30pm in the virtual mode. Details of the Six designed workshops are as follows, with the two that held in April (A & F) highlighted in green. Workshop E, in blue, held earlier:

A. High-Level Professional Development Workshop on postharvest engineering and the development of export processing zones/agro-industrial or knowledge parks to boost agro-industrial development.

B. High-Level Professional Development Workshop on harnessing Africa's water resources and modern irrigation technologies to boost agricultural productivity.

C. Masterclass on effective use of big data, artificial intelligence and blockchain technology in enhancing farm productivity and sustainability.

D. Masterclass on strategic engagement of digital technologies, youth and women in agriculture and rural transformation.

E. High-Level Professional Development Workshop on transforming tertiary institution curricula/programmes and pedagogies to promote quality graduates to meet the Agenda 2063 challenges – Growing Agricultural Engineering in Africa.

F. Masterclass on the principles and approaches for training and practice in intellectual property management for engineering professionals.

Conference Proceedings and Outlet Indexed Journals

This conference Proceedings has been put together by the Conference Technical Committee,led by Prof. A. P. Onwualu of the African University of Science and Technology (www.aust.edu,ng), Abuja and Deputy President (and In-coming President of the Nigerian Academy of Engineering, NAEng). It contains all materials presented at the conference, including the Plenary and Workshop presentations, Technical papers and Winning presentations from the Students' contests. Authors also have the option of getting their papers into indexed outlets including the PASAE's Journal of Advances in Agricultural Technology (JAAT). NIAE's Journal of Agricultural Engineering and Technology (JAET) (http://www.jaet.com.ng/ index.php/Jaet), Agricultural Mechanization in Africa, Asia and Latin America (AMA) (https://journals.indexcopernicus.com/search/ details?id=1674) and Int. J. Postharvest Technology & Innovation (https://www. inderscience.com/ijpti).

STUDENTS' PARTICIPATION

Getting students to participate actively in the activities of PASAE was a major objective, and the conference provided the opportunity to commence the initiative of a quiz competition and other creative means (technical presentations) of securing the interest of students. We can consider the outing at this conference to be a good start in the effort to catch our students young and get them involved in PASAE professional activities. The momentum generated from these activities have been very impressive and most inspiring. PASAE Council will build on these and harness the immense energy and creativity of our students. They have been very impressive in their preparation and participation in the activities. Hopefully, we shall have greater international spread and reach in the next editions.

SYNOPSIS AND FOLLOW-UP ACTION PLAN

Key Observations

The following were the key observations made at the session:

1.Agricultural mechanization remains an indispensable pillar for attaining the zero-hunger continental vision by 2015 of the Malabo Declaration of 2014, Aspiration 1 of the African Agenda 2063 and SDG No 2 by 2030. The need to double Africa's agricultural productivity, eliminating hunger and malnutrition by 2025 can only be realised if we inclusively provide access to mechanization services, improve access to all other agricultural inputs (good healthy seeds, fertilizer, herbicides and extension management services), provide efficient irrigation and make farming more attractive and profitable to the youth and women.

2.Presently, Africa is a net importer of food and agricultural products at a level of about 80 billion US dollars annually, with only a tiny fraction originating from the continent. This implies that if requisite investments are made in agriculture, at the minimum, Africa can increase cross border trade by capturing a significant share of the 80 billion US dollars of agriculture imports. However, African agriculture should not be aimed at food sufficiency alone, it must also address Africa's structural transformation into an industrial manufacturing power house, able to compete as a viable economic entity.

3.The Farmstead Planning Approach, which embraces the concept of Special Agricultural Production and Integrated Processing zones (SAPZ), being promoted by the African Development Bank (AfDB), presents a feasible pathway for achieving the goals of the Africa we want, and SDGs 1, 2 and 9 in Africa. The approach must be blended with the UNFAO's Framework for Sustainable Agricultural mechanization in Africa (F-SAMA) and ASABE's MAA designed for tackling the twin problems of poor agricultural productivity/food and nutrition insecurity compounded by acute postharvest losses and agro-industrialization to address much needed structural transformation of the African economy, as a necessity for creating wealth and employment opportunities for its rapidly growing population.

4.SAPZ, MAA and F-SAMA are construed, designed and built along the agricultural value chain, government and academia supported private sector driven initiatives (representing a triple-helix framework), environmentally compatible and climate smart in conception. They are economically viable and inclusive of the interest of small farmers and cooperatives (the bulk of African food producers), including women (who bear the brunt of farming) and youths (who must be encouraged to bring-in their creativity, innovation and entrepreneurship). They are also compatible with modernised indigenous African farming systems.

5.PASAE, NIAE and conference delegates subscribe to championing the attainment of (Aspiration5.PASAE, NIAE and conference delegates subscribe to championing the attainment of (Aspiration 6 of the African Agenda 2063): "An Africa whose development Is people-driven, relying on the potential of African people, especially its women and youth and caring for children". African knowledge and human capital must be the driver and engine of its emancipation and growth.

6.Consequently, African Agricultural, Biosystems and Environmental Engineers, working in partnership with various bodies with shared values (SDG 17), have a responsibility to drive the modernisation of Africa's agriculture and to create the foundation for its commercialisation. New technologies are critical in expanding hectarage; improving farm productivity not only in crops, but also livestock, aquaculture, marine and forestry products; ensuring efficiency in resource use and protecting the environment. Agricultural, Biosystems and Environmental engineers must also support the introduction of efficient and least-cost technologies and farming practices that will enhance productivity growth, eliminate post-harvest losses, and enhance the overall quality and acceptability of agricultural products on the African and global markets.

7.Modern digital technologies, including Artificial Intelligence, machine learning, use of drones, etc, hold the key to transforming Africa's agriculture and trade. The conference noted happily that AFREXIMBANK is investing heavily in a host of technologies including the Pan African Payments and Settlements System and the African Customer Due Diligence Repository, indicating one of the potential areas for collaboration with PASAE and NIAE.

8.To realise the full potential of the African Continental Free Trade Area Agreement (AfCFTA), deliberate policies and programmes to commercialise agriculture in Africa must proceed earnestly. These policies and programmes should focus on formalising the largely informal sector, reforming the land tenure and ownership systems, creating incentive schemes to leverage private capital into agriculture and acquiring modern farming technologies that will improve and sustain agricultural productivity.

9.PASAE and NIAE have successfully built bridges with key continental and international development agencies and private sector actors such as the AfDB, AFREXIMBANK, UNFAO, UNIDO, Intellidigest, CHEAM/FTN, Bari, ASABE, and CSAE to mention a few, to forge the partnership for action in alignment with SDG No 17 and the move towards the Africa we Want. This was one of the goals of PASAE in its strategic plan.

"Modern digital technologies, including Artificial Intelligence, machine learning, use of drones, etc, hold the key to transforming Africa's agriculture and trade. The conference noted happily that Afreximbank is investing heavily in a host of technologies including the Pan African Payments and Settlements System and the African Customer Due Diligence Repository, indicating one of the potential areas for collaboration with PASAE and NIAE".

10.The conference had good international participation, though it could have been better. In the case of Nigeria, this conference has substantially reawakened interest in the NIAE and we shall capitalize and build on the new momentum to reform our structures and governance in order to enhance the relevance of our profession to the country and sustain the interest of our members. We shall secure the understanding and buy-in of the larger society and industry into the immense possibilities to advance the cause of the Africa We Want which Agricultural, biosystems and environmental engineering practice entails.

11.Significantly, we recorded great success in mobilizing students and the youths through the Quiz and Technical presentation competitions which engaged students. The students were greatly inspired, mobilized and mentored. They were actually a major part of the success of our grow Agricultural Engineering campaign. The conference social media publicity could not have been this successful, but for the involvement of the youth and students. They are the strength for our profession now and in future.

12.We consider this as a good start in our initiative to catch our students young and get them involved in PASAE professional activities. The momentum generated from these activities have been very impressive and most inspiring. We shall build on these and harness the immense energy and creativity of our students. They have been very impressive in their participation. Next time we shall have greater international spread and reach.

13.During the Masterclasses, the plenary and technical sessions of the conference, it was clear that we know where we want to be. Indeed, there seemed to be an unrelenting large focus on technological systems that are currently in use for production and processing as well as emerging digital possibilities. So, we apparently also know what we need to do, leaving us with the big challenge of bridging the gap between this "where" and "what". The challenge is to reflect deeply on "how" to accomplish the goal in a cost-effective way, efficiently and sustainably, working at many different levels. Our work to promote the profession must embrace the small-scale farmer (especially women who will need to abandon the hoe, as symbolically pledged in Burkina Faso in 2019)as much as it does the large scale, intensive and commercial operations.

14.We recognise that there are always three groups in a society – those who make things happen, those that watch things happen, and those who do not know what happened. In other words, there are the 25% at the top who will apply all of the new emerging technologies anyway and another 25% at the bottom for whom whatever technology available has no meaning or attraction and consider them too big a risk. The strategic/systems approach impels us to focus on the 50% in the middle as those we need to influence the most. It is from this group that the change we need for impact will come.

15.Imperatively, we must also consider our intervention to embrace "Engineering in Agriculture", which entails use of all engineers from other disciplines who are essentially "converted" to engineers working in agriculture especially mechanical, industrial, mechatronic, electronic, electrical and civil engineers who need to be 'infected' with agriculture in order to make a contribution. Our universities and polytechnics should offer short courses or a post graduate degree for these disciplines to be more knowledgeable in agricultural issues (like agronomy, soil science, irrigation, food processing, to mention a few). These paradigm shift must be reflected in our academic/knowledge institutions (universities and polytechnics), research and development agencies (research institutes and centres, such as NCAM and FIIRO in Nigeria) and industrial establishments

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16.The need for a review and modernization of the curriculum of our universities,polytechnics and other higher-level training and research institutions has been emphasized in the Grow Africa Workshop, to bring them in tandem with the knowledge and skill needs of African agriculture, the challenges of mitigating poverty and hunger, and one that will entice the youths and address the issue of low enrolment in Agricultural Engineering Programmes. Our products need such new knowledge such as hydroponics technology, smart agriculture, IOT, drone/autonomous aerial vehicle (AAV) technology, as well as AI, ML and big data analytics.

The above are just a few of the issues to stir our memories in exploring from our individual and corporate perspectives the import of what this 2021 virtual adventure has represented to the goal of attaining "the Africa we want" with Agricultural, Biosystems and Environmental Engineering in the driving seat of the progress.

RESOLUTIONS WITH ACTION PLAN

Delegates at the conferenceresolved to RECOMMEND as follows:

1.**PASAE, and its regional and national member associations, to work with the critical mass of partnerships which it has leveraged in this conference** (AfDB, AFREXIMBANK, UNFAO, UNIDO, Intellidigest, CHEAM/FTN, Bari, ASABE (MAA), and CSAE to mention a few) to drive the modernisation of Africa's agriculture (through the development of technologies, systems and innovations) and to create the foundation for its commercialisation. **This would also include Partnership with the AFREXIMBANK in the promotion and support for the goals of AfCFTA,** to which ABE engineers have been found indispensable.

2.**PASAE will work with AfDB, UNFAO, IFAD, WFP and other critical stakeholders to entrench the framework for UNFAO's SAMA and ASABE's MAA into SAPZ for synergy and better impact.**

The following are the synergies and benefits derivable from this approach to sustainable mechanization:

(i) Improved productivity and timeliness of agricultural operations

(ii) Improved resource use efficiency in agriculture

(iii) Creation of new employment opportunities.

(iv) Reduction of manual labour time, relieves labour shortages

(v) Enhanced food quality, safety, nutrition, (vi) Reduced food loss, and

(vii) Mitigating the effects of climate change by reducing greenhouse gas emissions.

3.**PASAE will work with UNFAO, ASABE and other interested parties to Identify and explore opportunity in non-traditional areas of investment in mechanization, including:**

(i)Innovative systems for sustainable technology development and transfer

-Develop innovative technologies targeting small-scale farmers, youth, women

-Enhancement of research/technology development, testing, transfer and extension etc.

-Sub-regional collaboration for the development and transfer of technologies

(ii)Sustainable transformation of land preparation & crop/animal husbandry practices
- To transform crop production techniques from current conventional tillage methods to sustainable agricultural practices: e.g. conservation agriculture (CA),Climate Smart Agriculture (CSA) etc.
- Adoption of sustainable land preparation techniques i.e. convince farmers to change.

(iii) Stimulate private sector investments to drive a market-led agricultural transformation is important
- Promoting innovative financing mechanisms for agricultural mechanization, by supporting farmers through credit or direct grants; Encouraging private sector to lead the investment efforts; Public sector must create conducive environment
- Building sustainable systems for manufacture and distribution of mechanization inputs, by
  (a) establishing and operating viable entities to manufacture agricultural machinery and implements;
  (b) setting standards and testing;
  (c) supporting franchises for distribution, repair & maintenance
- Emphasis on human resources development and capacity building for SAMA.
  (a) Investing in human resources (Skills Development) to help develop mechanization in Africa and
  (b) Capacity development at all levels is essential at all levels (Farmers, technicians, Engineers, entrepreneurs).

(iv) Boosting the rapid development of modern agro-processing capacity in the country
- Invest towards value addition on locally produce and reduce postharvest losses: Value addition for high quality innovative food products using raw materials from the SAPZs clusters.
- Boost power availability using appropriate technologies & innovative business models on agro-processing
- Enhance access and use of power in the cluster areas (ownership/support hire services, example Hello Tractor that is using an "Uber" like approach)
- Building sustainable systems for manufacture and distribution of mechanization inputs for agro-processing and value addition coupled with development of entrepreneurship skills

4.PASAE to build on the success of the mobilization of students and the regional and national re-awakening by sustaining the support for the regional and national bodies to grow. In the same way encourage and strengthen the formalization of student chapters in all member countries, and sustain students' activities in the annual conferences and other events. Prioritize advocacy and embrace the broad application of all engineering knowledge and expertise, working with other engineering professional.

5.PASAE to ensure the review and modernization of the curriculum of all universities, polytechnics and other higher-level training and research institutions offering Agricultural, Biosystems and Environmental Engineering, to bring them in tandem with the knowledge and skill needs of African agriculture, the challenges of mitigating poverty and hunger, and one that will entice the youths and address the issue of low enrolment in Agricultural Engineering Programmes.

6.PASAE would engage with the African Union and member countries to secure official endorsement as the continental Partner in coordinating the formulation and implementation of agricultural mechanization policies in relation to the Continental Agricultural Development Plan and the African Agenda 2063 on behalf of the African Union Commission.

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CONFERENCE APPRAISAL

Some of the verdicts on the PASAE-NIAE conference are collated thus;

1.**Ing Alastair Taylor, Former Secretary/CEO, UK Institute of Agric Engineering**
"I would like to congratulate the COC Chairman and the team for delivering such an excellent event".

2.**Ms. Gaelle Elisha, International Development Officer, Royal Academy of Engineering, UK**
"Thank you for letting me know and sharing the students' competitions' brief; this is great use of the funding indeed. I attended about half of workshop A, most of the plenary sessions on Day 1 and half of Day 2. Congratulations to you and your team for organizing such a large event remotely. I got to learn a great deal and found that the quality of the presentations was outstanding, particularly at workshop A".

3.**A Delegate from the Company ZZ2 based in South Africa, Grobler:**
"You will notice that that I motivate that we should talk of "Engineering in Agriculture" instead of only "Agricultural Engineering". The situation at ZZ2 (see www.zz2. co.za for extent of business), and the lack of Agricultural Engineers necessitated that we took engineers from other disciplines and "converted" them to engineers working in agriculture especially mechanical engineers that are "closer" to agricultural engineers than the other the other disciplines. In the end the industrial, mechatronic, electronic, electrical and civil engineers need to be infected with agriculture in order to make a contribution. We are negotiating with the University of Free State to offer short courses or a post graduate degree for these disciplines to be more knowledgeable on agricultural issues. We are thinking of courses like agronomy, soil science, irrigation, food processing and so on." I like the idea that we "infect" other engineers with agriculture. We need to similarly "infect and enthuse" our youth as to what an exciting time it is to be involve in AgTech. Thank you for your kind words. It was a pleasure participating in the session and having the opportunity to learn from the other wonderful presenters".

ACKNOWLEDGEMENTS

In all, we had a fruitful and productive conference, with considerable strategic partnership networking that would impact and advance the future prospects for PASAE and its regional/national constituent members. There seems to be quite a lot to do by PASAE towards attaining the goal of the "Africa we want". The African Union Commission (AUC) should endorse PASAE as a Partner on the journey. The conference represents a great first step and the future seems already well anticipated in PASAE's Strategic Plan.

The COC acknowledges the support of all our sponsors and partners as already indicated in the last pages and back cover of the Brochure. An African, perhaps global adage, says "without money, nothing can be done", hence we can say that without the hefty financial support of the Royal Academy of Engineering of the UK, this conference would not have recorded the spectacular success it has. We hope the success would convince the AUC to endorse a strong **"Agenda 2063 Implementor Partnership"** with PASAE, and also enthuse AfDB, AFREXIMBANK, IFAD, UNIDO, ASABE to strengthen their partnerships with PASAE towards developing technologies, systems and innovation to oil the attainment of the Agenda. We thank all who have facilitated, participated and would benefit from the conference.

CONFERENCE STORY

Prof. M. O. Faborode
Conference Chairman

These are some of the pictures from the conference, earlier scheduled to hold in Abuja, Nigeria from September 21-24 2020, that later became the victim of COVID-19, and was postponed indefinitely, but subsequently rescheduled to hold virtually from April 19-22, 2021

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PRE-CONFERENCE PICTURES

PRE-CONFERENCE PICTURES

MINISTER OF AGRIC AND CHAIRMAN COC, ON COURTESY CALL IN 2020

CHAIRMAN COC BRIEFING THE MINISTER ON THE CONFERENCE IN THE MINISTRY'S BOARDROOM.

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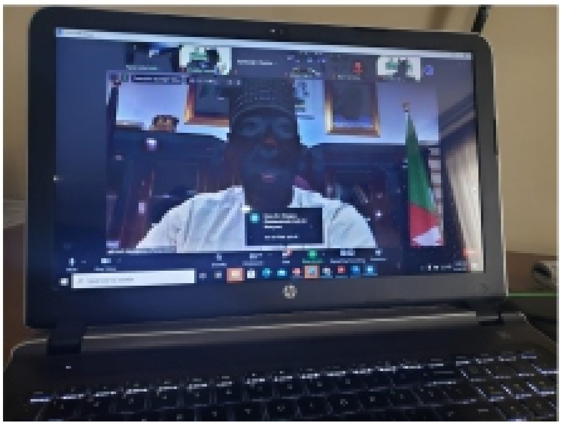
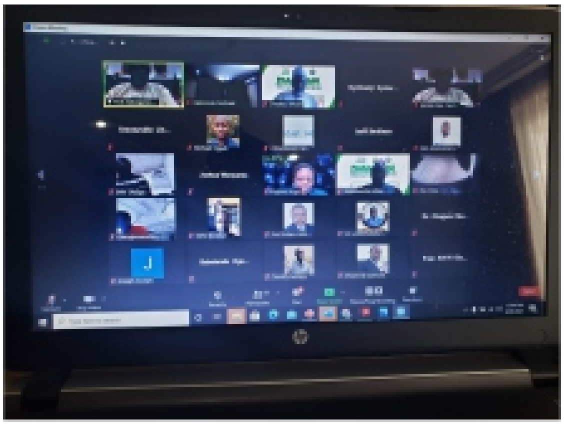
COUNT DOWN DESIGNS TO THE CONFERENCE

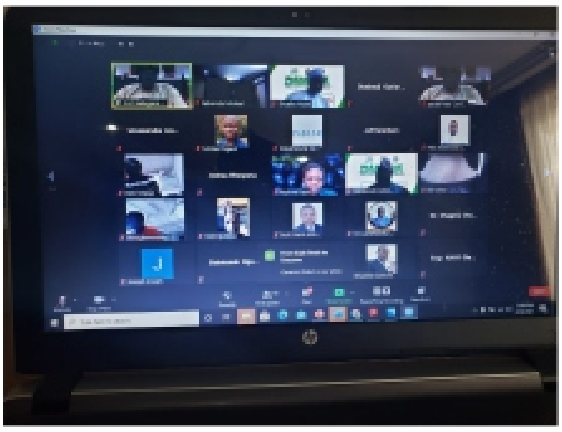
PAN AFRICAN SOCIETY FOR AGRICULTURAL ENGINEERING

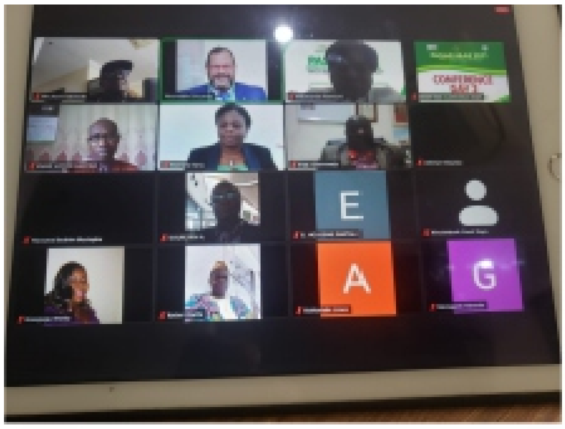
DURING THE VIRTUAL CONFERENCE

SCREENSHOTS FROM THE VIRTUAL CONFERENCE

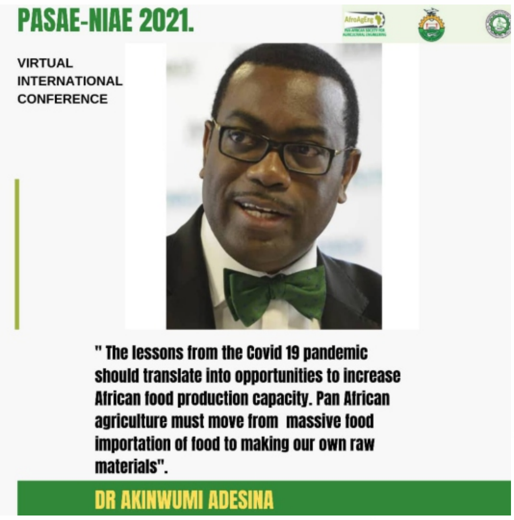








QUOTES FROM SPEAKERS



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QUOTES FROM SPEAKERS

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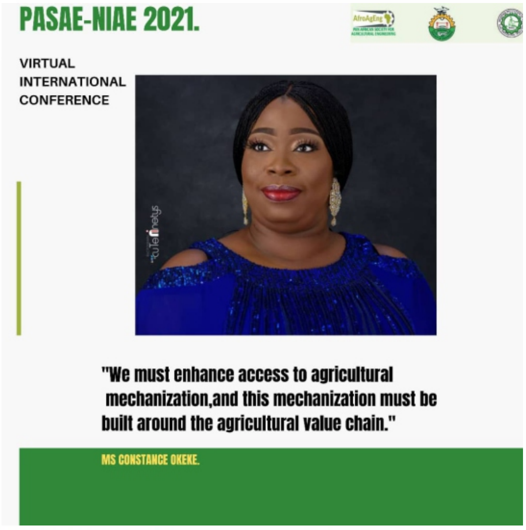
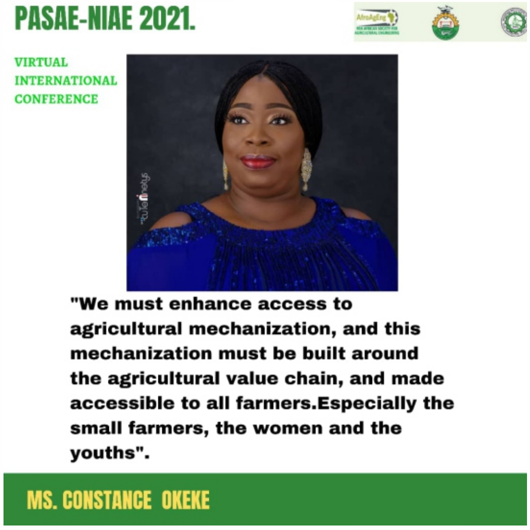
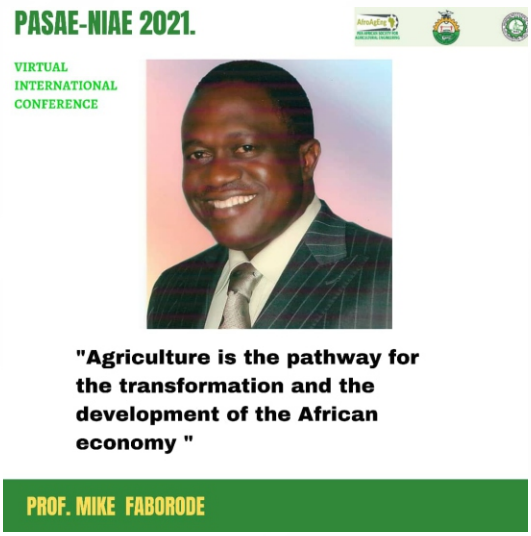
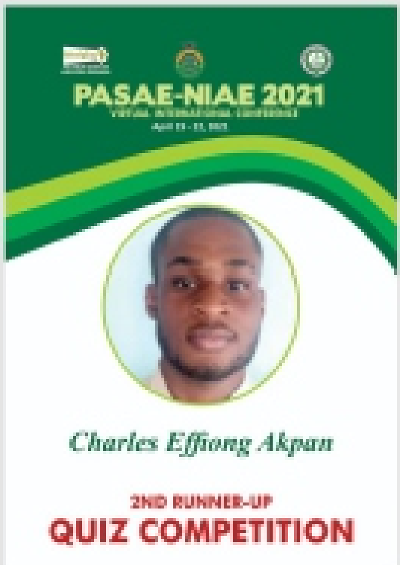






PASAE-NIAE
INTERNATIONAL QUIZ FINAL

Prof. J. O. Olaoye,
Vice Chairman, NIAE.
Coordinator




PASAE-NIAE 2021
VIRTUAL INTERNATIONAL CONFERENCE
Finals For The Students' Technical Competition
21st April, 2021 | Time: 12noon | Via- Zoom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PASAE-NIAE 2021 PAPER PRESENTATION COMPETITION
Date: 22nd April, 2021
Time: 2 pm
Platform: Zoom
Presenter 1: Adeyi Qudus Babatunde
University of Ilorin, Nigeria.
Presenter 2: Noel Benehieze Sadoh
Fed. Uni. Tech., Minna, Nigeria.
Presenter: 3
Audu Abduwahab Omeiza
Fed. Uni. Tec., Minna, Nigeria.
Presenter: 4
Hassan Bala Usman
Fed. Uni. Tech., Minna, Nigeria.
Presenter 5:
Michael Entonu
Fed. Uni. Tech., Minna Nigeria.
Presenter 6:
Adeyemo Adeniyi Gbenro
Fed. Uni. Tech., Minna, Nigeria.
Presenter 7: Fadele Oluwaseyi Fed. Col. Forestry Mech., Kaduna, Nigeria.

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"In all, we had a fruitful end productive conference, with considerable strategic partnership networking that would impact and advance the future prospects for PASAE and its regional/national constituent members. There seems to be quite a lot to do by PASAE towards attaining the goal of the "Africa we want". The African Union Commission (AUC) should endorse PASAE as a Partner on the journey. The conference represents a great first step and the future seems already well anticipated in PASAE's Strategic Plan".

Prof Peter Onwualu.

Co-Chair, COC; Chair Technical Committee; Deputy President, Nigeria Academy of Engineering. African Univ of Sciench & Tech, Abuja, Nigeria.

"PASAE and NIAE have successfully built bridges with key continental and international development agencies and private sector actors such as the AfDB, AFREXIMBANK, UNFAO, UNIDO, Intellidigest, CHEAM/FTN, Bari, ASABE, and CSAE to mention a few, to forge the partnership for action in alignment with SDG No 17 and the move towards the Africa we Want. This was one of the goals of PASAE in its strategic plan".

Prof. M. O. Faborode

Chairman COC. OAU, Ile-Ife, Nigeria.

PLENARY PRESENTATIONS

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PAN AFRICAN SOCIETY FOR AGRICULTURAL ENGINEERING

DR AKINWUMI A. ADESINA
PRESIDENT, AFRICAN DEVELOPMENT BANK

PASAE-NIAE VIRTUAL INTERNATIONAL CONFERENCE
April 19 – 20, 2021

Theme:
Engineering Africa's Agro-Industrial Transformation for Sustainable Development and Economic Prosperity: the import of Developing Agro-Industrial Processing Zones (SAPZs)

CONFERENCE KEYNOTE ADDRESS
By
DR AKINWUMI A. ADESINA
PRESIDENT, AFRICAN DEVELOPMENT BANK

Protocols and Greetings:

I am very delighted to address this gathering of the 3rd International Conference of the Pan African Society for Agricultural Engineering (PASAE) and the Nigerian Institution of Agricultural Engineers (NIAE). The theme of the conference and its focus on the **African Union's Agenda 2063: "The Africa We Want"** clearly conjures the big vision of an inclusive and sustainable transformation for Africa and reaffirms our collective efforts in awakening the huge but grossly undermined wealth creation potentials of the continent in agriculture, human and natural resources. The theme is clearly aligned with the AfDB's High-5.

Your chosen theme **"Engineering Africa's Agro-Industrial Transformation for Economic Prosperity and Sustainable Development"** advances the conversation with PASAE and NIAE as allies of AfDB in moving African agriculture from the realm of poverty management to that of innovation and wealth creation. In the true spirit of Pan-Africanism that this conference represents, if we will get "the Africa we want", I strongly believe in the capacity of Agricultural, Biosystems and Environmental Engineers in transforming our economies from the bastions of economic misery to that of prosperity. A meeting of this nature therefore, calls for sober reflection on our past experiences, where we now find ourselves and where we are going.

Where we are

Lack of food is the most critical dimension of poverty. Millions of Africans are working hard in the agricultural sector yet we remain the most food insecure region in the world due to low productivity among other factors. Two hundred and twenty (220) million - about a fifth of the continent's population and a quarter of the global total suffer from malnutrition. Africa spends a whooping $65 billion yearly, importing what it can and should produce, exporting jobs to producers of foods while experiencing plan-disrupting price fluctuations from global commodity supply chain. If the trend continues, imports may rise to $110 billion by 2025

Africa does very little Value added manufacturing. For example, as the producer and exporter of 75% of the world's cocoa, Africa gets only 3% of the $100 billion annual global revenue from chocolate. The price of cocoa may decline, but the price of chocolates does not. Similarly, as an exporter of cotton, which price has tend to trend down as with other raw materials, exporters tend to receive progressive less on their raw exports over time. The price of cotton may fall, but never will the price of clothes and garments. While coffee and tea farmers in East Africa face declining prices, coffee grinders and tea processors get richer. This applies to several other food, forest products, oil and rare minerals.

Between 2011-2013, Africa's manufactured goods made up only 18.5% of exports, while 62% of total imports were manufactured goods. This trade imbalance drains wealth away from the continent. Why will Africa have 60% of the world's arable land, yet remain a net importer of food? About 120 million Africans are out of work, 42% of the total population live below poverty line, 6 out of 10 most unequal countries in the world are Africans, with women and youth being the most vulnerable. This phenomenon has placed Africa at the bottom of the global wealth hierarchy with its share of global manufacturing only at 1.9%. The situation is worse in countries where a combination of structural constraints and political instability jeopardize any effort for private sector-led economic diversification and transformation. Consequently, most countries have not created the jobs necessary to absorb the significant number of youths, compelling hundreds of thousands to migrate overseas, sometimes in extremely dangerous and embarrassing circumstances.

Furthermore, while Africa is the least contributor to global carbon emissions, the continent is also the most vulnerable to climate variability, desertification, deforestation, drought, famine, and climate change adaptation difficulties. The convergence of these adverse circumstances perpetuate Africa's Low economy equilibrium characterized by joblessness, deepening poverty and rural-urban migration that is manifestly more pronounced in the rural areas. With over 70% of the population in rural areas depending on agriculture for a living, African's pathway out of poverty, pain, and penury is tied to the land, to what happens to agriculture. By making agriculture a big wealth-creating sector, new economic opportunities will be unleashed and millions of people will be out of poverty.

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The Africa we want is in our hands!!!

With a population estimated currently at 1.35 billion, Africa of the 21st century is more confident and keenly aware of its potentials. To transform rural economies, we need to be wary of solving new problems the old way: it is time to industrialize African agriculture, moving from Subsistence farming to modern agri-business. From hoe and cutlass, and drudgery to the use of new technologies, improved seed varieties and the deployment of digital tools that attract young people into this ecosystem. Africa today, has a lot more technologies than Asia at the time of its green revolution. Industrial agri-business enables access to global food value chains through manufacturing value addition to our raw materials.

Africa's agribusiness market estimated at one trillion dollars ($1 Trillion) by 2030 holds the key to accelerated recovery and growth post-pandemic, economic diversification and job creation for African economies. We need to Build Back stronger, faster and greener. The AfDB projects that about 39 million Africans may be pushed into extreme poverty in 2021 as a result of the corona virus. We should therefore turn the COVID-19 challenge into opportunities to rebuild Africa's manufacturing capacity, including a resilient health and agri-business infrastructure.

Engineering African Agriculture for the Africa we Want: Wither Agricultural, Biosystems and Environmental Engineers?

Within the context of the Bank's **'High 5s' Priority areas (*Light up and Power Africa; Feed Africa; Industrialize Africa; Integrate Africa; and Improve the Quality of Life of the people of Africa*)**, Agricultural Engineers primarily have tremendous opportunities in at least four (4) – feed, industrialize, integrate and improved livelihoods. The high 5s now interface with 90% of the SDGs and the Agenda 2063 of the African Union. The technologies to feed Africa, reduce postharvest losses and food waste reduction system from the farm to storage, transport, processing and marketing are within your purview as Agricultural Engineers.

What of the provision of good infrastructure, power supply, access roads, rail transport and water supply for crops, livestock and human? Infrastructure-enabled zones (with uninterrupted power and water supplies, good roads and ICT facilities) will minimize the comparative cost of agribusiness, while reducing a substantial 1.3 bn tons postharvest losses. The fiscal space in the rural areas will expand and food imports will reduce; saving African economies billions of dollars, and transforming African rural economies into zones of economic prosperity. African agriculture must move from exporting basic raw materials to processing its raw materials.

The AfDB's "Special Agro-industrial Processing Zones (SAPZ)" initiative is a major initiative of the Bank that we are rolling out in several African countries. The overall goal of the SAPZ is to concentrate agro-processing activities within areas of high agricultural potential to boost productivity and integrate production, processing and marketing of selected commodities, thereby turning African rural landscapes into zones of prosperity. The SAPZ promotes the development and technological upgrading of SMEs, foster industrial clustering of firms, reduce transaction costs, lower asymmetric information. Clustering of firms within a SAPZ provides the critical mass needed for the provision of services such as eco-friendly waste recycling and disposal, which is difficult when firms are dispersed across a wider geographic space. Clearly the SAPZ allows economies of scale through reduction of overall cost of production, less postharvest losses.

The presence of multi-modal transportation, water and energy systems lower costs and leads to higher returns, improved quality outputs, off season availability, better traceability, and enhanced productivity. The provision of support services to farmers to enhance agricultural productivity (including support on technology, inputs, finance, production and postharvest support and, uptake markets). The industrial capacity linked to agriculture within the zones will help unleash Africa's competitive advantage in value added agro-allied industries. No nation or region on earth has succeeded by simply exporting primary commodities. Africa must create industrial growth engines that will propel it to become competitive in manufacturing.

The African Bank Development Bank (AfDB) has established SAPZs in several countries) in several RMCs including Nigeria (multi-locational), Senegal (Centre), Cote d'Ivoire (Nord), DRC (Ngandajika), Tanzania, (Lake Zone); Mozambique (Pemba-Lichinga) and Ethiopia with Productivity Enhancement Support to the Agro-Industrial Parks and Youth Employment (PES YAPE). Also, preliminary works and pipeline development have started for Uganda, Kenya, Mauritius, South Africa and they should be ready for implementation in in 2022. Furthermore, implementation progress has been made with projects already approved for SAPZs in Togo, Senegal Sud, Guinea, Mali, Madagascar and Ethiopia phase 2.

The overall objective of the SAPZ is to support the structural transformation of African economies through improvement of competitiveness and business environment of the agriculture sector, through the provision of hard and soft infrastructure that would allow the crowding-in of private investment into the sector, both at the upstream and downstream axes of the value chains. Programme interventions would lead to improved household incomes, job creations for youth and women, food and nutritional security through increased productivity, value addition, market access and private sector investment in select agricultural value chain commodities.

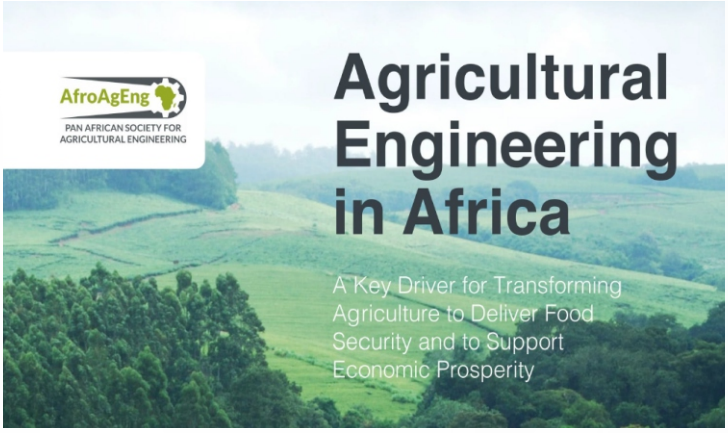
Another initiative of the AfDB, Technologies for African Agricultural Transformation (TAAT), is to help the continent attain its enormous potential in the sector. This is by developing and employing proven, high-impact technologies to boost productivity, mitigate risks and promote diversification. In getting African citizenry and leaders to understand that agriculture is not a way of life or developmental activity but strictly business; new frontiers of global techno-industrial development must be urgently mainstreamed into African agricultural industry.

We must break the cycle of misery in Africa. The region remains poor because it got stuck in a stable equilibrium of per capita income which is close to subsistence as it is for most of rural Africa and the informal economy. In this situation, savings and investment remain at very low level and whenever there is some level of savings and investment, they result in increase of the population. Accordingly, per capital income remains at its stable equilibrium level resulting in low-level equilibrium trap.

I believe this is what this gathering is all about, to get African professionals to rise to the challenges of the continent's underdevelopment and give hope to our people. Our collective destiny in Africa is tied to breaking down the barriers separating us, occluding our vision and impeding our progress. Africa does not need anyone to believe in her or to affirm her place and position in history. With passion, dedication, knowledge, innovation and commitment, our greatest instrument of success lies right within us all!

Thank you and God bless you all.

Alastair Taylor MIAgrE, Cenv, IEng



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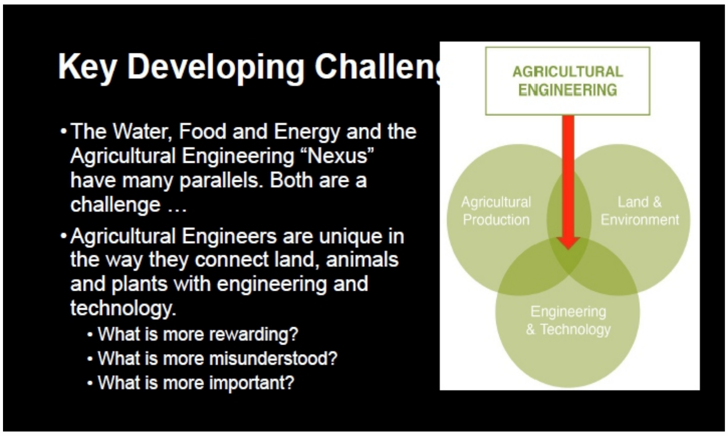
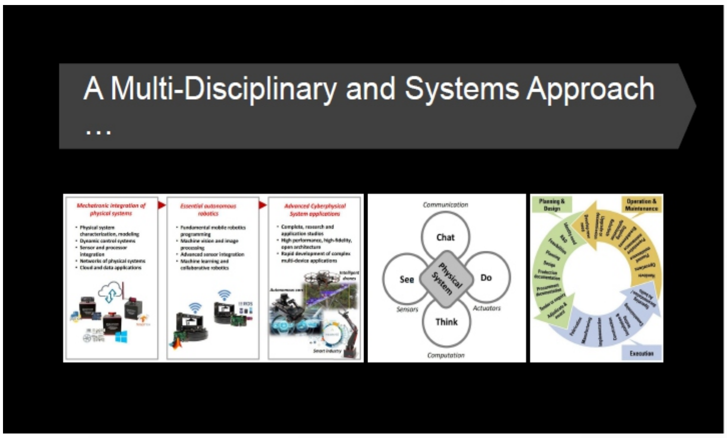
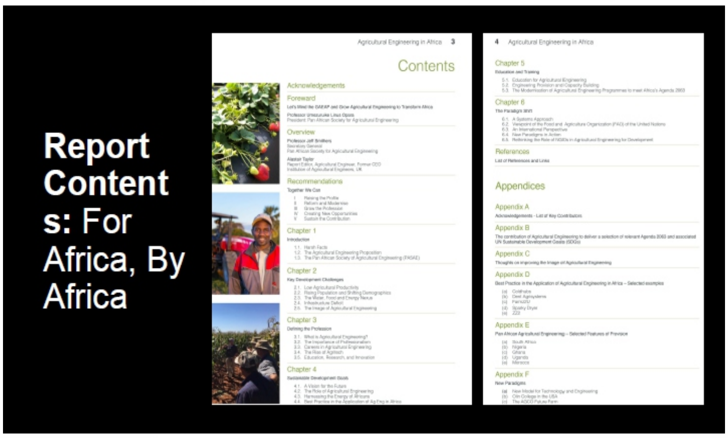







Raising the Profile
• Increase awareness across government, industry and the general public.
• Celebrate the exciting opportunities and highlight the contribution they make.
• Feature Agricultural Engineering more across the media.
• Identify key partners, professional partners and important advocates.
• Commence dialogue and "*make a noise*".


Reform and Modernise
• Review the curriculum in universities and schools.
• Relate the Science, Technology, Engineering and Mathematics (STEM) agenda to food, soil, and environmental security.
• Embrace new technological developments across universities.


Reform and Modernise
• Establish a Pan African standard for the engineering curriculum.
• Share resources and approaches.
• Develop a new generation of leaders.
• Engage with the engineering industry to bring new skills and technologies to educational practice.


Grow the Profession
• Promote the concept of "professionalism" and professional Agricultural Engineers.
• Engage with government to showcase the role of professional engineers.
• Identify advocates and celebrate their work and the contribution they make.
• Develop a central database showcasing the professional status of engineers and academic institutions.

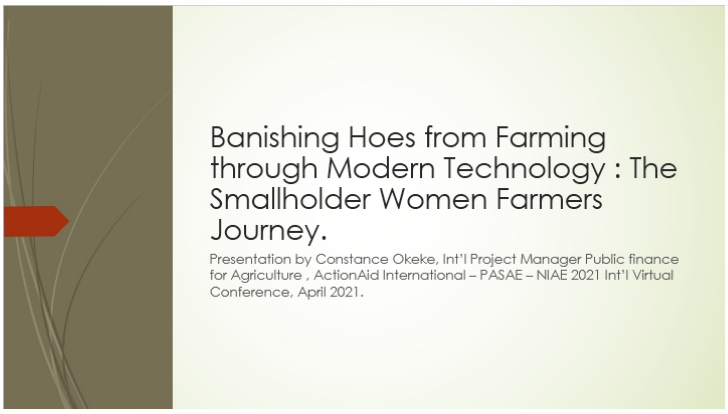

Creating New Opportunities
• Make sure the UN Sustainable Development Goals are supported by Agricultural Engineers.
• Make it clear how the Ag Eng profession "touches" all of the food chain process.
• Engage with the broader engineering profession to highlight the contribution they can and should make.

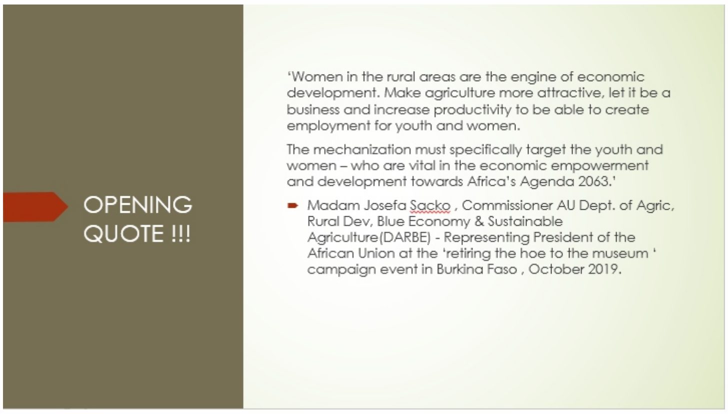

Creating New Opportunities
• Collaborate within and accross universities and stop working in isolation.
• Identify the barriers to progressing Ag Eng and address these.
• Work with funding agencies and financial institutions to highlight the role of Ag Eng .

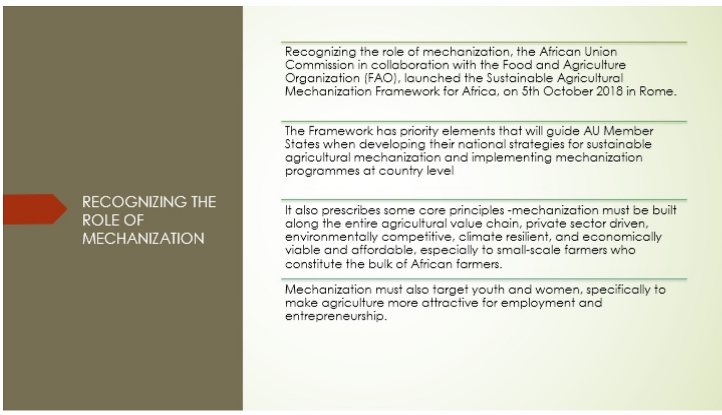

Sustain the Contribution
• Work globally with machinery manufacturers and infrastructure developers.
• Influence Non Governmental Organisations (NGO) and charity partners to make sure their contributions are better planned and the money better spent.
• Don't go for the "quick fix", instead we must look for the long term sustainable solution.
• Invest in PASAE/AfroAgEng so that there is a consistent approach. It will take time to embed this excellence.


Who is our Audience?
• Governments – national, regional, & local.
• Universities and education providers.
• Global research and development partners.
• Multi national manufacturers and suppliers.
• Media and press outlets.
• Finance, banks and funders.
• The people of Africa and particularly the next generation.
LAGOS STATE FADAMA III PROJECT

Rotarian Constance Ogadimma Okeke (PHF)







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WHAT HAS BEEN DONE SO FAR !

- In Gender Pre-Summit consultations held on the margins of the 25th Ordinary summit, Women of Africa identified key priorities for the advancement of women empowerment, including the critical role of women in Agriculture.
- Building on this, an initiative on "Empowering Women in Agriculture"-EWA was launched with the aim to recognize and escalate the role of women in the development of Africa, through mechanization of agriculture and alleviation of the burden on women in rural communities.
- Few years after, the former Chairperson of the AUC and the mobilization of women around the theme, the AU Commissioner of Rural Economy and Agriculture together with the First Lady of Burkina Faso, inaugurated the first Statue in Burkina Faso to symbolize the retiring of a Hand-Held Hoe as part of International Rural women's day in 2019.

WHAT HAS BEEN DONE SO FAR !

- The construction of this first monument in Burkina Faso symbolizes the campaign to end the Hand Hoe in Africa in recognition of the difficult conditions of farming in rural areas.
- This monument is not intended to be a mere representation, but a living testimony of the African woman who faces an unequal division of work between man and woman in the rural environment.
- In addition, it is a testimony of society's dedication to the implementation of the AU Agenda 2063, especially Aspiration six, "An Africa whose development is people - driven, relying on the potential of African people, especially its women and youth and caring for children"
- Putting an end to the use of the hand-held hoe will contribute significantly to attaining the objectives of this Continental Agenda, and for agriculture, the 2014 Malabo Declaration

SIGHTS FROM BURKINA FASO – HOE TO MUSEUM CAMPAIGN

More sights from Burkina Faso

SWOFON RETURNING HOE TO MUSEUM

- SWOFON MEMBERS TOOK HOME THE LEARNING FROM BURKINA AND SENT THEIR HOES TO THE MUSEUMS.
- THEY ALSO PRESENTED THEIR DEMANDS TO THE PARLIAMENT COMMITTEE ON AGRICULTURE

WHAT NEEDS TO BE DONE!

In a bid to comprehensively address the gender gap in Agriculture and ensure equity and equality in access and distribution of agricultural assets, the Federal Ministry of Agriculture and Rural Development, in 2019 launched the National Gender Policy in Agriculture.

The National Gender Policy in Agriculture is a consummation of the Sustainable Development Goals (SDGs) of eradicating poverty (SDG-1), ending hunger, achieving food security, improved nutrition and sustainable agriculture (SDG-2), and achieving gender equality and empowerment of women and girls (SDG-5).

It also succinctly captured the gaps in gender integration and responsiveness in the 2011-2015 Agricultural Transformation Agenda.

The National Gender Policy in Agriculture is a sectorial gender mainstreaming strategy document which aims at strategic implementation of existing gender -based frameworks, plans and programming.

WHAT NEEDS TO BE DONE!

The National Gender Policy is an assertive document, which recognizes the limitation of growth and development of the agricultural sector because of the exclusion of smallholder women farmers in strategic participation and in key decisions making and access to agricultural assets.

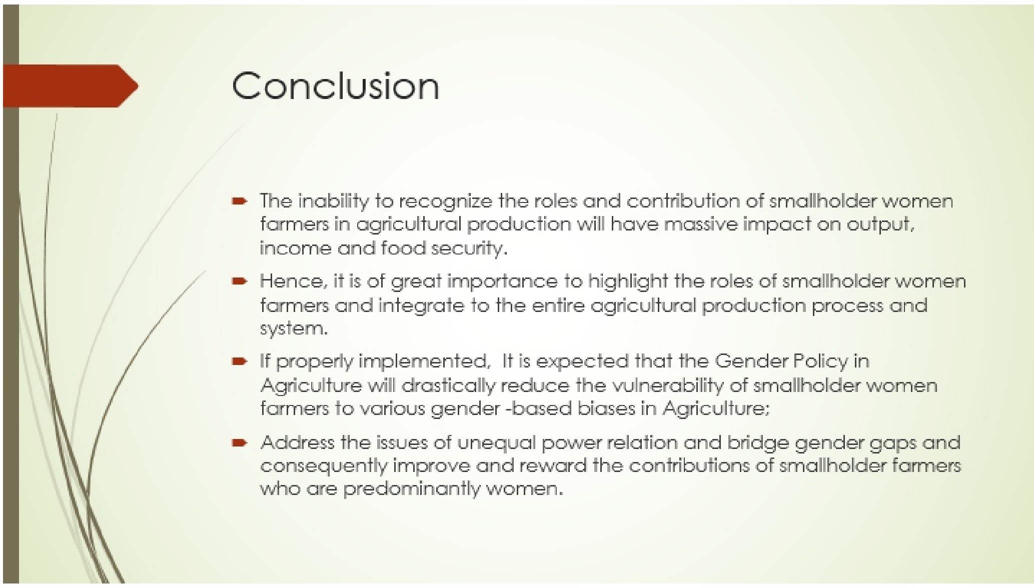
The document provides a clear direction and lead for implementation of guidelines and actions that will ensure fair and equal participation of smallholder women farmers in the entire agricultural process and food systems.

The document seeks to promote and ensure the adoption of gender sensitive and responsive approaches towards full implementation and execution of agricultural plans and programmes in a way that men and women will have equal access and control to agricultural resource and funding.

WHAT NEEDS TO BE DONE!

It seeks to eliminate gender biases and engender stronger participation of smallholder women farmers in utilizing agricultural assets and in decision making processes.

THIS CAN ONLY BE WORTH IT IF IMPLEMENTED!


Conclusion
The inability to recognize the roles and contribution of smallholder women farmers in agricultural production will have massive impact on output, income and food security.
Hence, it is of great importance to highlight the roles of smallholder women farmers and integrate to the entire agricultural production process and system.
If properly implemented, It is expected that the Gender Policy in Agriculture will drastically reduce the vulnerability of smallholder women farmers to various gender -based biases in Agriculture;
Address the issues of unequal power relation and bridge gender gaps and consequently improve and reward the contributions of smallholder farmers who are predominantly women.

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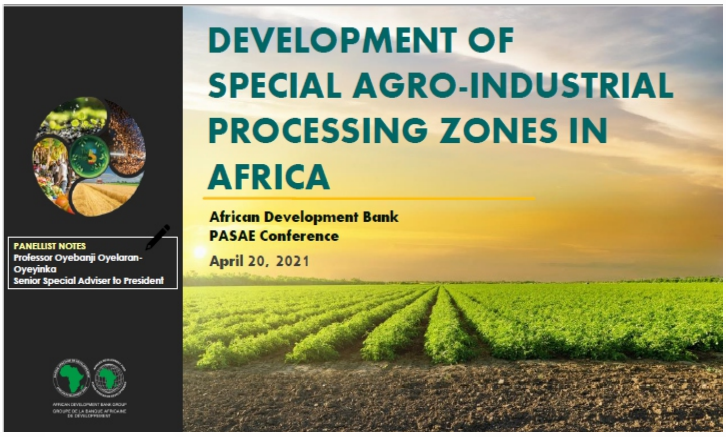
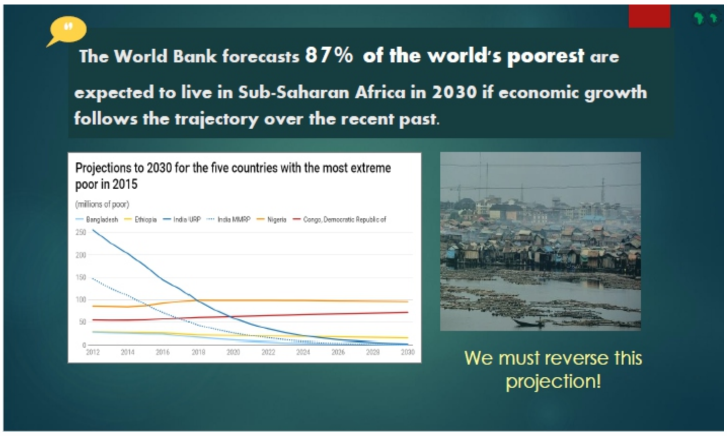
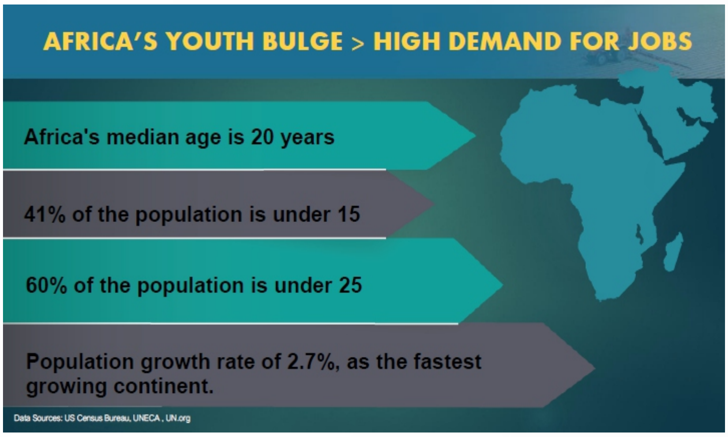
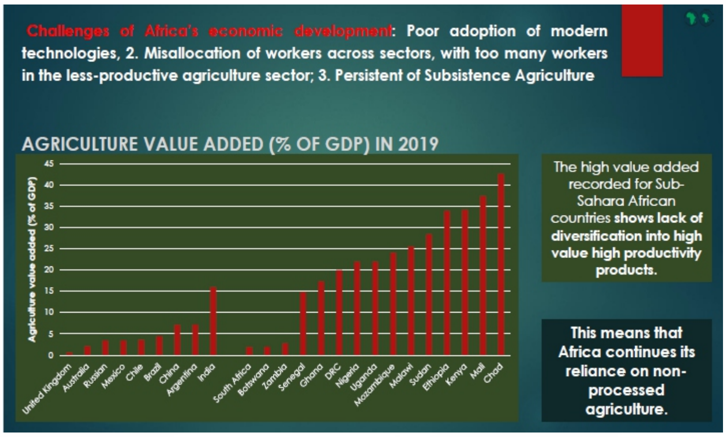
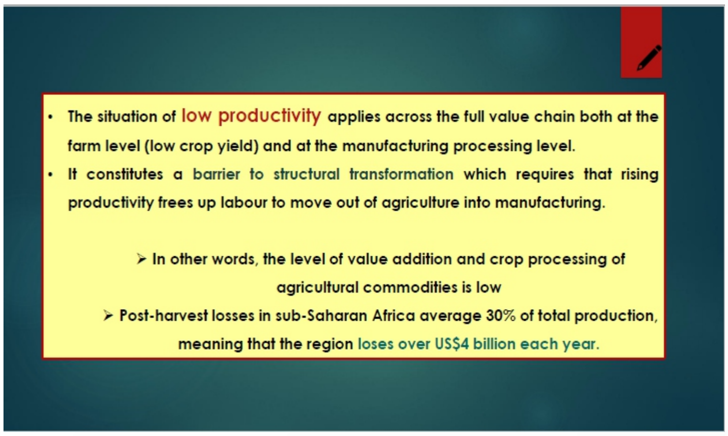
Prof. Oyebanji Oyelaran-Oyeyinka
Senoir Special Adviser To The President Afdb On Agro-Industrialization, Cote D'ivoire

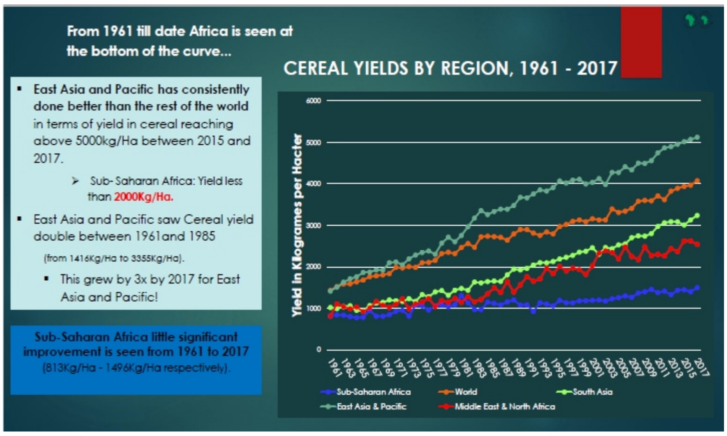


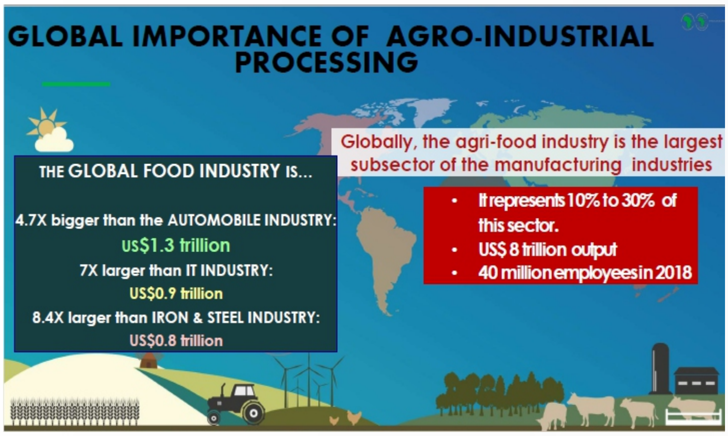












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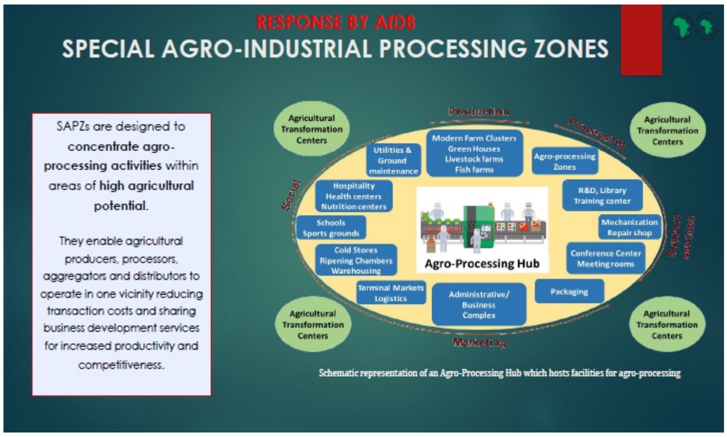
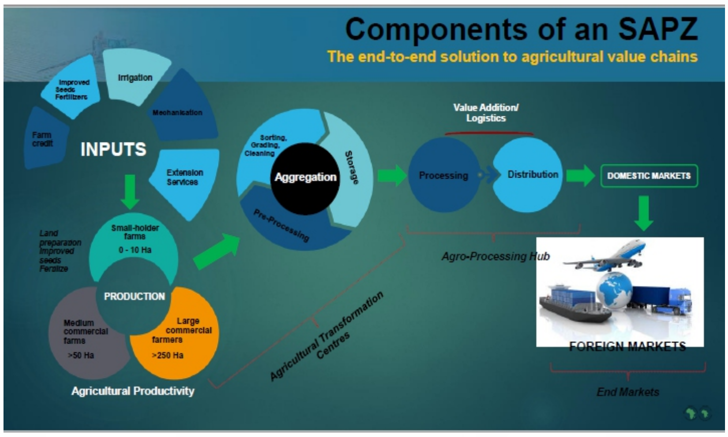
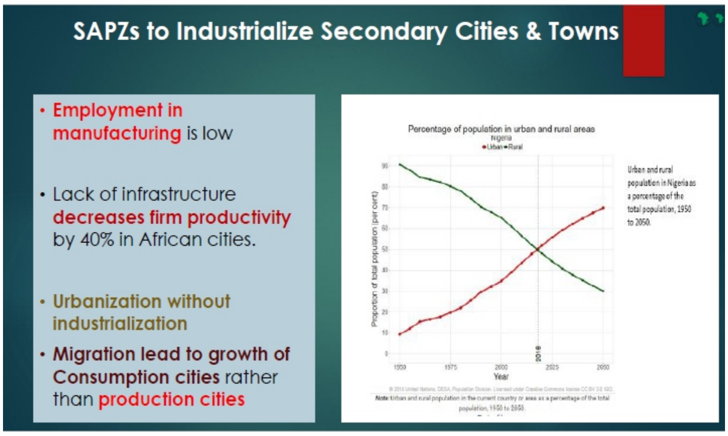
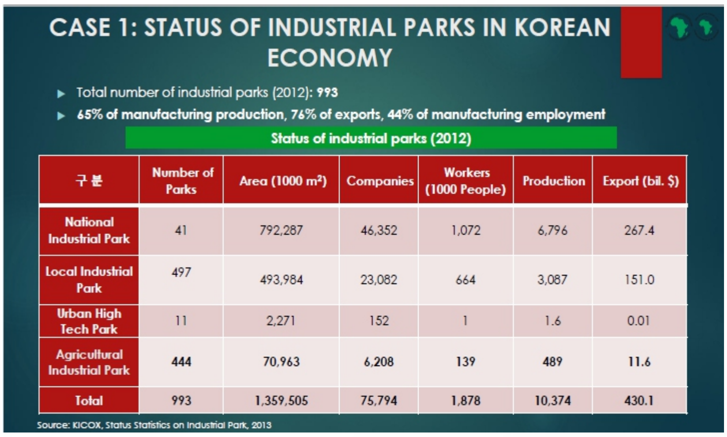


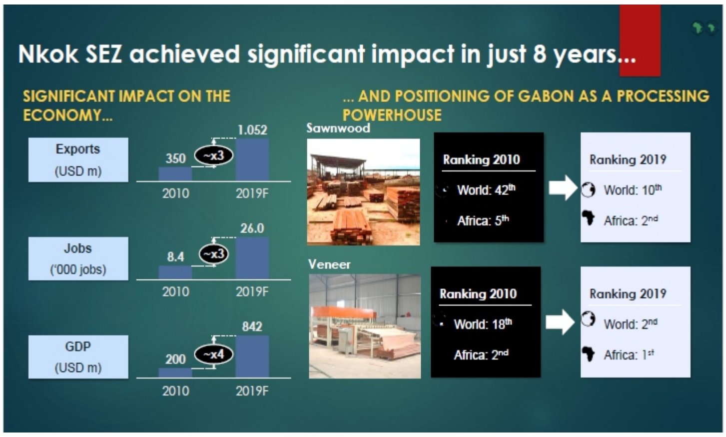






구 분	Number of Parks	Area (1000 m²)	Companies	Workers (1000 People)	Production	Export (bil. $)
National Industrial Park	41	792,287	46,352	1,072	6,796	267.4
Local Industrial Park	497	493,984	23,082	664	3,087	151.0
Urban High Tech Park	11	2,271	152	1	1.6	0.01
Agricultural Industrial Park	444	70,963	6,208	139	489	11.6
Total	993	1,359,505	75,794	1,878	10,374	430.1

Source: KICOX, Status Statistics on Industrial Park, 2013



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Joshua Wanyama
Makerere University

Agriculture, smart farming and the 4th industrial revolution-exploiting modern intelligent technologies in farming and rural transformation

1

Joint Virtual Conference of the Pan African Society for Agricultural Engineering (PASAE) and the Nigerian Institution of Agricultural Engineers (NIAE)
20th April 2021

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Makerere University

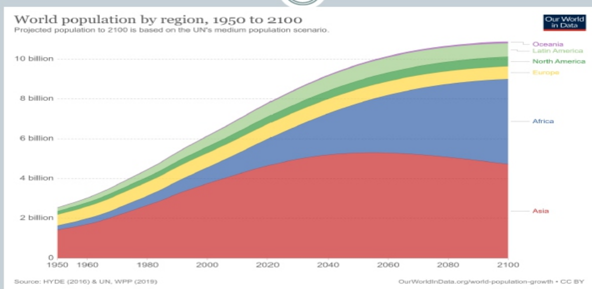
Structure of Presentation

2

- Agriculture in Africa
- Smart Farming
- 4th Industrial revolution in Agriculture
- Opportunities from 4th Industrial revolution in Agriculture
- Key drivers for adoption of smart farming
- Conclusion

Population projection

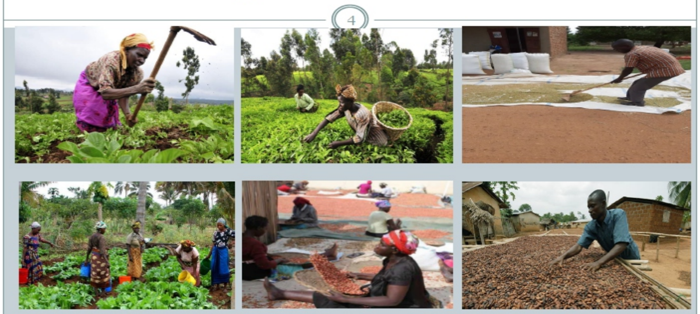
3



Africa's population to double by 2050 – need to increase food production

Agriculture in Africa

4



Food production practices characterized by use of rudimentary technology

Agriculture in Africa

5

Climate change and variability is a grand challenge affecting food production on the continent

Smart Farming

6

- Integration of Information and Communication Technology in farming to increase the quantity and quality of products while optimizing input resources required
- Objective of smart farming is to make every aspect of farming more reliable, predictable and sustainable

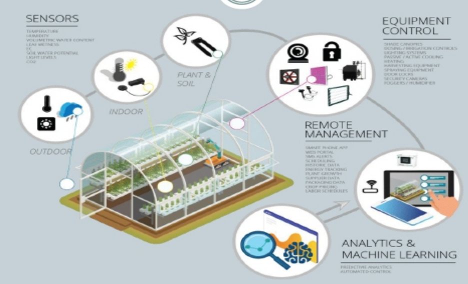
Technologies used in smart farming

7

Irrigation control and precise plant nutrition

Technologies used in smart farming

8



Smart greenhouse climate and control systems

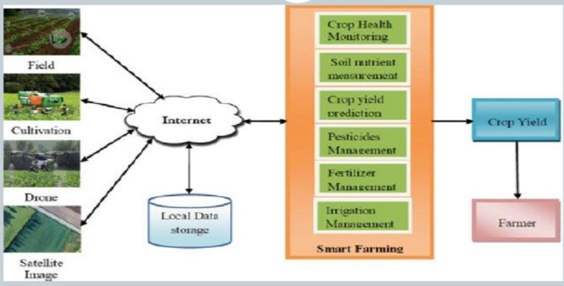
Technologies used in smart agriculture

9

Sensors – for the soil, moisture and temperature management

Technologies used in smart agriculture

10



Software platforms

Technologies used in smart agriculture

11

Drone technology

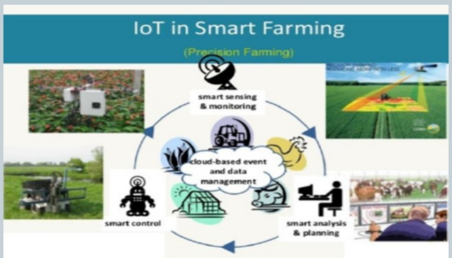
Technologies used in smart agriculture

12

Robotic technology - weed control, planting seeds, harvesting, soil analysis

Technologies used in smart agriculture

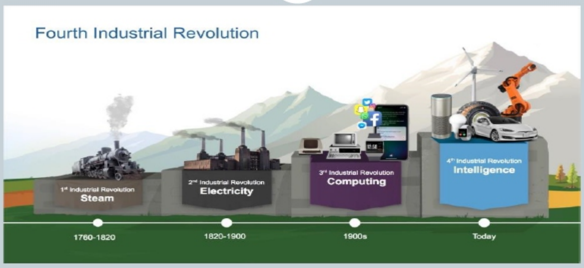
13



IoT- Farmers can monitor the processes on their farms and take strategic decisions remotely from their tablet, phone or other mobile device

4th Industrial revolution in Agriculture

14



Disruptive technologies - Artificial Intelligence (AI), Blockchain, the Internet of Things (IoT), Big Data Technology, Drones, 3D printing

Opportunities from 4th Industrial revolution in agriculture

15

- 3D printing for quickens prototyping solving the traditional time constraints encountered with traditional prototyping methods
- Automation through artificial intelligence (AI) thereby saving resources and creating new types of jobs
- Customized agricultural robots improving the quality of existing jobs and freeing people's time for other activities
- Internetworking of physical devices (IoT) catalyzing automation in nearly all agricultural fields

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Key drivers for adoption of smart farming

16

- ICT knowledge and know-how
- Awareness creation
- Investment in ICT infrastructure - broadband availability
- Extensive research efforts - User friendliness of smart technologies and Application Algorithms
- Investment in Rural Electrification
- Subsidies for investing in environmentally friendly technologies to lower up-front cost of investing in smart farming
- Clear policy on data sovereignty and security could promote trust between farmers and technology providers
- Profit advantage of using smart technologies

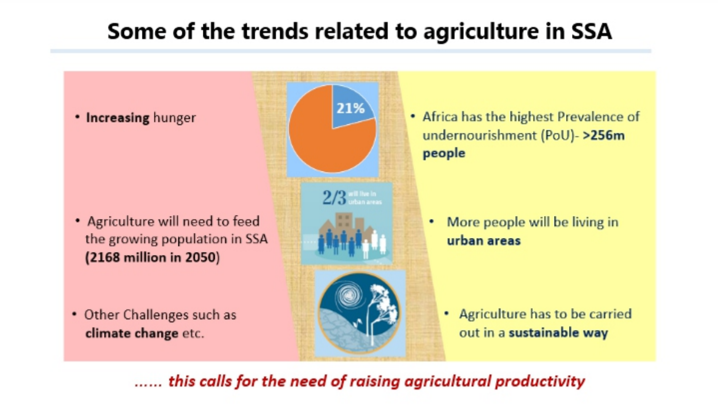
Conclusion

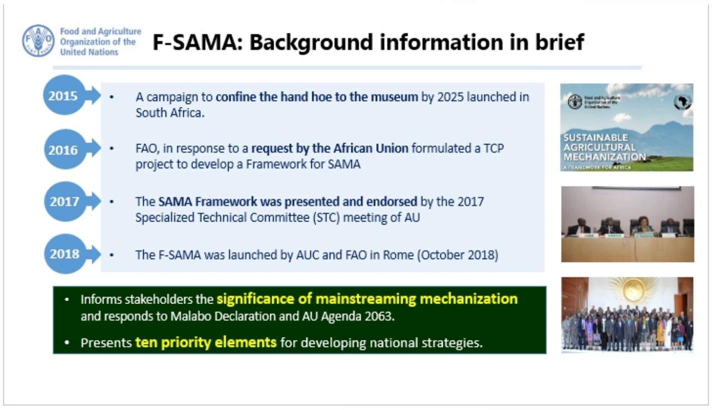
17

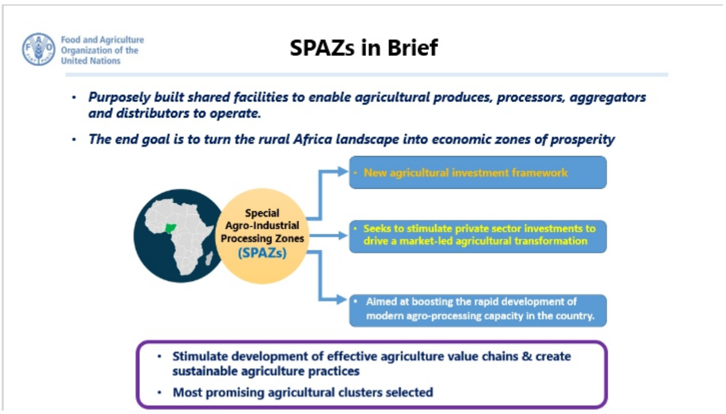
Africa must embrace innovative technological efficiency in order to satisfy the growing demand of food needs

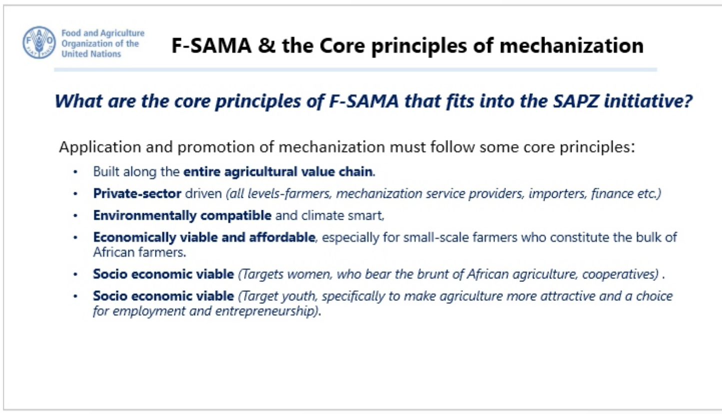
Thank you for listening to me

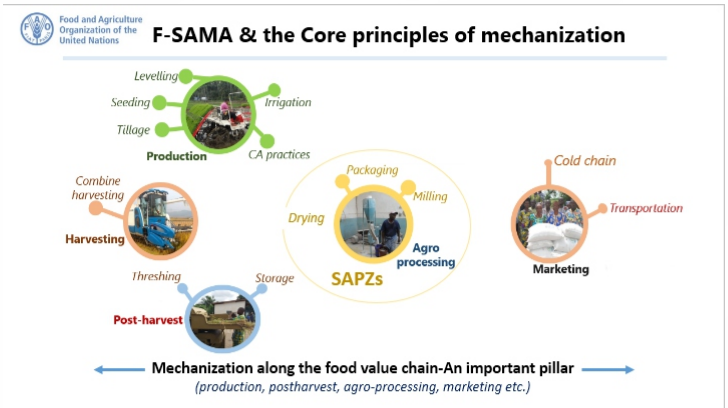
Dr. Joseph Mpagalile
Agric. Engineer (Sustainable Mech),
UNFAO Regional Office, Accra, Ghana

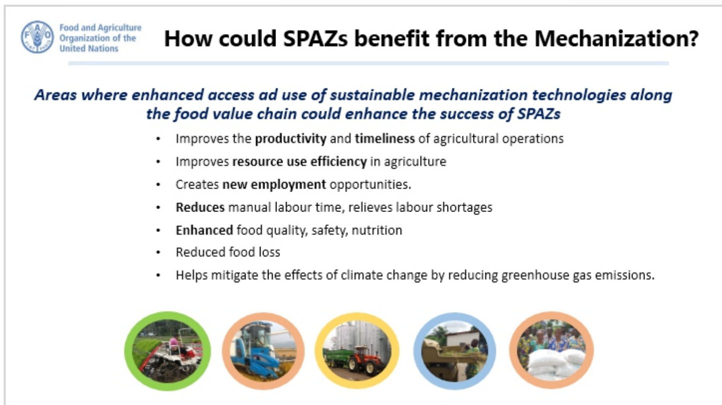


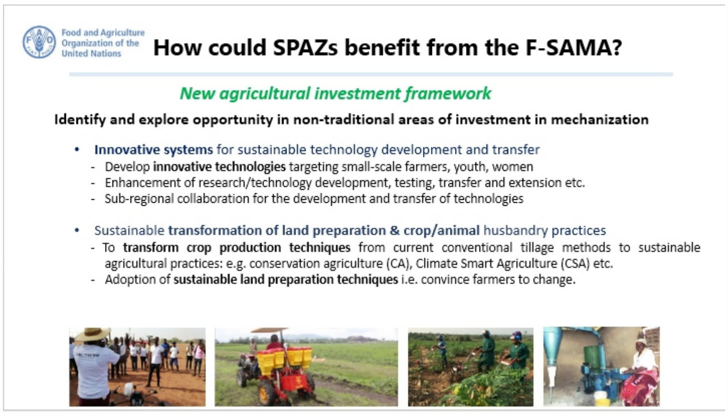


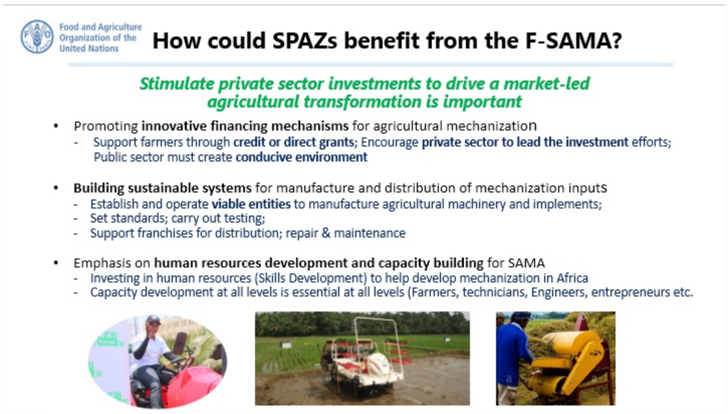


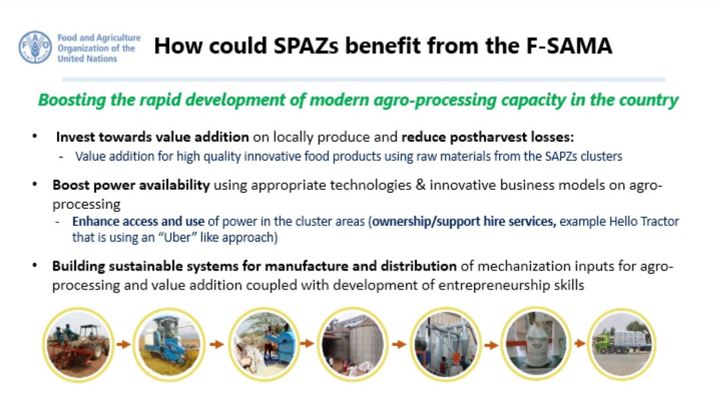


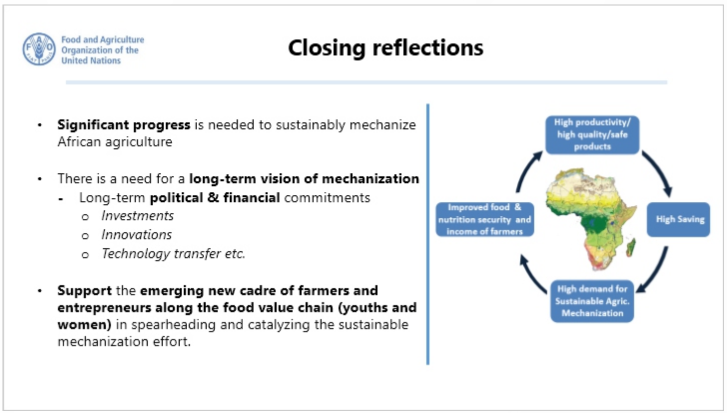


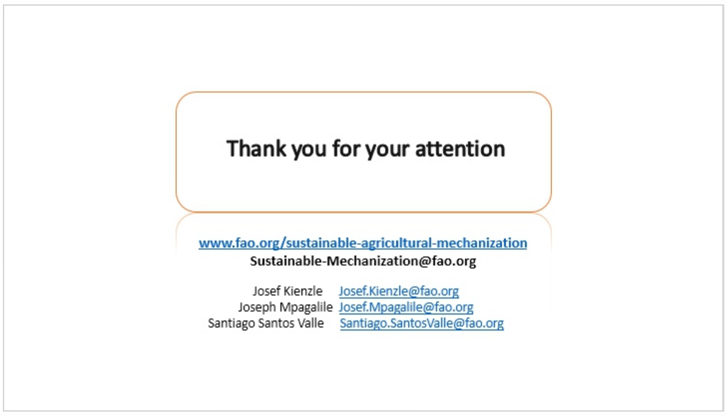



Food and Agriculture Organization of the United Nations
How could SPAZs benefit from the F-SAMA?
New agricultural investment framework
Identify and explore opportunity in non-traditional areas of investment in mechanization
Innovative systems for sustainable technology development and transfer
- Develop innovative technologies targeting small-scale farmers, youth, women
- Enhancement of research/technology development, testing, transfer and extension etc.
- Sub-regional collaboration for the development and transfer of technologies
Sustainable transformation of land preparation & crop/animal husbandry practices
- To transform crop production techniques from current conventional tillage methods to sustainable agricultural practices: e.g. conservation agriculture (CA), Climate Smart Agriculture (CSA) etc.
- Adoption of sustainable land preparation techniques i.e. convince farmers to change.


Food and Agriculture Organization of the United Nations
How could SPAZs benefit from the F-SAMA?
Stimulate private sector investments to drive a market-led agricultural transformation is important
Promoting innovative financing mechanisms for agricultural mechanization
- Support farmers through credit or direct grants; Encourage private sector to lead the investment efforts; Public sector must create conducive environment
Building sustainable systems for manufacture and distribution of mechanization inputs
- Establish and operate viable entities to manufacture agricultural machinery and implements;
- Set standards; carry out testing;
- Support franchises for distribution; repair & maintenance
Emphasis on human resources development and capacity building for SAMA
- Investing in human resources (Skills Development) to help develop mechanization in Africa
- Capacity development at all levels is essential at all levels (Farmers, technicians, Engineers, entrepreneurs etc.


Food and Agriculture Organization of the United Nations
How could SPAZs benefit from the F-SAMA
Boosting the rapid development of modern agro-processing capacity in the country
Invest towards value addition on locally produce and reduce postharvest losses:
- Value addition for high quality innovative food products using raw materials from the SAPZs clusters
Boost power availability using appropriate technologies & innovative business models on agro-processing
- Enhance access and use of power in the cluster areas (ownership/support hire services, example Hello Tractor that is using an "Uber" like approach)
Building sustainable systems for manufacture and distribution of mechanization inputs for agro-processing and value addition coupled with development of entrepreneurship skills


Food and Agriculture Organization of the United Nations
Closing reflections
Significant progress is needed to sustainably mechanize African agriculture
There is a need for a long-term vision of mechanization
- Long-term political & financial commitments
o Investments
o Innovations
o Technology transfer etc.
Support the emerging new cadre of farmers and entrepreneurs along the food value chain (youths and women) in spearheading and catalyzing the sustainable mechanization effort.
High productivity/ high quality/safe products
High Saving
High demand for Sustainable Agric. Mechanization
Improved food & nutrition security and income of farmers


Thank you for your attention
www.fao.org/sustainable-agricultural-mechanization
Sustainable-Mechanization@fao.org
Josef Kienzle Josef.Kienzle@fao.org
Joseph Mpagalile Josef.Mpagalile@fao.org
Santiago Santos Valle Santiago.SantosValle@fao.org

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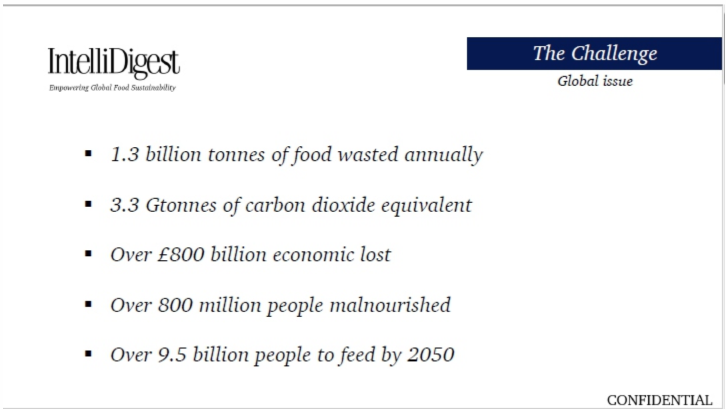
Dr. Ifeyinwa Kanu



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Dr. Margaret Gitau
Assoc. Professor, Purdue University; Klein E Ileleji, Professor and Extension Engineer, Purdue University, and Prof. Ajit Srivastava, Michigan State University, USA

MODERNIZING AFRICAN AGRI-FOOD SYSTEM (MAA)

A Business Case for Investment in Agri-Food System Technologies in Africa

An ASABE Global Engagement Initiative in the context of sub-Sahara Africa

Margaret Gitau, Ajit Srivastava, and Klein Ileleji

April, 2021

Organizing Committee


Ajit Srivastava (Co-Lead) Michigan State University, USA


Klein Ileleji (Co-Lead) Purdue University, USA


Margaret Gitau (Co-Lead) Purdue University, USA


Akindele F. Alonge University of Uyo, Nigeria


Kifle Gebremedhin Cornell University, USA


Kumar Mallikarjunan University of Minnesota, USA


U. Linus Opara Stellenbosch University, South Africa


Michael Ngadi McGill University, Canada


Nicholas Kiggundu Makerere University, Uganda


Noble Banadda Makerere University, Uganda


Senorpe A-Hiablie Penn State University, USA


Daniel U. Dooyum Kyungpook National University, South Korea

Background – Challenges and Opportunities

80%
Africa's 51 million farms are smallholders (< 2 ha)

30%
Small farms produce total agricultural output

< 2B
Population by 2050

60%
Population living in cities by 2050

$1.3T
Spending of top 18 cities by 2030

$80B ROI/yr
Markets created by $315- 400B transformation of 18 agricultural value chains over 10 years

MAA Initiative

Vision - A modern, productive, and profitable agri-food system in sub-Saharan Africa that ensures food security, provides economic growth, and improves quality of life in a sustainable, equitable, and responsible manner.

Mission - To promote modernization of African agri-food value chains from production to consumption through development and deployment of modern technologies and methodologies.

Organisation - The MAA initiative is organized under the American Society of Agricultural and Biological Engineers (ASABE).

Why ASABE?

1. Agricultural engineers have played a significant role in transforming American agriculture from subsistence farming to the mega industry it is today.
2. ASABE, representing the profession, is uniquely positioned, in partnership with sister societies, to play a pivotal role in modernizing African agriculture.
3. The society provides consistent and reliable access to a network of professionals with a wide range of expertise that can be harnessed
4. ASABE's leadership in areas such as standards development, professional meetings, educational program accreditation, recognition of private sector accomplishment such as AE50, etc. will be especially valuable in the long-term success of the MAA initiative

Guiding Principles

1. Agricultural development is intrinsically linked to economic development
2. Smallholder producers are central in the process of modernizing agriculture
3. Focus should be on growing productivity and profitability
4. Innovations (technologies, methodologies, policies and organizations) should be relevant, transformational, sustainable, and cost effective
5. Innovations should foster environmental protection, economic growth, and human-capital empowerment

Pillars

ASABE is providing leadership through the E-2050/MAA subcommittee and will facilitate activities based on **the four pillars**

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MAA Pillars

Entrepreneurship and Business Development

- Facilitate technology evaluation/transfer/scaling
- Help create international public/private partnership by identifying such opportunities
- Play an advocacy role to funders in setting investment priorities and fund allocation strategies

MAA Pillars

Capacity Building and Workforce Development

- In collaboration with academic institutions and research centers in the region, develop training/educational programs
- Through the network of international partners identify and create funding opportunities for training of professionals, e.g. the Master Card program

MAA Pillars

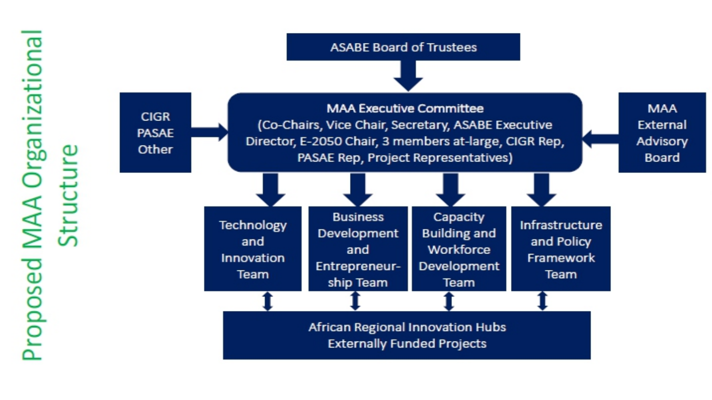
Infrastructure and Policy Framework

Identify potential partners/key players and advocate for funding for the development of infrastructure and enabling policy framework

Innovation Hubs

Facilitate establishing a network of MAA Innovation Hubs in the East, West, Central and Southern African regions to:

- Conduct a Strengths, Weaknesses, Opportunities, and Threats (SWOT) Analysis
- Promote technology and methodology development and innovation grants
- Promote business development entrepreneurship investment funding
- Capacity building and workforce development (Agricultural Technology Management, Integrated education campaign materials in local languages, Innovation boot camps and farmer field schools etc.)



Outcomes and Impact Assessment

- Identification of the bottlenecks and development of African-centered technological solutions
- Portfolios of innovations – technologies, methodologies, processes, policies, standards etc.
- Establishment of innovation hubs in strategic locations
- Establishment of networks of potential research collaborations
- Knowledge-based transformation where the stakeholders develop skills through training
- Business and investment opportunities and providing support (infrastructure, funding and training) for entrepreneurs and subsequent establishment of Small to Medium scale Enterprises
- Impact assessment conducted through considered metrices and score cards

Activities and Milestones of MAA Initiative

2019
ASABE AIM, Boston, MA
MAA initiative was discussed at ANGASABE meeting.
Planning committee formed

2020
Special Session at ASABE AIM
Made contacts and connections with others with common vision
Clearly defined activities and outcomes of MAA

2021
ASABE AIM, Anaheim, CA
Day-long special events with thought leaders. Present strategic plan, identify stakeholders, and seek funding. Engage partners and take steps to implement the MAA initiative

2023
Bi-annual event rotating in different countries in Africa. Continue assessing the status of the MAA, share ideas, bring together stakeholders/actors, and keep momentum going

Funding Model

Four levels: Planning Funding; Recurring Base Funding; Project-Based Funding; **Innovation Hub Funding**

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MAA Pillars

Technology and Innovation

- Identify potential partners and collaborate to identify technology and methodology needs and develop strategies to meet needs
- Coordinate and manage responses to Request for Applications from funding agencies and in special circumstances undertake projects such as developing standards for more uniform development and uptake of technology

Planning Funding: $125,000 to conduct a detailed assessment and develop a strategic plan for MAA

Planning activities will include;

- Consulting with key organizations/experts/agri-food system producers
- Organizing focus groups and collecting and organizing relevant data
- Laying out a short-term, medium term, and long-term plan

Funds will support; ASABE support staff time and Incidental costs and travel

Funds will not support; Salary of ASABE members or MAA committee members

Recurring Base Funding: A $250,000/year over 5 years to deliver items listed under 'Approach".

Will support a proposed organizational structure within ASABE dedicated to the proposed mission of MAA. Specifically,

- A part-time Director (25%)
- Summer faculty support
- Post doc, visiting scholars
- ASABE support staff
- Necessary travel

Innovation Hub Funding: Each regional MAA Hub funded at about $50M for 5 years

Funding will be a partnership of development banks, donor agencies/foundations, and participating countries in the region. Less than 5% of funding will support administration of each hub.

Funds will support:

- Hub infrastructure establishment
- Capacity building and training program development and implementation
- Technology and methodology development, testing and de-risking activities
- Low-cost business loans
- Knowledge sharing – Technology/Innovation fairs
- Services – feasibility studies, market analysis, business plan development, incubation and consultation

Funding Model

- **Planning funding:** $125,000 to conduct a detailed assessment and develop a strategic plan for MAA. Up to 1 year.
- **Recurring Base Funding:** A $250,000/year over 5 years to deliver items listed under 'Approach". Will support an organizational structure within ASABE dedicated to the proposed mission of MAA.
- **Project Based Funding:** case-by-case basis.
- **Innovation Hub Funding:** Each regional MAA Hub funded at about $50M for 5 years. A partnership among development banks, donor agencies/foundations, and participating countries in the region.

MODERNIZING AFRICAN AGRI-FOOD SYSTEM (MAA)

A Business Case for Investment in Agri-Food System Technologies in Africa

Thank You for Your Attention

Contact Us

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Dr. Julia Kigozi,
Agricultural Engineer, specializing in Food Process Engineering

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LEVERAGING OPPORTUNITIES AND POSSIBILITIES IN AGRICULTURAL PRODUCTION, AGRO-PROCESSING, AGRO-PHARMACEUTICALS , TRANSPORT INFRASTRUCTURE AND ENERGY.

PASAE-NIAE VIRTUAL INTERNATIONAL CONFERENCE
APRIL 19-22, 2021, ABUJA, NIGERIA.
BY ZOOM

By Dr. Julia Kigozi,
Department of Agricultural and Bio-systems Engineering,
Makerere University;
21st April, 2021

PRESENTATION OUTLINE

- The Agricultural Engineering training
- Industry Options for the Agric. Engineering Practice
- Description of operations in the Industries
- Achievements by Agric. Engineers in the industries
- Opportunities in the industries
- Skills required
- Vehicles to extend agricultural engineering practice

THE AGRICULTURAL ENGINEERING TRAINING

- Agricultural Engineering brings together science (particularly chemistry and biology) with engineering and technology solutions is a unique way which makes its different from many "pure" engineering disciplines.
- Agricultural Engineering education and training presents a fine example of a more inclusive approach which could be an excellent model for the future .

KEY AREAS OF TRAINING

- Irrigation Engineering
- Land and Water Resources Engineering
- Post-harvest Handling Engineering
- Biological and Agro-Process Engineering
- Machinery & Equipment Engineering; Simulation and modelling (EDEM and CFDs)
- Renewable Energy Engineering
- Wastewater and Sanitation
- Environmental Engineering
- Design of Structures : Farm Structures, Agro- processing facilitates

INDUSTRY OPTIONS FOR THE AG ENGINEERS TO PRACTICE

- Agro-processing
- Agricultural Production,
- Agro-Cargo Transport Infrastructure (Road, Air, Rail, Sea),
- Agro-Pharmaceuticals
- Energy
- Environmental Impact Assessments and management

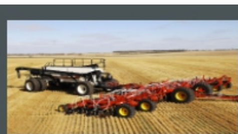
AGRICULTURAL PRODUCTION

Agricultural production involves;

- the exploitation of resources such as; soil, water, and energy to ensure production to feed a growing world population
- Conserving resources for future generations to thereby ensuring 'sustainable' agricultural methods.

OPERATIONS IN THE AGRICULTURAL PRODUCTION INDUSTRY

Land preparation
Planting
Weeding
Fertilizer/ pesticide application
harvesting



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ACHIEVEMENTS IN THE AGRICULTURAL PRODUCTION INDUSTRY BY THE AGRICULTURAL ENGINEERING PROFESSION

- The mechanization and automation of farming processes such as cultivation, sowing and harvesting has taken away the drudgery of these traditional activities and has led to great efficiency and higher work rates
- Evolving technologies such as remote sensing and monitoring which when combined with developing mobile phone networks and Apps has facilitated the use of mobile technologies to provided farmers and growers with real time information on climate, markets and optimization
- The "systems engineering" approach of Agricultural Engineers, combined with their multi-disciplinary approach has facilitated a better integration of production systems such as mechanisation, fertiliser application, harvest, post-harvest storage and marketing. This presents an important move toward horizontal integration of production systems.

OPPORTUNITIES IN THE AGRICULTURAL PRODUCTION INDUSTRY

- Design/setup and management of farming systems, (small, medium large scale)
- Design/selection of equipment,
  - Design of Small/medium scale agricultural production equipment
  - Selection and maintenance of medium/large scale agricultural equipment
  - Utilization of smart agriculture technologies
- Design and setup of irrigation systems
- Design and construction of water harnessing and conservation structures
- Design and set up of farm infrastructure
- Agro-production transport infrastructure and logistics
- Environmental impact assessments

SKILLS REQUIRED

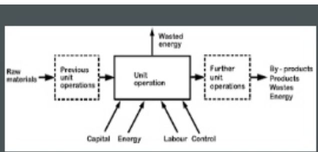
- Design of equipment- Study books and design tools (SOLID WORKS, EDEM, SOLID EDGE)
- Knowledge of Equipment Fabrication techniques
- Optimization of Farming operations (Design expert, RSM)
- Design of Farm structures and facilities (Autocad)
  - Farm layouts
  - Engineering drawings
  - Structural design
- Acquaintance with smart technologies for agricultural production
- Environmental impact assessment techniques
- Project planning, management and implementation
- Techno-economic analysis

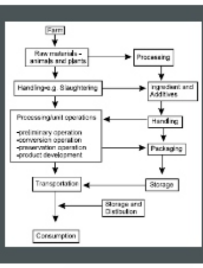
AGRO-PROCESSING AND AGRO-PHARMACEUTICALS INDUSTRY

- **Agro processing** could be defined as set of technoeconomic activities carried out for;
  - conservation of agricultural produce to maintain quantity and quality
  - Handling of agricultural produce to minimize loss
  - Processing of products by changing the form to improve and to make it usable as food, pharmaceuticals feed, fibre, fuel or industrial raw material to meet societal demands.
  - Storage and transportation of agricultural produce of produce

OPERATIONS IN THE AGRO-PROCESSING INDUSTRY

The unit operations which are used to recover agro-products include those which facilitate raw material preparation, processing operations, separation and recovery of solids and liquids, packaging, storage and transportation





- These industries provide crucial farm-industry linkage accelerating agricultural development

ACHIEVEMENTS IN THE AGRO-PROCESSING INDUSTRY BY THE AGRICULTURAL ENGINEERING PROFESSION

Improvement in food security by alleviation of post harvest losses. The agro processing Industry is able to;

- create edible or usable forms, of agricultural products
- improve storage and shelf life,
- create easily transportable forms,
- enhance nutritive value
- extract chemicals for other uses.

Ag Eng Contribution : Design and management of processes, Design/selection of equipment, and Design and set up of processing facilities

OPPORTUNITIES IN THE AGRO-PROCESSING INDUSTRY

- Design/setup and management of processes,
- Design/selection of equipment,
  - Design of Small scale processing equipment
  - Selection and maintenance of large scale processing equipment
- Design and set up of processing facilities
- Training in agro-processing fundamentals
- Agro-processing transportation infrastructure & logistics

SKILLS REQUIRED

- Design of equipment- Study books, material and energy flows, and design tools (SOLID WORKS, EDEM, SOLID EDGE)
- Knowledge of Equipment Fabrication techniques
- Optimization of Food technologies (Design expert, RSM)
- Simulation and Optimization of agro- processes (ASPEN, Design Expert)
- Design of processing structures and facilities (AutoCAD)
  - Plant layouts
  - Engineering drawings
  - Structural designs
- Techno economic analysis (Processes that are financially viable and economically feasible)
- Project planning, management , implementation and M&E

PROCESS SIMULATION TOOLS

Software	Developer	Applications	Operative system	License	URL
Advanced Simulation Library (ASL)	Avtech Scientific	Process data validation and reconciliation, real-time optimization, virtual sensing and predictive control	Windows, Linux, FreeBSD, Mac	open-source (AGPLv3)	[1]
APMonitor	APMonitor	MATLAB/Python/Julia-based data reconciliation, real-time optimization, dynamic simulation and nonlinear predictive control	Windows, Linux	open-source (BSD-2-Clause)	[2]
Apros	Fortum and VTT Technical Research Centre of Finland	Dynamic process simulation for power plants	Windows	closed-source	[3]
ASCEND	ASCEND	Dynamic process simulation, general purpose language	Windows, BSD, Linux	open-source (GPLv2)	[4]
Aspen Custom Modeler (ACM)	Aspen Technology	Dynamic process simulation	Windows	closed-source	[5]
Aspen HYSYS	Aspen Technology	Process simulation and optimization	Windows	closed-source	[6]
Aspen Plus	Aspen Technology	Process simulation and optimization	Windows	closed-source	[7]
ASSETT	Kongsberg Digital	Dynamic process simulation	Windows	closed-source	[8]
BatchColumn	ProSim	Simulation and Optimization of batch distillation columns	Windows	closed-source	[9]
BATCHES	Batch Process Technologies, Inc	Simulation of recipe driven multiproduct and multipurpose batch processes for applications in design, scheduling and supply chain	Linux	closed-source	[10]

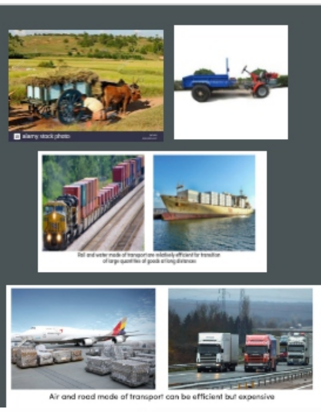
TRANSPORT INFRASTRUCTURE

- The development of transport and the improvement of logistics performance are crucial issues for countries seeking to become more competitive on the international geo-economic scene.
- Good infrastructure helps to facilitate trade flows and is therefore an additional guarantee of success in industries, while at the same time providing local solutions to improve access to certain marginalised regions and allow them to play their part in the national economy.

MEANS OF TRANSPORT

Traditional; manual method of transport, used on every farm, usually includes very short distances (for instance, the transition from the field to the storage that is located on the farm).

Mechanized and advanced transport; includes longer distances that require the use of certain means of transport.



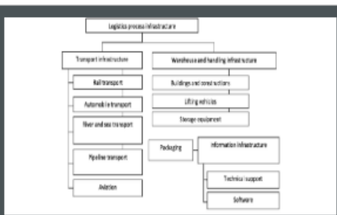
Air and road mode of transport can be efficient but expensive

OPERATIONS IN THE TRANSPORT INDUSTRY

Transportation is simply the mode to execute the planning, and moving a product from A to B

Logistics on the other hand, makes it all possible, factoring in the following:

- Product packaging
- Containerization
- Documentation & insurance
- Storage (warehousing etc.)
- Regulatory rules (importing & exporting)
- Choosing the appropriate freight class (TL / LTL, etc.)
- Managing & maintaining vendor and partner relationships
- Risk mitigation



Engineers work to maximize productivity while eliminating waste and minimizing risk and error in order to improve productivity and profits.

They schedule and track deliveries, and analyze the effectiveness of existing operations.

SKILLS REQUIRED

- Simulation and Optimization of transport processes (simulation packages)
- Process management tools transportation, stock control, warehousing and monitoring the flow of goods. (tools to track processes)
- Design of transport structures and facilities (AutoCAD)
  - Facility layouts
  - Engineering drawings
  - Structural designs
- Design and fabrication of small scale transportation carts for farm operations
- Techno-economic analysis
- Project planning, management and implementation

ENERGY

- Modern agriculture requires an energy input at all stages of agricultural production such as direct use of energy in farm machinery, water management, irrigation, structures, agro-processing and for human consumption
- Energy is provided by
  - basic human work for tilling, harvesting and processing, together with rain-fed irrigation
  - Draft animal technology ;
  - Grid Hydro-electric power
  - Application of renewable energy technologies such as wind, solar dryers and water wheels, biomass, biofuel crops, biogas and fossil fuel based technologies for motive and stationary power applications, and for processing agricultural products.

ENERGY SOURCES

Agricultural Engineering expertise required.

1. Knowledge of existing energy sources; best practices, advantages and disadvantages
2. Harnessing of exiting energy sources
3. Energy efficiency testing fuels/ stoves
4. Optimization /Set up and maintenance of energy management systems e.g. biogas
5. Techno-economic analysis
6. Project planning, management and implementation


VEHICLES TO EXTEND EXPERTISE
Ag. Engineering Consultancies and workshops
Jobs in Govt, NGO's, Academia in Agricultural Engineering
Projects between government, private sector and academia
University community outreach
Research support by academia to industry
Training for the sectors
Note
Interventions are required for small, medium and large scale industry.


THANK YOU!
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HE, Dr. Jean Bakole
Regional Director, UNIDO Regional Office Hub, Abuja, Nigeria.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION — SUSTAINABLE DEVELOPMENT GOAL 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

The Role of UNIDO in Agro-industrial Transformation and Job Creation Opportunities in AfCFTA

Presented during the

JOINT VIRTUAL INTERNATIONAL CONFERENCE OF THE PAN AFRICAN SOCIETY FOR AGRICULTURAL ENGINEERING (PASAE) AND NIGERIAN INSTITUTION OF AGRICULTURAL ENGINEERS (NIAE), APRIL 20-21, 2021

Mr. Jean Bakole
Regional Director
UNIDO Regional Office Hub, Abuja

Overview of UNIDO

- The 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals are a universal call to collectively mobilize efforts and active participation of the whole society to end all forms of poverty, fight inequalities and tackle climate change, while ensuring that no one is left behind.
- Amidst international efforts, the United Nations Industrial Development Organization (UNIDO), is a United Nations specialized agency focusing on industrialization,
- UNIDO is at the forefront of Industrialization by promoting and accelerating inclusive and sustainable industrial development to achieve shared prosperity and environmental sustainability.
- Furthermore, UNIDO is leading the implementation of the Third Industrial Development Decade for Africa 2016-2025, which is a clear resolution seeking to promote internal engines of growth and enable Africa to attain self-reliance through inclusive and sustainable industrialization.

UNIDO's AGRIBUSINESS Transformational Change

- With African Population on the increase, bold actions would be required to achieve higher productivity and social, economic and environmental sustainable growth in the agriculture and agro-industrial sector.
- Agriculture is a key component of the economy of many developed and emerging countries and an opportunity for achieving livelihood, job creation and shared prosperity responding to the 2030 Development Agenda and SDG1, SDG2 and SDG9.
- "The development of agriculture-based industry is a first step towards the structural transformation of developing countries economies".
- The United Nations Industrial Development Organization (UNIDO) helps developing countries to add value to their agricultural produce that will in turn increase employment and income and lead to a higher level of prosperity.
- UNIDO programme on agribusiness development covers food and food systems, leather and leather products, textile and garments, wood and woodworking, agriculture mechanization and inputs supply and creative industries, as well as human capital development with focus on rural populations.

- Inclusive and Sustainable industrialization (ISID) promoted by UNIDO focuses on upgrading and greening value chains to enable food systems to deliver safe food, better nutrition and fair income without jeopardizing economic, social and environmental resources.
- UNIDO facilitates the transfer and adoption of appropriate and green agro-processing and post-harvest technologies and practices as well as waste minimization

Agro-industrial transformation and Job Creation Opportunities in AfCFTA – UNIDO's Roles.

MSME Development

- Small and medium-sized enterprises (SMEs) make up more than 90% and more than 50% of employment worldwide, and there are some 500 million smallholder farms worldwide with more than 2 billion people that depend on them for their livelihoods.
- UNIDO focuses on fostering enterprise creation, training and nurturing SMEs in member states to link agriculture, processing and marketing, and to promote job creation and enhanced prosperity.
- UNIDO places special attention, on empowering SMEs by facilitating access to capital (human, knowledge, social and financial) to make them active economic actors - especially in AfCFTA.
- In this context, UNIDO focuses on strengthening the entrepreneurial ecosystem by supporting start-ups and upgrading existing SMEs in agribusiness sector and integrating agriculture and agro-industry pursuing circular economy objectives.

Integrated Agribusiness Investment Region (ABIR), Special Crop Processing Zones, Special Economic Zones, Integrated Agro-industrial Parks, etc.

- Despite strong economic growth, job creation and poverty reduction remain major challenges for governments across Africa.
- Many African member states are looking to China, which has proven over the last three decades how industrialization can create jobs and allow unprecedented numbers of people to move out of poverty.
- An important vehicle for China's economic growth has been the successful use of special economic zones (SEZs)/Intergrated Agro-Industrial Parks) since the early 1980s.
- UNIDO is supporting African countries to embrace SEZs, IAIPs, etc as a means of attracting foreign direct investment, transfer of technology and knowhow, ensuring quality and standards, create employment as well as promoting regional and international market - AfCFTA.
- SEZs are currently experiencing a renaissance in a number of African countries. Promising developments can be found in Ethiopia, Nigeria and Zambia, where some SEZs have unleashed broad interest of international investors in the respective country's economy

Integrated Agribusiness Investment Region (ABIR), Special Crop Processing Zones, Special Economic Zones, Integrated Agro-industrial Parks

- UNIDO promotes the establishment of agro-industrial park(s), agro-processing hubs with the aim of enabling inclusive rural economy structural transformation through the agro-industrialisation.
- Provides a range of technical cooperation services for the development of agribusiness processing hubs in agriculture growth corridors, connecting agricultural production areas to end markets like AfCFTA through shared infrastructure, services and technologies.
- UNIDO supported the government of Nigeria in developing the Staple Crops Processing Zones (SCPZ) project which was implemented in the framework of the first Country Programme.
- The project developed masterplans for six sites with focus on different agricultural commodities/value chains.
- UNIDO is working in collaboration with the Government of Nigeria, the World Bank and the African Development Bank to implement the Staple Crop Processing Zones using the masterplans developed under the previous Country Programme.

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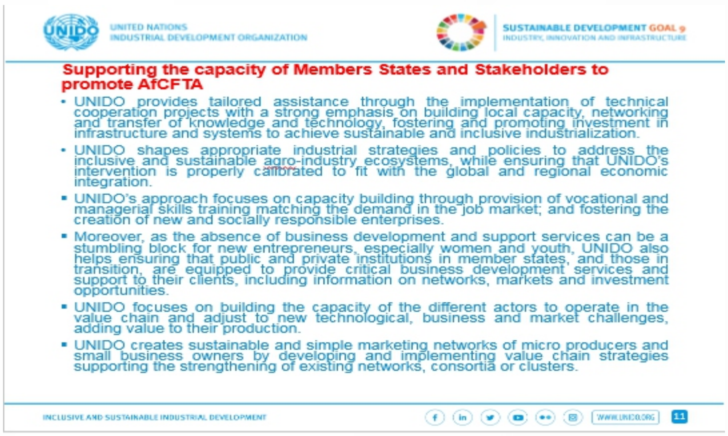
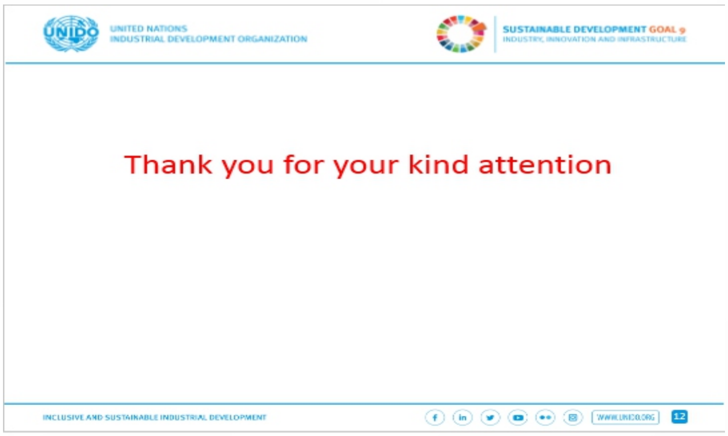
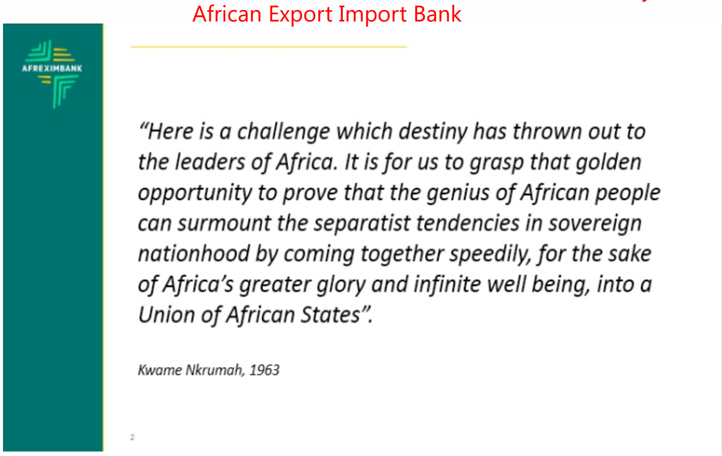
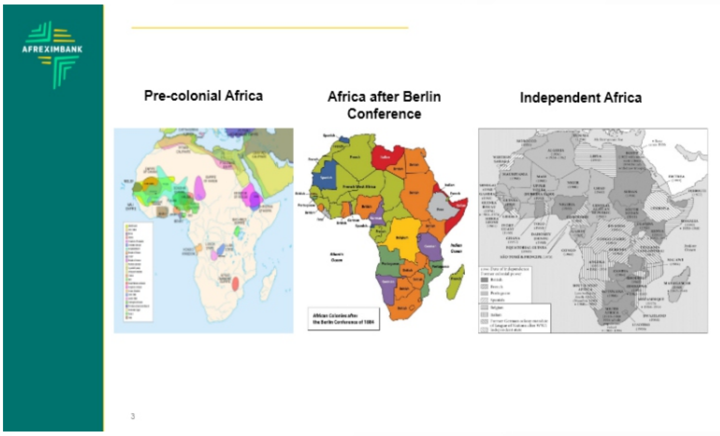
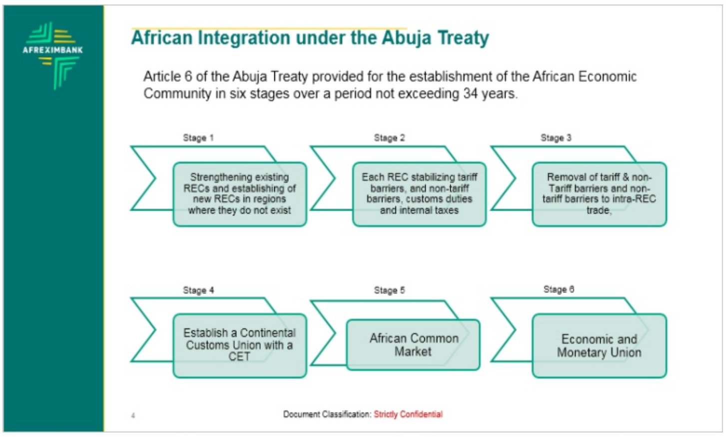


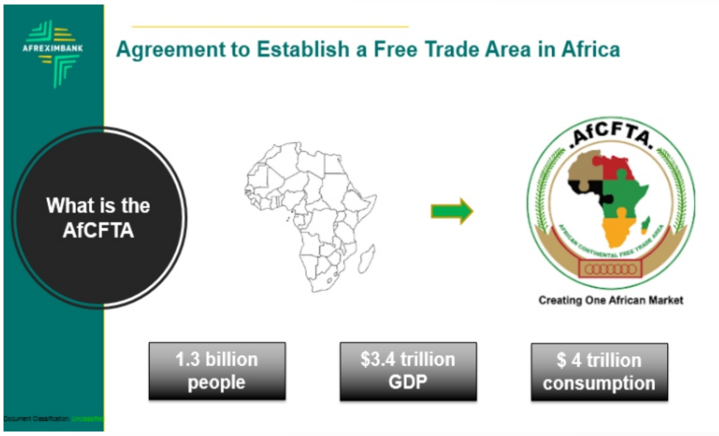


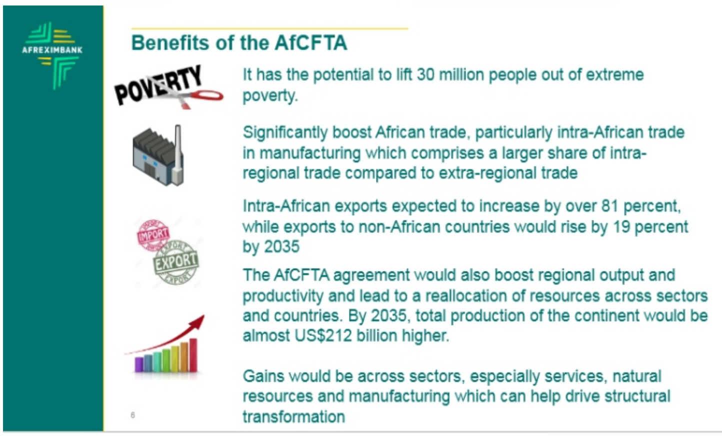
Yusuf Daya
Director AU/AfCFTA Relations and Trade Policy,
African Export Import Bank

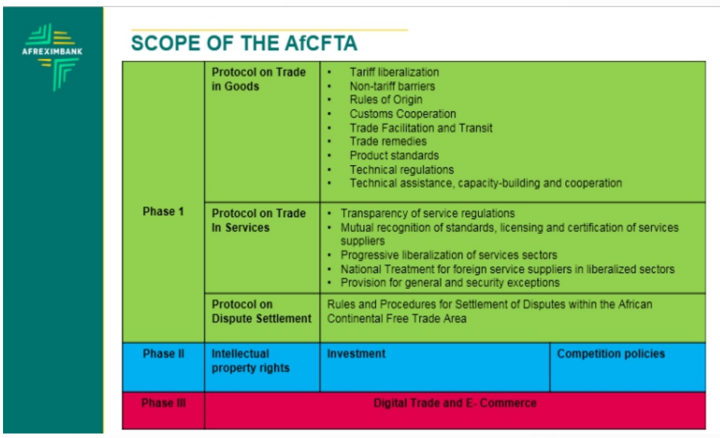












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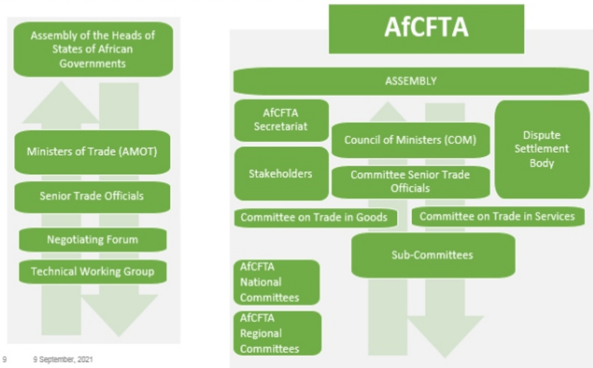
AfCFTA Principles

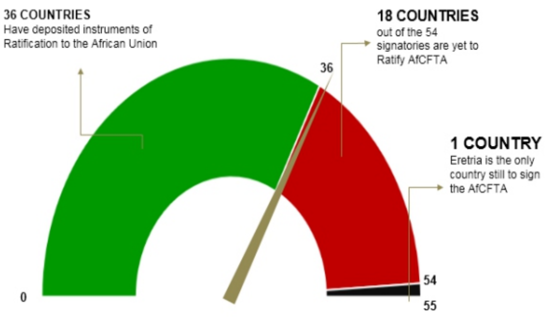
- Driven by member states of the African Union;
- RECs free trade areas (FTAs) as building blocs for the AfCFTA;
- Variable geometry;
- Flexibility and special and differential treatment;
- Transparency and disclosure of information;
- Preservation of the acquis;
- Most-favoured-nation (MFN) treatment;
- National treatment;
- Reciprocity;
- Substantial liberalization;
- Consensus in decision-making; and
- Best practices in the RECs, in the state parties and international conventions binding the African Union.

Institutional Framework for the AfCFTA



9 9 September, 2021

Status of Ratification



10 9 September, 2021

Negotiations _ Trade in Goods

	LDCS	Non-LDCS
Non-sensitive products To be fully liberalized 90%	Complete elimination of tariffs within a timeframe of 10 years	Complete elimination of tariffs within a timeframe of 5 years
Sensitive products To be fully liberalized over a longer period 7%	Complete elimination of tariffs within 13 years	Complete elimination of tariffs within 10 years
Excluded products : 3%	To be excluded from liberalization	To be excluded from liberalization;

11 9 September, 2021

Status of Negotiations _ Trade in Goods

Submitted	Benin	Egypt	Madagascar	Sierra Leone
	Botswana	Equatorial Guinea	Malawi	Seychelles
	Burkina Faso	eSwatini	Mali	South Africa
	Burundi	Gabon	Mauritania	South Sudan
	Cabo Verde	Gambia	Mauritius	Togo
	Cameroon	Ghana	Namibia	Uganda
	Chad	Guinea	Niger	United Rep. of Tanzania
	Central African Rep.	Guinea-Bissau	Nigeria	Zambia
	Congo Republic	Kenya	Rwanda	
	Cote d'Ivoire	Lesotho	Sao Tome and Principe	
	Dem. Rep. of the Congo	Liberia	Senegal	

12 9 September, 2021

Negotiations Trade in Services

- Aims to progressively liberalise trade in services among its Members, enhance competitiveness of services and foster domestic and foreign investment (Article 3, Protocol on Trade in Services)
- Liberalisation of trade in services is determined on the basis of Member States' schedules of specific commitments.
- 5 priority sectors to be liberalized (business, communication, financial, tourism and transport), also to be finalized by June 2021
- COVID impacts: Health and education services are also being considered

13 9 September, 2021

Status of Negotiations Trade in Services

Submitted initial offers on trade in services	Benin	Guinea-Bissau	Mauritania	Sierra Leone
	Burkina Faso	Dem. Rep. of the Congo	Mauritius	South Africa
	Burundi	Egypt	Namibia	South Sudan
	Cabo Verde	eSwatini	Niger	United Rep. of Tanzania
	Comoros	Kenya	Nigeria	Togo
	Cote d'Ivoire	Lesotho	Rwanda	Uganda
	Gambia	Liberia	Sao Tome & Principe	Zambia
	Ghana	Madagascar	Senegal	
	Guinea	Mali	Seychelles	

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OPERATIONAL INSTRUMENTS TO SUPPORT THE AFCFTA

1	NTB Monitoring Mechanism	The private sector can directly report trade obstacles on the portal. The NTB complaints are directly sent to formally nominated government officials (National Focal Points) who monitor and eliminate the barriers.
2	African Business Council AfBC	The Africa Business Council will be an advocate of Africa's private sector for the enormous potential of the AfCFTA, and help guide partnerships with African governments through trade facilitation
3	African Trade Observatory	The African Trade Observatory serves as a repository of trade information and allows to monitor, in real time, the pace of trade and economic integration in Africa. it provides updated and reliable data to inform business and policy decisions and to monitor the implementation process of the agreement and its impact

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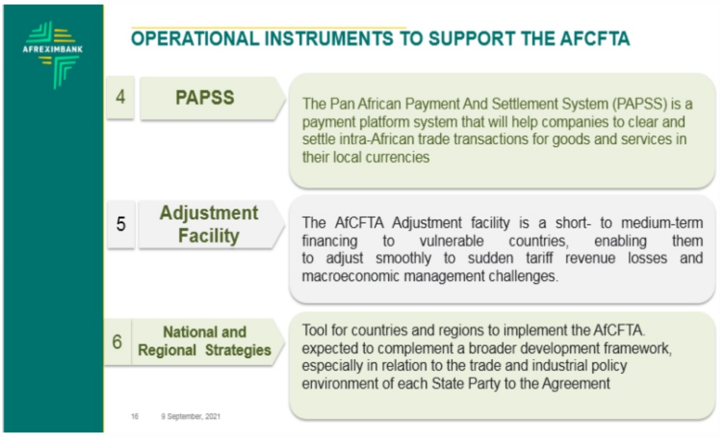
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OPERATIONAL INSTRUMENTS TO SUPPORT THE AFCFTA
4
PAPSS
The Pan African Payment And Settlement System (PAPSS) is a payment platform system that will help companies to clear and settle intra-African trade transactions for goods and services in their local currencies
5
Adjustment Facility
The AfCFTA Adjustment facility is a short- to medium-term financing to vulnerable countries, enabling them to adjust smoothly to sudden tariff revenue losses and macroeconomic management challenges.
6
National and Regional Strategies
Tool for countries and regions to implement the AfCFTA. expected to complement a broader development framework, especially in relation to the trade and industrial policy environment of each State Party to the Agreement
16
9 September, 2021


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Engaging with AfCFTA institutions
National Level:
AfCFTA implementation committee
National NTB committee
National AfCFTA focal point/ministry
Private sector associations/umbrella organizations
Regional Level:
Regional AfCFTA committees
Regional Private sector organizations
Continental Level:
AfCFTA Secretariat,
PAFTRAC, AfBC
17
9 September, 2021
Document Classification: Unclassified


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Concluding Remarks
While the AfCFTA provides an opportunity for Africa to boost intra-African trade and reduce the vulnerability of its economies to external shocks, the implementation of the agreement will be complex, given the large number, diverse nature and different stages of economic development of its member states.
Effective implementation of the AfCFTA will require investments in trade-facilitating infrastructure to ensure that supply-side constraints are addressed, and market access benefits are fully realized.
Addressing NTBs, including, among others, standards and currency inconvertibility is also critical to the successful implementation of the AfCFTA.
Addressing trade information gaps and working with the private sector, who are to a large extent those with the ultimate responsibility of operationalizing integration, is necessary to support implementation.
Regional and continental institutions managing the process of regional integration need to be strengthened, as does national capacity for the implementation of protocols and agreements.


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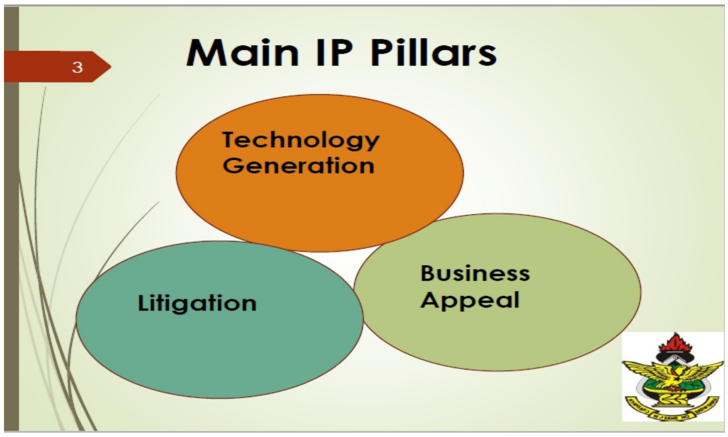
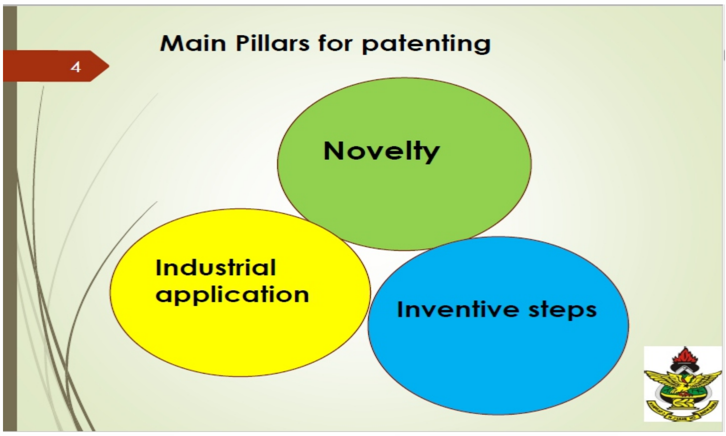
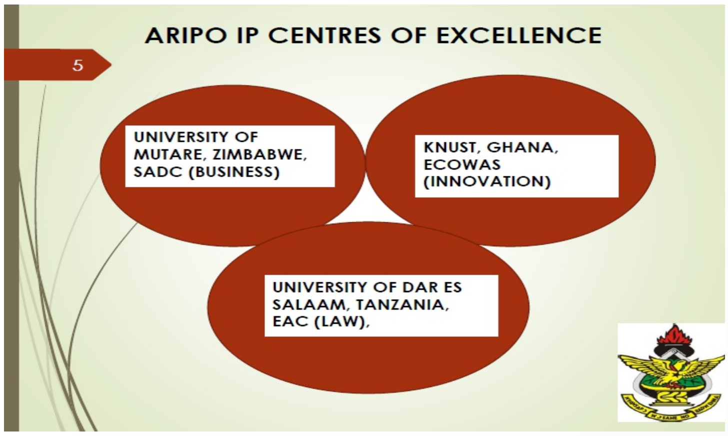
THANK YOU
ydaya@afreximbank.com
African Export-Import Bank
Banque Africaine D'Import-Export
Transforming Africa's Trade
Document Classification: Unclassified

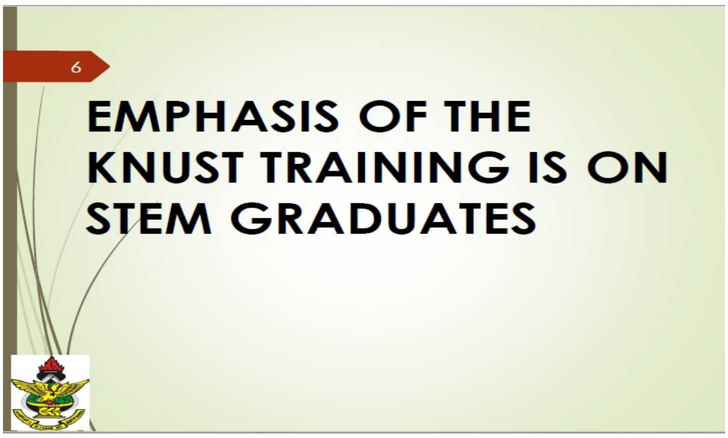
WORKSHOP F PRESENTATIONS

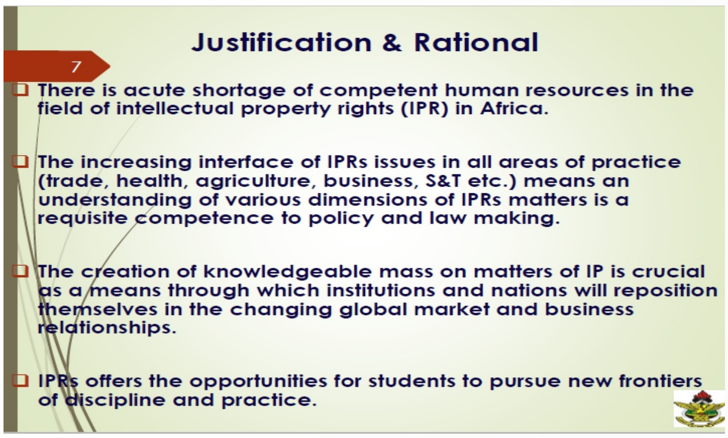
Professor Emmanuel Bobobee
Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.











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16

For the First cohort, we have admitted 21 applicants from eight African countries in 2018

Country	Qualified Applicants Admitted	Registered Candidates
Ghana	16	6
Nigeria	1	0
Kenya	1	1
Tanzania	1	1
Namibia	1	1
Uganda	1	1
Malawi	1	1
Botswana	1	1
TOTAL	23	12

17

For the second cohort, we have admitted 34 applicants from eight African countries in 2019

Country	Qualified Applicants Admitted	Registered Candidates
Ghana	18	8
Nigeria	3	0
Kenya	4	1
Rwanda	1	0
Namibia	1	1
Uganda	2	1
Sierra Leone	1	1
Zimbabwe	1	1
Malawi	3	1
TOTAL	34	14

18

The third cohort, we have admitted 26 applicants from seven African countries in 2020

Country	Qualified Applicants Admitted	Registered Candidates
Ghana	16	7
Kenya	1	0
Tanzania	2	1
Namibia	3	1
Uganda	1	1
Zambia	1	1
Malawi	2	1
TOTAL	26	12

First Semester Taught Courses

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CODE	COURSE/MODULE	TEACHING STAFF
MIP 551	Introduction to Intellectual Property	Mr. Emmanuel Sackey (ARIPO) Prof Emmanuel YH Bobobee (KNUST)
MIP 553	International Intellectual Property System and Institutions	Mrs. Doreen Adoma Agyei (KNUST) Mr. Fernando dos Santos (ARIPO)
MIP 555	Industrial Property (Patents, Utility Model and Innovation, and Industrial Designs)	Mr. Said Ramadhan (ARIPO) Mrs. Sarah Anku (Private Legal Practice)
MIP 557	Branding (Geographical Indications, Trademarks, Breach of Confidence and Unfair Competition)	Ms. Grace Issahaque (GHIPO) Mr. Kwame Anyimadu-Antwi (MP)
MIP 559	IP on Biotechnology, Public Health, Food Security, Plant Breeders Right	Prof. Richard Akromah (KNUST) Dr. Alex Wireko Kena (KNUST)
MIP 561	Copyright and Neighbouring Rights	Ms. Eudora Oppong (Judge) Miss Eunice Boateng (KNUST)
Electives		
MIP 563	Intellectual Property, Innovation and Creative Economy	Dr. Ernest Owusu Dapaa (KNUST)
MIP 565	Intellectual Property and Business Environment	Mr. Samuel Akomeah (KNUST) Ms. Eunice Boateng (KNUST)

Second Semester Taught Courses

CODE	COURSE/MODULE	TEACHING STAFF
MIP 552	Protection of Traditional Knowledge, Folklore and Genetic Resources	Mr Emmanuel Sackey (ARIPO) Mr Kwame Anyimadu-Antwi (MP)
MIP 554	Strategic Planning, Technology Transfer, Licensing, Commercialisation and Start-ups (IP & Social Dimensions)	Dr Ahmed Agyapong (KNUST) Dr George Obeng (KNUST)
MIP 556	IP Management, Audit, Valuation and Monetisation	Dr Wilberforce Owusu-Ansah (KNUST) Ms Eunice Boateng (KNUST)
MIP 558	Respect for Intellectual Property Rights, Infringement and Litigation	Doreen Adoma Agyei (KNUST)
MIP 562	Intellectual Property Rights for Engineers and Scientists	Mrs Sarah Anku (Private Legal Practice)
MIP 568	Intellectual Property and Cyber Space	Dr. Albert Antwi-Bosiako (
MIP 560	Research Methods, Pedagogy and Statistics	Dr Francis Kemausuor (KNUST) Dr William Amponsah (KNUST)

MIP 651 Integrated Study Assignment 1st Cohort

21

No	Topic
1	Industrial Property compliance of undergraduate and Graduate students' theses at the College of Engineering from 2013-2018.
2	Copyright compliance of undergraduate and Graduate students' theses at the College of Humanities and Social Sciences from 2013 – 2018.
3	Traditional Knowledge (TK) topics and compliance of undergraduate and Graduate students' theses at the College of Art and Built Environment (CABE) from 2013 – 2018.
4	Critical Issues to Consider in the Review of the KNUST IP Policy and its Linkages with the National IP Policy and the University's Research Policy

MPhil Theses Topics (1st Cohort)

No	THESIS TOPIC
1	Utilization of intellectual property tools to protect and commercialize innovative herbal products from selected herbal plants in Ghana.
2	Addressing challenges facing Ghana in establishing plant variety protection (PVP) system. Assessing the roles of stakeholders.
3	Adopting KNUST research output in Renewable energy sector using Intellectual Property Policies.
4	Are we innovating or innovation on shelves? A case study of College of Engineering, KNUST
5	Factors affecting the growth of the creative industries in Ghana. Case study of music and movies.
6	Integrating intellectual property into the informal economy of Ghana.
7	Assessing the use of intellectual property options for the protection of textiles in Ghana.
8	The effectiveness of IP Policies of Universities and Public Research Organization on Technology Transfer in Kenya.
9	Integration of intellectual property education in tertiary institutions as a tool of investing Intellectual Property in future generation. A comparative study of Ghanaians and Malawian universities.
10	The effective utilization of intellectual property by SMEs in Ghana in promoting the growth of their business.
11	Assessment of Intellectual Property awareness and interest among academic staff at KNUST
12	Respect of Copyright in Uganda: analysis of the role of CMOs in achieving compliance.

Lecturers actively teaching on the programme

23

- Prof. E. Y. H. Bobobee, KNUST
- Mr Said Ramadhan, ARIPO
- Mrs Sarah Norkor, Private legal Practitioner and IP Specialist
- Mr. Emmanuel Sackey, ARIPO
- Mr. Fernodo dos Santos, DG-ARIPO
- Dr Ernest Dapaah, KNUST
- Mrs Doreen Adoma Agyei, KNUST
- Mrs Eunice Boateng, KNUST
- Hon. Kwame Anyimadu-Antwi, (Member of Parliament)
- Prof. R. Akromah, KNUST
- Dr. W. Kena, KNUST
- Dr. Albert Antwi-Bosiako
- Dr. Ernest Owusu Dapaah, KNUST
- Dr Wilberforce Owusu Ansah, KNUST
- Mrs Eudora Oppong, KNUST
- Dr. Outule Rapuleng, ARIPO
- Mr. Samuel Akomea, KNUST
- Dr Francis Kemausuor, KNUST
- Dr William Amponsah, KNUST

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Challenges Facing Developing Countries

8

- Lack of awareness of the importance of IP for development,
- Although, almost all African countries have established IP institutions, capacity and skills are still a problem,
- Lack of adequate regulations for the management of IP rights,
- Lack of adequate infrastructure for the operations of the IP Offices,
- Lack of examiners to perform high quality substantive examination,
- Procedures in certain IP offices are very cumbersome,
- Many IP offices are still lagging behind with regard to automation.

Brief Background

9

- As a result of resolution adopted by the Administrative Council of ARIPO at its 35th Session held in Accra, Ghana in November 2011,
- KNUST was selected to launch and host the MIP degree programme in the ECOWAS Sub-Region,
- KNUST is running MPhil degree programme in Intellectual Property.

MPhil Intellectual Property (MIP) at KNUST

10

- The programme is jointly established by the African Regional Intellectual Property Organisation (ARIPO), Kwame Nkrumah University of Science and Technology (KNUST), Kumasi and Intellectual Property Office of Ghana (GHIPO),
- The Programme adopts a comparative approach, with particular emphasis on Africa,
- Lectures are given by leading academics, intellectual property practitioners, intellectual property officers and other experts drawn from across Africa.

Objectives & Focus of the Programme

11

- To provide an in-depth training and expose students to a wide array, dimensions, and interface of intellectual property policy and regulatory issues as they apply in a broad spectrum of societal developmental issues.
- The focus is to develop regional (West Africa and Africa as a whole) tailor-made approach to delve into the best IPR approaches that can be used taking into account the context of the region.

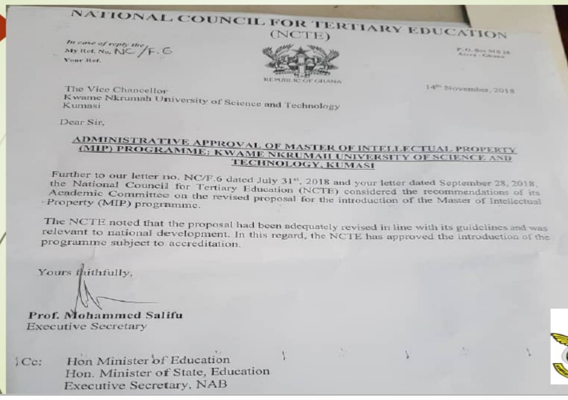
Implementation

12

- Accreditation was sought from the national regulatory bodies:
  - National Council for Tertiary Education (NTCE) and
  - National Accreditation Board (NAB) for the running of the programme
- KNUST being a public university, NCTE gave Administrative approval and recommended to NAB for accreditation of the programme to start.

NCTE APPROVAL FOR ACCREDITATION BY NAB

13


NATIONAL COUNCIL FOR TERTIARY EDUCATION
(NCTE)

In case of reply the
My Ref. No. NC/F.6
Your Ref.

REPUBLIC OF GHANA

14th November, 2018

The Vice Chancellor
Kwame Nkrumah University of Science and Technology
Kumasi

Dear Sir,

ADMINISTRATIVE APPROVAL OF MASTER OF INTELLECTUAL PROPERTY (MIP) PROGRAMME: KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

Further to our letter no. NC/F.6 dated July 31st, 2018 and your letter dated September 28, 2018, the National Council for Tertiary Education (NCTE) considered the recommendations of its Academic Committee on the revised proposal for the introduction of the Master of Intellectual Property (MIP) programme.

The NCTE noted that the proposal had been adequately revised in line with its guidelines and was relevant to national development. In this regard, the NCTE has approved the introduction of the programme subject to accreditation.

Yours faithfully,

Prof. Mohammed Salifu
Executive Secretary

Cc: Hon Minister of Education
Hon. Minister of State, Education
Executive Secretary, NAB

Programme Management

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- The MIP is hosted like any other Academic Programmes at the College of Engineering (COE), but has KNUST wide appeal and support.
- Staff from COE, Business School & Law Faculty are playing key roles in running the programme.
- The Programme is advertised by School of Graduate Studies for students to apply .
- There is a programme coordinator responsible for the programme.

Programme Management (cont'd)

15

- Programme jointly coordinated by KNUST, Ghana's Registrar General's Department & Copyright Administrator and ARIPO through a Programme Advisory Board (PAB).

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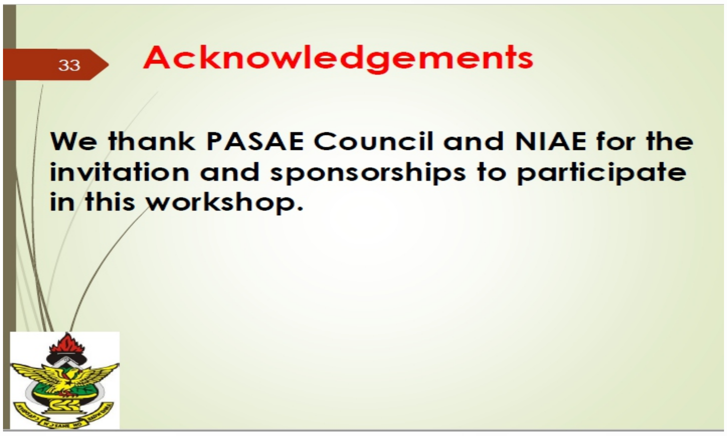
32
PLANS FOR FUTURE ACADEMIC YEARS
Embark on more vigorous advertisement using available resources such as
KNUST Website
ARIPO Website
Contacts at International bodies like AAU, CORAF, FARA
Selected Newspapers
Flyers and Brochures
International Conferences/Workshops
Secure sustainable funding sources


33
Acknowledgements
We thank PASAE Council and NIAE for the invitation and sponsorships to participate in this workshop.

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PROTOCOLS & APPRECIATIONS…

NIAE - PASAE 2021

A Presentation© By

Engr Umar Buba Bindir PhD

BABBAN MUFTI ADAMAWA EMIRATE

FAEng, FNSE, FNIAE, FSESN, CEng, COREN® NPoM

ubindir@yahoo.com

NIAE - PASAE 2021

BRIEF ON: UMAR B. BINDIR

- YOLA TOWN, ADAMAWA STATE; BSc (Maid), MSc, PhD (UK)
- Agricultural Power & Machinery Engineering Specialist
  - Rural Engineer (Poverty solution provider)
- FAEng, FNSE, FNIAE, COREN®, CEng, NPoM, etc
- ACADEMIA (Local and International)
- INDUSTRY (Local and International)
- CIVIL SERVICE (Federal Government)
  - FEAP, THE PRESIDENCY (Director) – Poverty Alleviation using Indigenous Production Technology
  - NAPEP, THE PRESIDENCY (Director) – Poverty Eradication
  - Federal Ministry of Sports & Social Development (Director)
  - Federal Ministry of Science & Technology (Director)
- DG/CEO, NOTAP (2009 – 2015)
- Secretary to Government Adamawa State (SGS) (2015 – 2019)
  - Real time Poverty Environment
- SOCIAL ENTREPRENEUR (Practioner on a slice of poverty)

ubindir@yahoo.com

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3

Nigeria
Good People, Great Nation

THEORIES OF INTELLECTUAL PROPERTY REGIMES, CASE STUDIES OF PATENTED INNOVATIONS, THE ROLE OF IPR IN THE PROCESS OF COMMERCIALISATION OF INVENTIONS, INNOVATIONS AND OTHER R&D OUTPUTS

A PAPER PRESENTED AT THE WEBINAR CONFERENCE ON CHALLENGES AND PROSPECTS OF DRUG DISCOVERY & DEVELOPMENT IN NIGERIA

Monday 19th April 2021

NIAE - PASAE 2021

4

FOR ANY COUNTRY TO DEVELOP, INDUSTRIALISE, BE RESPECTED & BE VISIBLE REGIONALLY, CONTINENTALLY OR GLOBALLY

IT MUST HAVE UNDERSTOOD THAT….

NIAE - PASAE 2021

5

THE VIBRANCE, CONNECTIVITY AND EFFICIENCY OF IT'S KNOWLEDGE SYSTEMS HINGED ON:

THE EFFECTIVENESS OF IT'S SCIENCE, TECHNOLOGY & INNOVATION ECO-SYSTEM

"THIS IS THE MASTER KEY"

(AND THERE IS NO CUTTING CORNERS)

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6

WHICH IS TOTALLY MIS-UNDERSTOOD

PARTICULARLY IN AFRICA!!

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7

SO LET US BRIEFLY LOOK AT THE THEORIES & PRACTICE OF THE STI VALUE CHAIN!!

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8

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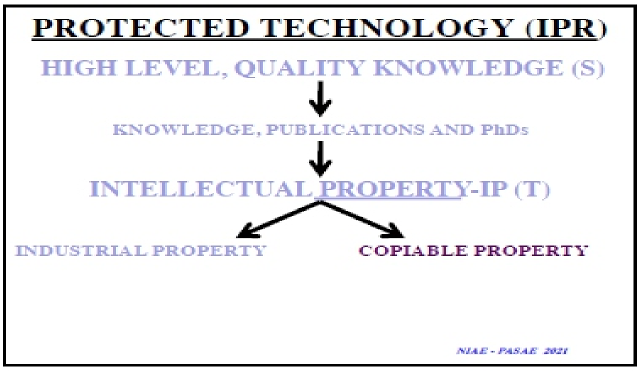

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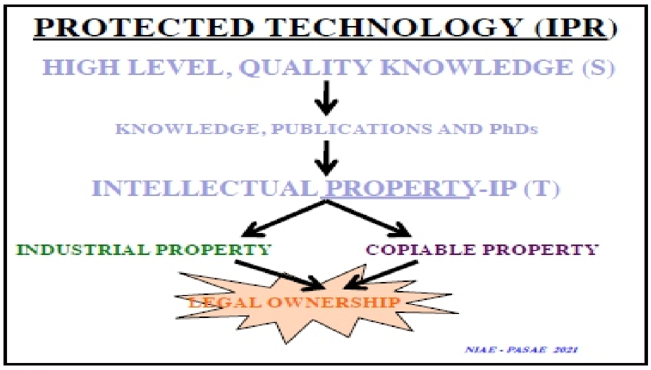

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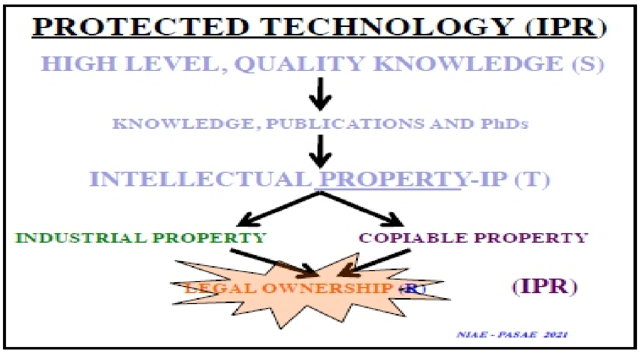

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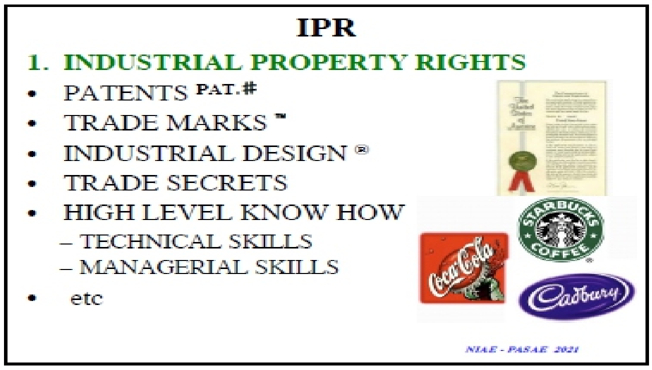

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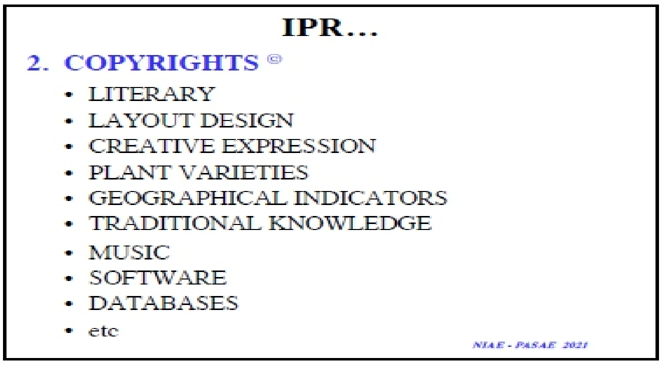

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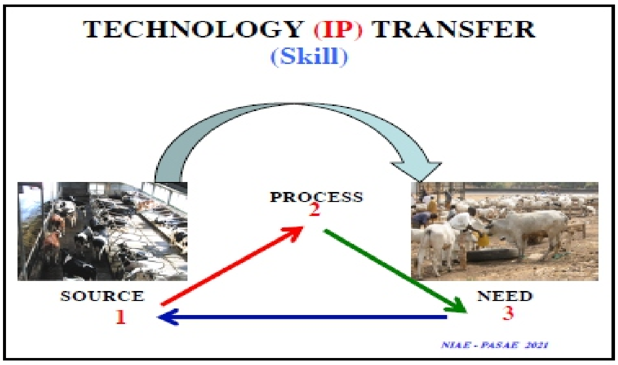

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DESPITE THESE OUTPUTS, CREATIVITIES AND INNOVATIONS ON THE GROUND……

THE REALITIES (rural life 70%)

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• >50% OF THE POPULATION
(OVER 100 MILLION)

SUB-URBAN/RURAL LIFE DOMINATES

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BASIC EDUCATION

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WATER SUPPLY

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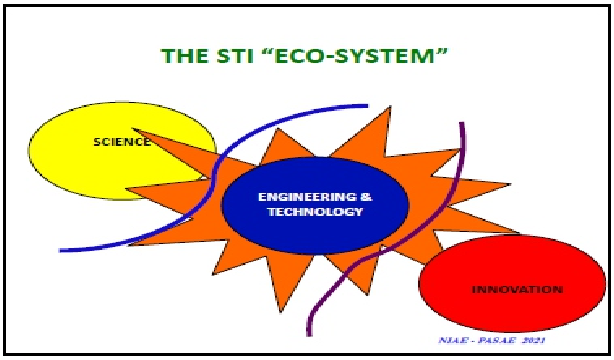

SCIENTIFIC CAPACITY (RESEARCH)

FACTS AND FIGURES (Research)

SCIENCE

Ability to study, generate knowledge, discover, conceive possibilities, document, communicate, publish…

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RESEARCH

- SPECIALISTS (SCIENTISTS/RESEARCHERS)
- HIGHLY TRAINED AND QUALIFIED
- "LONG TERM" INVESTMENTS
- EXPENSIVE TOOLS AND FACILITIES
- HIGH MOTIVATION
- etc

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RESEARCH

- RESEARCH INFRASTRUCTURE (Labs & Equipment)
- WORLD CLASS PUBLICATIONS/PhDs/PROFESSORS)
- HIGH IMPACT/CITATION/ACADEMIC PARTNERSHIPS…
- RELEVANCE?

HIGH LEVEL, QUALITY KNOWLEDGE

↓

KNOWLEDGE, EXPERTISE, SPECIALISTS

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DEVELOPMENT CAPABILITY

POSSIBILITIES AND APPLICATIONS (Development)

TECHNOLOGY

Ability to transform knowledge (S) into socio-economic solutions and assets)

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TECHNOLOGY

- TECHNOCRATS (ARTISANS, TECHNICIANS, HANDY MEN/WOMEN…. OTHERS)
- HIGHLY SKILLED IN TRANSFORMING KNOWLEDGE
- PROOF OF CONCEPTS ON PRODUCTS AND PROCESSES
- PRODUCTION PROCESSES INFRASTRUCTURE
- PROTOTYPES AND PILOT PLANTS
- TECHNOLOGY SERVICES
- RELEVANCE ?

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TECHNOLOGY (IP)…

HIGH LEVEL, QUALITY KNOWLEDGE (S)

↓

KNOWLEDGE, PUBLICATIONS AND PhDs

↓

INTELLECTUAL PROPERTY-IP (T)

???…

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PROTECTED TECHNOLOGY (IPR)

HIGH LEVEL, QUALITY KNOWLEDGE (S)

↓

KNOWLEDGE, PUBLICATIONS AND PhDs

↓

INTELLECTUAL PROPERTY-IP (T)

↙

INDUSTRIAL PROPERTY

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INNOVATION & ENTREPRENEURSHIP

ENTREPRENEURSHIP

Creative skills and trait of using proven and tested solutions to provide & move goods and services efficiently for very clear benefits

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ENTREPRENEURSHIP & INNOVATION (I)

- EVERYBODY….. ARTISANS
- FEASIBILITY, FINANCING, TRAINING
- IP MANAGEMENT & LICENSING
- BUSINESS PLANNING/MANAGEMENT
- PRODUCTION, MARKETING, BRANDING….

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ENTREPRENEURSHIP & INNOVATION (I)

- PRODUCTS
- PROCESSES
- KNOW-HOW SERVICES (Consultancy etc)
- INDUSTRIAL SKILLS
- MANAGERIAL SKILLS

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Trade marks:
- Made by "Nokia"
- Product "N95"
- Software "Symbian", "Java"

Patents:
- Data-processing methods
- Semiconductor circuits
- Chemical compounds

Copyrights:
- Software code
- Instruction manual
- Ringtone

Trade secrets:
?

Industrial Designs (some of them registered):
- Form of overall phone
- Arrangement of buttons in oval shape
- Three-dimensional wave form of buttons

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THE PRACTICALS
(where is NIGERIA?)

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CURRENT NIGERIAN NATIONAL DEVELOPMENT & GROWTH STRATEGY

THE NEXT LEVEL/100 mill out of poverty in the next 10 years

(VISION 20-2030)?

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THE NIGERIAN STI CONTENT

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STI INFRASTRUCTURE (SUPPLY)

- Nearly 200 Universities
- Over 600 NBTE Accredited (~140 Polytechnics)
- Nearly 100 COE
- Over 300 Research Institutions/Centres
- Many Research capabilities (Labs, Workshops, Libraries)
- Many World-Class Foreign Industries
- Large pool of high class capacities (Professors, PhDs, Professional bodies, Diaspora capacity)
- LARGE NUMBER OF OTHER NETWORKS

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RESEARCH FACILITIES & OUTPUT

FACTS AND FIGURES (Research)

SCIENCE

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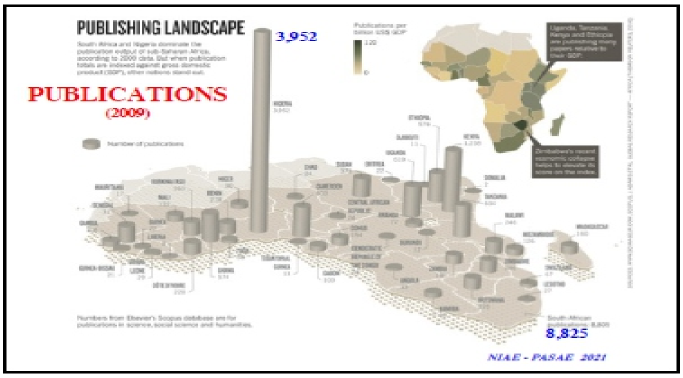

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DEVELOPMENT "POTENTIAL" (T)

POSSIBILITIES AND APPLICATIONS (Development)

ENGINEERING & TECHNOLOGY

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SCIENCE KITS

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INNOVATION "OPPORTUNITIES" (I)

SOLUTIONS AND PRODUCTS

INNOVATION

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Cottages & SMEs

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THE LIST IS LONG!!!

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A CLEAR EVIDENCE OF RESEARCH AND SOCIO-ECONOMIC DEVELOPMENT DISCONNECTION

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THE FUNDAMENTAL "HIDDEN" CHALLENGE & WAY FORWARD????

(PRACTICALLY!!)

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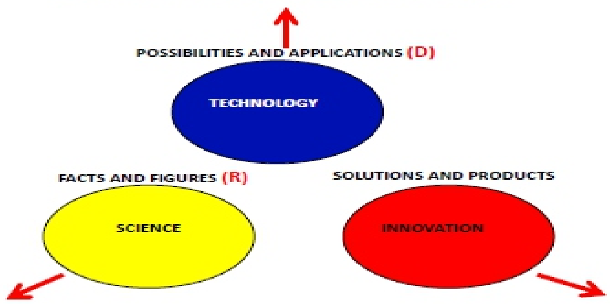
REALITIES OF STI POSTURE?



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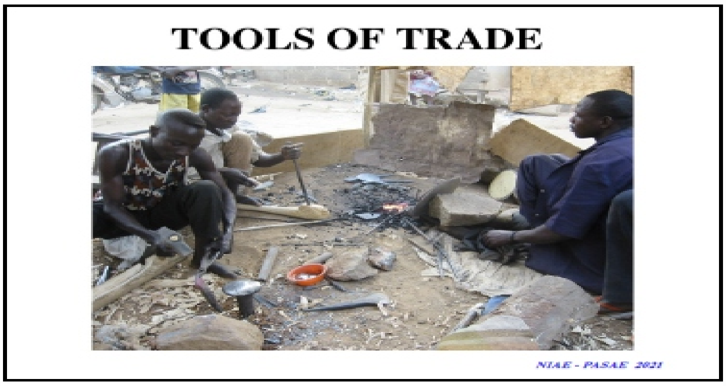

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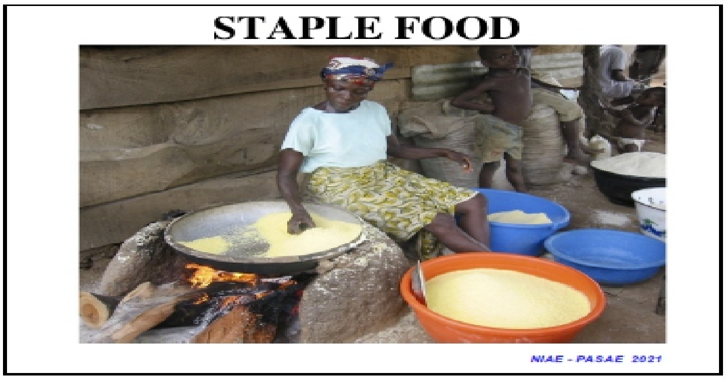

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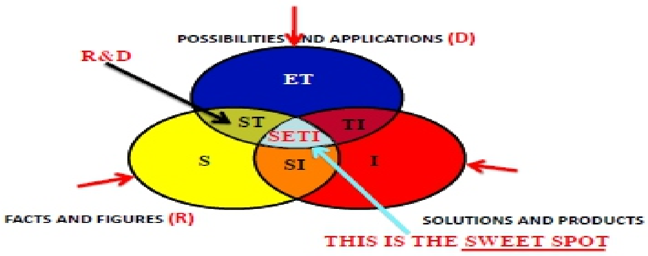
UNLEASH THE INTERNAL KNOWLEDGE ENERGY



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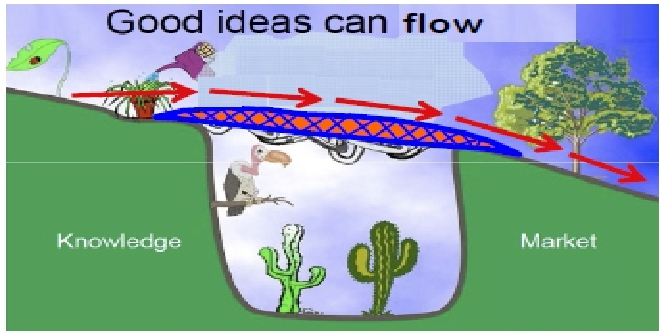
VIABLE LEADERSHIP & INNOVATION!



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CONCLUSIONS

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TO UNLEASH THE TECHNICAL ENERGY FOR COMMERCIALISATION OF R&D RESULTS:

HERE ARE SOME RECOMMENDATIONS

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RECOMMENDATION (1)

INTENSE/PROUD PROMOTION OF QUALITY NIGERIA'S TECHNOLOGY OUTPUTS:

PROPER & STANDARD NATIONAL EXHIBITIONS & TECHMARTS

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RECOMMENDATION (2)

DEVELOP
VIABLE AND VISIBLE PARTNERSHIPs THAT ENGENDERS CREATIVITY AND INNOVATION DIFFUSION

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RECOMMENDATION (3)

BUILDING THE CRITICAL MASS OF "CREATIVE & INNOVATIVE" MANPOWER STRATEGICALLY

(FOREIGN TECHNOLOGY TRANSFER, ADAPTATION AND DOMESTICATION)

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RECOMMENDATION (4)

IASP

THINKING OUT OF THE BOX

TO LINK ACADEMIA TO SOCIO-ECONOMIC DEVELOPMENT

WAITRO

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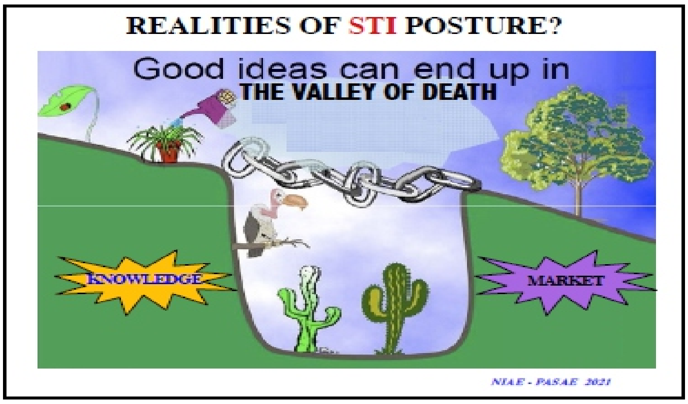

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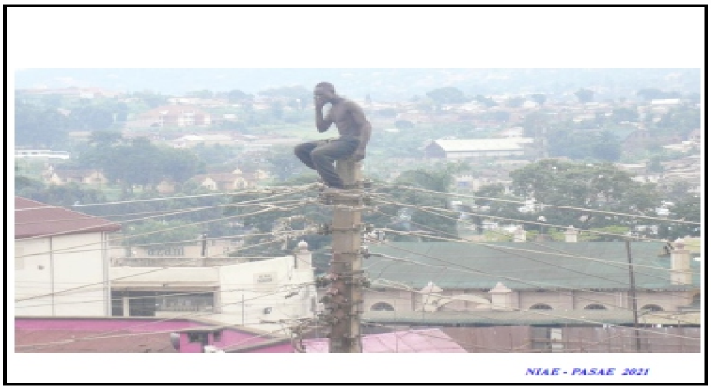

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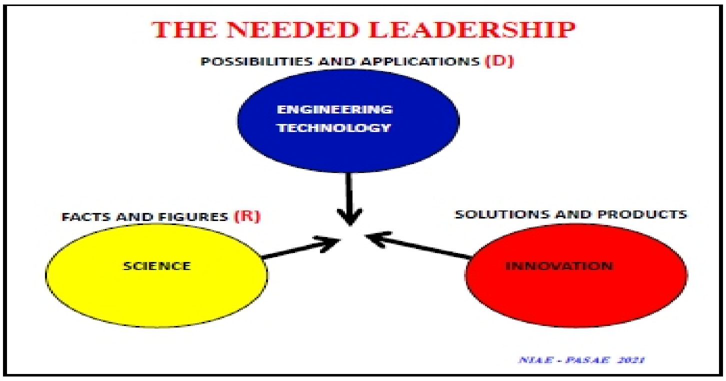

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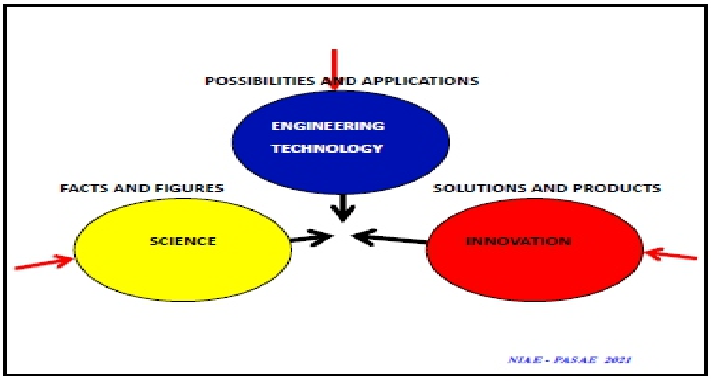

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RECOMMENDATION (5)

SYNERGISED IMPLEMENTATION OF EVIDENCE BASED STI POLICIES

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Mrs. Funke Araba
Retired Director, NOTAP

SOCIO-ECONOMIC PERSPECTIVES OF INTELLECTUAL PROPERTY: SUBSTANTIVE AND PROCEDURAL DISTINCTIONS OF IP REGIMES

Paper presented at

PASAE-NIAE VIRTUAL INTERNATIONAL CONFERENCE

BY ZOOM

High level Preconference Professional Development Workshop/Masterclass F

By

By Funke Araba–Lashmann
(*Retired Director, NOTAP*)

April 19, 2021

OUTLINES

1.0 INTRODUCTION

Given the multifaceted nature and the importance of IP in the global knowledge driven economy, IP has virtually permeated all fields of human endeavours ranging from law, arts, culture to science, engineering etc.

- IP has indeed contributed to socio-economic development of many nations that have developed IP regime. USA, UK, China and some emerging countries have used IP system as a tool for economic growth thereby transforming to knowledge driven economy and information society.
- Intellectual capital (IP and human capital) has gained pre-eminence over financial capital and knowledge is reflected as a factor of wealth in the global market place and in the new economy.

- IP is defined by World Intellectual Property Organisation (W.I.P.O.) as "creations of the mind". W.I.P.O. identifies two major categories of IP as **Industrial property** which includes patents for inventions, industrial design, trademarks, utility model, geographical indications and trade secrets whilst **Copyright** includes literary, artistic and scientific works including related rights to copyright which are performances and broadcast in radio and television programmes.

2.0 SOCIO-ECONOMIC PERSPECTIVE

2.1 Intellectual Property System

The IP system guarantees and confers "**exclusive rights**" on the owners of IP. The intellectual creations listed under the definition are intangible assets capable of being owned and protected. When protected by appropriate laws it becomes IP rights. These rights accord the owners the following:

- Exclusive control of the exploitation of their works for a specific period according to the law governing it.
- Recognition of owners of IP.
- Financial benefits from the intellectual product.
- Legal enforceable rights to prevent others from using or selling the creative works without authorisation/defense against infringement.
- Authorisation to set terms and conditions for the exploitation of their granted rights, scope and their mode and territorial limitation.

2.2 Socio-Economic Advantages

- In return for full disclosure of the technical information on invention seeking to be patented. IP system enables them derive maximum benefit from the products of their labour for specific period during which the owners have opportunity to recoup their investment (in form of time, labour and funds) expended on such works, Owners of IP grant to users, either exclusive or non-exclusive licenses to exploit their rights in return for payment of royalty or lump sum fees for outright purchase of products or a fixed percentage of turnover of company using the IP.

- Income/financial benefit earned from IP are shared according to the sharing formula agreed in the contract by the stakeholders which may include university/research institute, inventors, enterprises/industries and sometimes faculties/departments etc.
- In the case of patent, the holder of a patent has the exclusive right to exploit his innovation for a period of twenty (20) years while copyright (literary work) is for the owner's life time and fifty (50) years after his death.

- The IP system provides big incentives for investment in research and development (R&D) by encouraging firms to invest and risk undertaking new ventures which lead to industrialisation.
- IP stimulates innovation and inventive activities therefore tertiary institutions and research institutes could use IP to jump-start domestic knowledge-development, which can fuel the running of the national innovation cycle.
- IP promotes technology acquisition where IP regime is well established and other matrix factors for technology development

- IP promotes technology acquisition where IP regime is well established and other matrix factors for technology development exist, thus technology advances are generated faster and powered by the Intellectual Property system.
- IP promotes foreign investments as the protection of the rights it guarantees is a major determining factor in safe guarding results of further technological development.

- By virtue of the disclosure which IP creates, a pool of information "data base" in all fields of technology becomes readily available. This deposit of information represents the most valuable and comprehensive source of technology information available in the world today, that could be exploited and utilised by researchers/engineers for productive research and innovative work, once the legal pre-conditions are met.
- Intellectual property spurs development and offers equal opportunities and access to technology information for all, world-wide.

- Intellectual property can be used as a strategic instrument for planning, analytical tool for economic decision (at both enterprise and national level) and for the assessment of likely trends of future technological development.

2.3 Intellectual Property as an Economic Asset

- Knowledge Creations of intellectual property are intangible but when commercially exploited and transformed into goods or services either by the rightful owner or his agent or proxy, it becomes economic rights producing entrepreneurial assets.

- IP has become an asset to be traded in the global market through licensing and other channels. Vast commercial activities particularly those that reach across national boundaries use IP to safe-guard their invaluable assets within the international trade environment. (ref. Agreement on TRIPS of 1994).
- In the last two decades, the use of IP as economic asset particularly in the information and communication technology, publishing, entertainment, pharmaceutical industries as well as computer programmes, digital data base has become imperative in view of the ever changing technology being generated in the market.

Intellectual Property as:

- Intangible Asset:
  - Knowledge now surpasses material assets as the main factor of wealth creation.
- Tradable Asset:
  - Economic rights whose mode of economic exploitation can be out rightly sold, licensed or inherited.
  - Can be a basis for technology-based arrangement for cross licensing or spin-out companies.
- Major Industrial Asset:
  - Used as strategic business assets and sometimes may account for up to 70% to 90% of new wealth creation. Most industrial assets within the global market are IP assets, (IP assets are greater than 70% of total company assets).
- Financial Asset:
  - Valuable IP assets used for financing purposes in recent times in developed economies as mergers and strategic alliances are sometimes based on IP assets.
- Competitive Advantage:
  - Can block competitors or delay their market entry: therefore, provides basis for creating sustainable business and competitiveness.
  - Helps to protect knowledge, trade, or manufacturing secrets from free riding.
- Exclusivity:
  - IP system has in-built assured incentive system to exclude others from unauthorized use of the rights granted.
  - Rights to recuperate the funds expended on R&D through licensing etc. of other industrial use, for specific duration.
  - Rights to stop pirates, counterfeiters, imitators and in some cases 3rd parties infringement including independent investors.
- Enterprise Differentiation: (trademarks, trade names)
  - Knowledge components are predominant elements that help in differentiating one enterprise from the other. It is used as business identifier particularly for global marketing and branding, (commercial reputation and goodwill).

2.4 Social Perspective

- IP has contributed significantly to the ease with which the world (which has become a global village) has access and communicate with each other across the globe (within the continents, regional blocks, nations, states etc.). This is obvious with the goings-on in the various social networking applications presently in existence e.g. WhatsApp, Facebook, Telegram, WeChat, Instagram, Twitter etc. In view of these, information, trade and other values easily cross boundaries into different societies across the globe.
- IP promotes education through the use of information technology application for online training and schooling.
- Social media applications are created bringing useful information to people free of charge through myriad of podcast and short clips, a good example are health/medical experts who provide useful information on various functional methods of healing the body or keeping the body healthy.
- Social technology platforms created with the use of IP help create awareness of all things old and new, they serve as a marketing arena for IP products and due to the global reach they have created, IP owners or licensee's can influence a sea of people through their messages, advertisements and media campaigns, which in turn can bring in sizable economic benefits.

3.0 SUBSTANTIVE AND PROCEDURAL DINSTINCTIONS OF IP REGIMES (PATENT)

- Substantive and Procedural IP Regimes are the two types of procedures for the grant of patents across the world.

3.1 Substantive IP Regime

- The substantive procedure is more detailed and technical in approach. Substantive is mostly adopted in the developed countries whose IP regime and laws are well developed and where they have capacity in the knowledge of IP, with professionals, experts in science and engineering, law, social scientist etc. and patent examiners to carry out substantive examination of patent applications in all fields of technology.

❖ Competitive Advantage:

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- Under this regime, substantive examination is majorly done by patent examiners experienced in the chosen field of the invention to determine whether the patent application satisfy the criteria of patentability (novelty, inventive step and industrial application).

- Novelty – whether the invention is new and different from the prior art. This is by carrying out patent search on the prior art i.e. information on existing inventions earlier patented in the same field of technology in which the patent application is filed. Subsequently, a search is compiled and sent to the applicant. Decision on whether or not to grant the patent is therefore based on the search report. In case of a prior art, the patent application will be rejected. However, where there is the need for modification, the applicant is advised accordingly.

- Inventive step (non- obvious) - the patent application is examined to determine whether the invention consists of inventive achievements which is not obvious to an ordinary person skilled in the art based on what already exists.
- Industrial application – this is to determine the usefulness of the invention for which an application is filed.

Among other criteria are:

- Patentable subject matter - whether the subject matter of the application falls within the scope of patentable subject matter to be qualified as a valid patent'
- Description of the invention – this examines whether the description discloses the invention in a manner sufficiently clear and complete for it to be put into effect by a person skilled in the art in the field of knowledge to which the invention relates. The description is also examined whether it supports the specified claim (s).

- Specified claim(s) – whether the claim(s) state the scope of protection being sought within the limit of the description and whether it is drafted clearly and is concise. The claim must be supported by the description and not broader.
- Sufficient Disclosure - The applicant must disclose the claimed invention in a manner sufficiently clear and complete for it to be carried out by a person skilled in the art.
- Foreign priority - whether a prior application, or an application benefitting from a foreign priority, has been made in the country where the application is filed in respect of the same invention, and whether a patent has already been granted as a result of the application.

- It is pertinent to note that substantive examination helps in the determination of the validity of the patent in the court as it shifts the onus of proof to the person challenging the validity.

3.2 Procedural IP Regime

- The Procedural IP regime otherwise referred to as the formal examination of patent.
- The procedure is preceded by the filing of a patent application at the respective Patent Office nationally, regionally or internationally by an inventor, his patent attorney or patent agent accompanied by a power of attorney in the case of the latter.
- This is followed by the formal examination which involves the following:

(i) completion of the application form which contains all the relevant issues required.
(ii) ensuring that all the necessary documents have been submitted.
(iii) ensuring that the applicable fee has been paid.
(iv) information provided usually includes the title of the invention; the names and addresses of the inventor or his agent and power of attorney where an agent is used, the description and the claims for the invention, payment of the prescribed fee, etc.

- During the process, the applicant is given the opportunity to correct any defect(s) in the application within a specific time frame and where there is a delay the Registrar will reject the application.
- After the successful completion of the formal examination publication is carried out in the patent journal without any objection or opposition, or where an opposition is unsuccessful, the patent office will grant the patent.

- Following the grant of a patent either through the substantive or the procedural examination, the details will be recorded in the patent register and a patent certificate is issued to the applicant.
- Thereafter, the patent is published in a gazette for inspection by the public. In most cases, patent information is published 18 months after the filing date or the priority date to facilitate timely access to the technical information contained in the patent document.

- Apart from these administrative/procedural issues, no technical examination is carried out as regards the novelty, inventive step and/or industrial application of the invention.
- With the procedural examination, patents are granted at the risk of the patent owner as the onus of proof of the validity of the patent lies on him where such is subsequently raised in the court.

4.0 CONCLUSION

- IP is a valuable tool for socio-economic and national development through its contributions to the success of large industries and the growth of SMEs.
- IP is equally rewarding to researchers, creators, inventors/innovators and entrepreneurs by increasing their revenue base through royalties paid on licenses for their creative works or intellectual products.

- Recognising Agricultural Engineers as the brain behind the carrying out of innovation in the development of farm implements, modern agricultural processes, design of storage facilities which transform agricultural landscape of many economies, application of IP is quite germane in this field of operation.
- Since IP cut across professions and all of us present here today witness daily its growth in all dimensions of life, the need for a multi-disciplinary treatment of IP is not only justified but is indeed inescapable.

- Agric Engineers and all other professionals will benefit immensely by building capacity on intellectual property matters and applying the knowledge in their professional activities.
- The large deposit of technical information in the disclosures which IP generates in all fields of technology can be utilised to create novel products and avoid reinventing the wheel.
- For African continent to achieve its full potentials on the use of IP to garnish wealth where it has comparative advantage, all members should endeavour to carry out policy reforms on their IP institutional and legal frameworks. This will facilitate taking advantage of new opportunities created by the new continent – wide African market.

Reference

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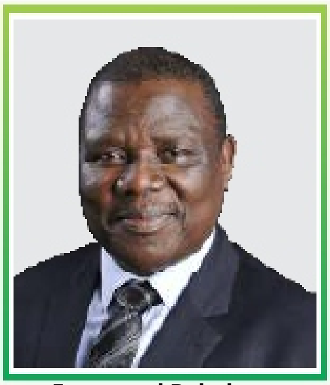

Professor Emmanuel Bobobee
Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

PASAE-NIAE International Conference in Nigeria
19-22 April, 2021

Fundamental concepts in intellectual property rights and application to agribusiness and agro-technology innovations in Africa

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OUTLINE

- Definition and Importance of IP.
- Origin of IPR system.
- Case studies of a patented innovation.

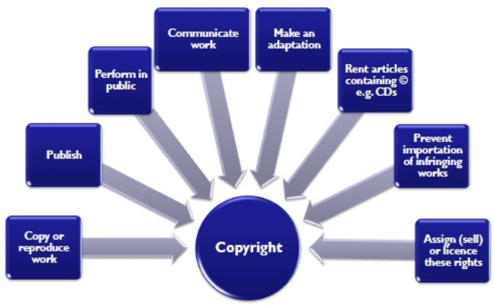
Definition and Importance of Intellectual Property

- **Intellectual Property (IP) refers to creative and innovative works which are the products of the human intellect.**
- IP covers a wide range of works, but traditionally, it is divided into two branches: Industrial Property, and Copyrights and Related rights
- **Industrial Property** refers to aspects such as scientific, technical and agricultural innovations,
- **Copyrights** cover works such as printed materials and works of art.

Intellectual Property Toolbox

COPYRIGHT

Copyright is a bundle of rights which allows the owner exclusive rights to:



- Innovation is the source of progress.
- Without it, livelihoods contract and prosperity declines.
- In medicine, innovation leads to disease prevention and cures.
- In the farming and food sectors, innovation increases production, improves post-harvest handling, as well as reduces the environmental footprint to deliver greater value to consumers.

"**Innovation is significant, positive change.**"

- Innovation is something you work toward.
- It should be the end result or outcome.
- It is the sum of an organization's efforts to keep its value proposition to customers and end-users both relevant and compelling

There is no market for innovations without user adoption nor any scope for impact or investor reward.

Understanding adoption is therefore key

Two most important factors that drive adoption are:

(1) Relevance from the user's point of view, offering real improvements compared with what they already have and reducing satisfaction gaps they deal with in their daily lives.

(2) Availability in the market, allowing supply to fulfill demand, so that value creation can take place.

Adoption-friendly business conditions are important too but may be beyond developers' immediate control.

- Policy bias against agriculture,
- disrespect for property rights,
- and inadequate farmer access to information, finance, insurance, and markets can also inhibit adoption.

- **the overarching objective of innovation should be improving the wellbeing, quality of life and outlook of end-users.**

Agriculture's innovation footprint is evident in developed countries. The payoff was considerable.

- Food became more affordable.
- People became less likely to starve.
- And the increased productivity from the automation of agriculture led farm workers to migrate to cities.
- There they helped the industrial economy develop and grow.
- New goods and services were created and consumption increased.
- Productivity rose even more as automation drove costs down on a global basis, making transportation, healthcare, and education more affordable.

Despite such undeniable progress, innovation in agriculture did not have the same impact globally

- Innovation plays a pivotal role in providing affordable, nutritious food, feedstuff, and fibers to humankind.
- The need for increasing its success rate is even more pressing with the looming challenges of climate change.
- At only 1.2 °C of mean global surface warming, many aspects of climate change are not just visible, they are severe.
- The challenges agriculture face to feed the world will rise with increasing temperatures.
- Indeed, recent modelling work shows that a warmer world will reduce global yields of wheat, rice, maize, and soybean , crops that provide two-thirds of human caloric intake.

Origin of IPR system

AFRICAN CIVILIZATION AS FOUNDATION FOR THE SUCCESS OF THE WORLD`S CIVILIZATION

- The early Egyptian civilization, shaped the world`s civilization.
- The earlier settlers in Egypt were blacks of African race who settled in the middle Nile and later migrated to equatorial Africa to constitute the nucleus of the African civilization that lasted for a period of ten thousand years.

Four (4) main kingdoms led the civilization at that time with mining, medicines, science, astrology, logic and mathematics;

1) The Axum kingdom (Science, architecture and agriculture)
2) The Mali Empire (Astrology, Science)
3) The Ghana Empire (Medicine and Taxation)
4) The Zimbabwe Kingdom (Construction of stone walls, architectural designs, Mining, Metallurgy and Trade)

Three (3) key invasions resulting from territorial expansion and imperialism changed the African dynamics;

- Conquest of Egypt by Persians in 525 BC
- Conquest by Alexandra the Great in 330 BC
- Conquest by the Romans under Julius Caesar in 50 BC

The invasion of Egypt and the plunder of knowledge and resources contributed to the development of knowledge in Greece and Rome.

For example Aristotle – the great mathematician and astronomer is said to have stayed in Egypt for 16 months.

Greek mythology was derived from the Egyptians.

The Romans and the Greeks looted libraries and temples that contained sacred knowledge and manuscripts which contributed to the philosophical foundations of the Greek and Roman civilizations.

The so called Plato`s Republic and the 4 cardinal virtues (Justice, Wisdom, Temperance and Courage) were derived from the Egyptian temples.

This knowledge piracy brought about misappropriation of African Traditional Knowledge and Folklore

No documentation of what happened to Africa is known from these times until the medieval period.

It is during this medieval period that the colonisation of Africa began.

Medieval Period and Colonization of Africa

This was also shaped by 3 key events;

- Exploration of Africa by Victorian explorers, missionaries and scientists,
- The discovery of the route to the east via Cape of Good Hope by the Portuguese,
- The discovery of the America`s by the Spaniards,

The origins of Intellectual Property – 500 BCE

- The history of intellectual property is complex and fascinating.
- It began in 500 BCE when Sybaris, a Greek state, made it possible for citizens to obtain a one year patent for "any new refinement in luxury."
- Patent, trademark and copyright laws have become more complicated in the ensuing centuries but the intent remains the same.
- Countries establish intellectual property laws to foster creativity and to make it possible for the inventor to reap the benefits of their ingenuity.

Intellectual Property Legislation -1623 (Statute of Monopolies)

- Mentions of copyrights, patents and other matters of intellectual property law are sparse in early history.
- Europe passed some major and well-known legislation in medieval times
- The first of these was the British Statute of Monopolies established in 1623 .
- At the time, all major industries were controlled by guilds.
- Each guild held considerable power, with the government endowing them with the ability to dictate what products and raw materials could be imported as well as how those items would be produced and sold.
- Moreover, the guilds were responsible for bringing all new innovations to the marketplace, essentially giving them ownership and control over inventions even if they had nothing to do with their creation.

Ownership Rights – 1710 (Statute of Anne)

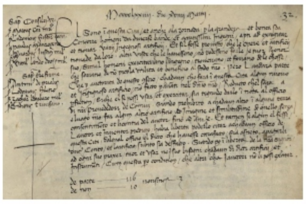
- After the Statute of Monopolies (1623), came another significant legislation in 1710 - the Statute of Anne.
- The law also guaranteed the inventor a 14 year period during which he had the exclusive right to govern how his invention was used.
- It provided a 14 year term of protection and also gave inventor the option of seeking a 14 year renewal term.
- Aimed largely at copyrights, this law granted authors rights in the recreation and distribution of their work.

History of Patents

Origin of the word "patent":

•lat. Litterae patentes, open letter' (a letter from a sovereign issued granting rights or privileges)

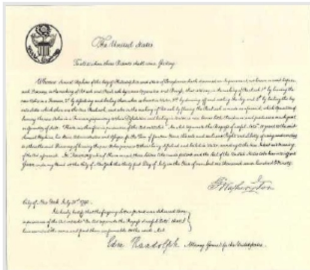
•Latin verb "pateo": to lie open



The first US Patent: 1790

Right enshrined in US Constitution:

- promote progress of science and useful arts
- exclusive right for a limited time



Intellectual Property in colonial US – Early 1800's

- After the U.S. broke away from Great Britain, most of the 13 colonies (except Delaware) had established their own systems for intellectual property protection.
- However, it was soon apparent that having each state operate its own system of intellectual property protection was problematic, leading to the establishment of federal laws that had precedence over any state laws.

Global Intellectual Property – Late 1800's

- **The Paris Convention of 1883** was an international agreement through which inventors could protect their innovations even if they were being used in other countries.
- **The Berne Convention of 1886** for writers led to protection on an international level for all forms of written expression as well as songs, drawings, operas, sculptures, paintings and more.
- **Madrid** Agreement of 1891 protected Trademarks
- The **Paris and Berne Conventions** eventually combined to become the **United International Bureaux for the Protection of Intellectual Property**, the precursor of today's **World Intellectual Property Organization**, which is an office of the United Nations.

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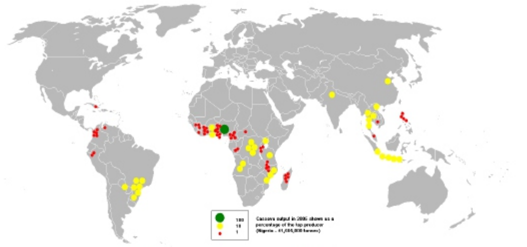
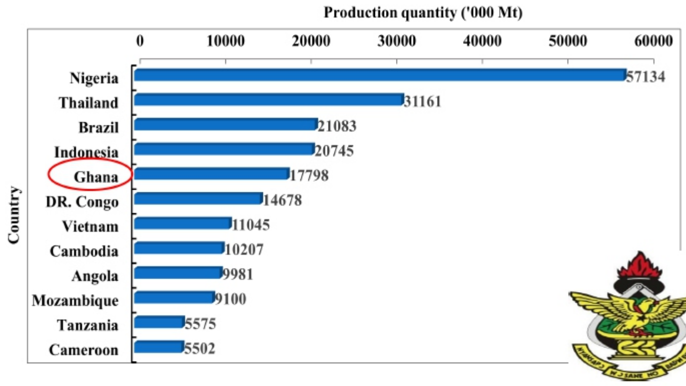
Global Distribution of Cassava



Africa	56%
SE Asia	30%
South America	14%
(FAOSTAT 2017)	



Cassava production in Africa

•Cassava (*Manihot esculenta* Crantz) is an important crop nutritionally.

•It is food to over a billion people on the globe (SDG 2),

•Cassava has high carbohydrates to be converted into several products including bio-ethanol and others (SDG 1 & 9)

•Africa is the global leader in cassava production, but least exporter of cassava products.

The challenge to commercial cassava production

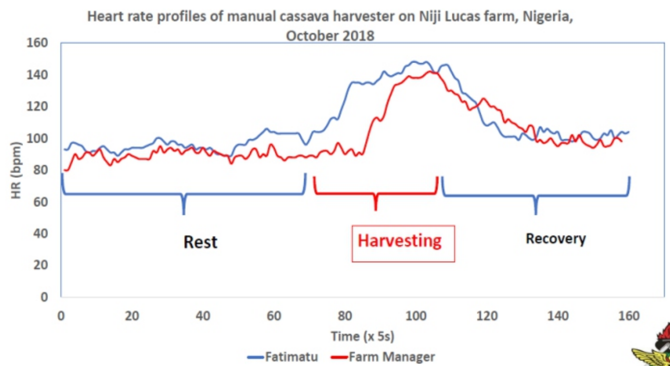
- Smallholder agriculture is dominant on the continent
- Agriculture is a way of life not treated as a business
- Agricultural labour is aging in Africa
- The youth are not interested in agriculture
- Cassava is planted randomly with little mechanisation
- Manual harvesting is a predominant, painful and stressful activity full of drudgery,
- Until recently, there are no commercial mechanical cassava harvesters in Africa.

Cassava production by task and days per ha in the Congo, Côte d'Ivoire, Ghana, Nigeria, Tanzania and Uganda *(Source : Nweke et al 2001)*

Task	Country					
	DR Congo	Cote D'Ivoire	Ghana	Nigeria	Tanzania	Uganda
Land preparation (manual)	66	53	44	49	54	45
Seedbed preparation	21	29	31	41	27	31
Planting	39	22	28	32	27	28
Weeding	27	28	34	38	28	32
Harvesting	48	44	53	62	46	52
Total days	201	173	191	222	182	187

Painful manual harvesting – biggest challenge

Manual Cassava harvesting in NIJILUCAS Farm, Nigeria, 2018



Frequently Asked Questions

In a nutshell, how did intellectual property come to our society?
Earliest official records date back to 1421 when an Italian inventor received the world's first modern patent. However, archeological discoveries push the date as far back as 600 BCE.

What are the earlier forms of intellectual property rights?
Similar to the modern iterations of the intellectual property rights, earlier norms related to the matter take root from the idea of exclusive production and indication of origins.

How did intellectual property influence the development of society?
Establishing sole rights since the dawn of civilization enabled more room for innovation by incentivising creative solutions.
However, it is also important to note that the motivation was not necessarily anthropocentric from the outset.
Most of the attributable social practices revolved around religious beliefs, and it was only after the humanist movement post-Renaissance that inventiveness took the fore.

What can we learn from the development of intellectual property throughout the ages?

Perhaps the most important insight we can glean from the history of intellectual property is that since the beginning, we as a society have a penchant for innovating our communities.

Albeit somewhat hindered with each great paradigm shift, we always move towards rediscovery of our core human values.

What can we expect in the near future?

Informed with the dynamic past of the practice, we see the trend of conformity with the prevailing value system.

With this in mind, we can expect that intellectual property will adapt to modern sensibilities.

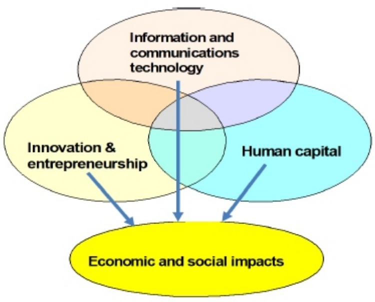
In fact, we are already at the forefront of equalising opportunities previously unavailable due to outdated traditional belief

KNOWLEDGE-BASED ECONOMY (KBE)

A *knowledge-based economy* is an economy in which the

use of knowledge *for* ***production*** and ***distribution*** is the main driver of growth, wealth creation and employment across all industries. (OECD 1996, APEC 2000)

KBE is based on 3 core dimensions



Remember – all economies have always rested on knowledge but in KBE, knowledge has significantly changed to embrace the following four perspectives;

i. Knowledge has become an input
ii. Knowledge has become a product
iii. Knowledge has become a significant component of a process
iv. Knowledge is driven by ICT

Innovation is no longer based on discovery but on Learning

Why do Intellectual Property Rights Matter in research?

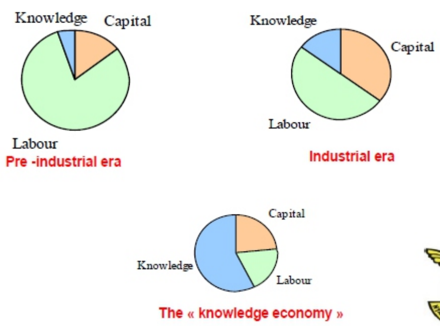
In few words:

"Research is the conversion of money in knowledge
Innovation is the conversion of knowledge in money"

(Bayer- Bruxellesip2004)

The Plough

The plough kick-started civilization and ultimately made our modern economy possible.



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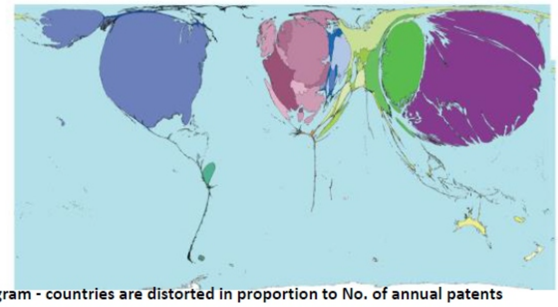
Map of global granted Patents



Cartogram - countries are distorted in proportion to No. of annual patents granted there. Japan & USA each accounts for roughly 1/3 of patents worldwide.

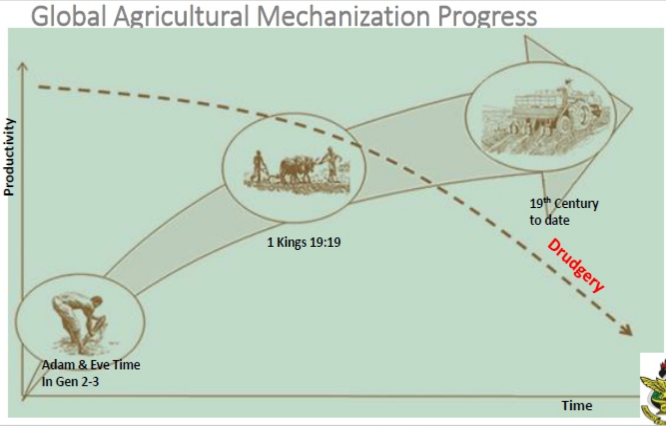
Case studies of patented innovations – The TEK Mechanical Cassava Harvester

Innovations in Cassava Production: The journey of an African Academic

Outline

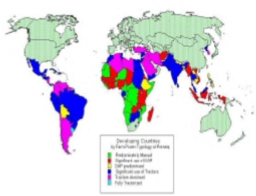
- Challenges to mechanised cassava production in Ghana and Africa
  - ❖ Drudgery in agriculture
  - ❖ Over-reliance on manual tools
  - ❖ Haphazard or random planting
  - ❖ Aging agricultural labour force
  - ❖ Slow progress in agriculture mechanisation
- Innovations developed to address them by Bobobee *et al.*
  - ❖ The TEK Mechanical cassava harvester
  - ❖ Durable digging blade
  - ❖ Double-disc ridger for ridging and weed control
  - ❖ Motorised peeler
  - ❖ Use of drones for cassava production

Global Agricultural Mechanization Progress



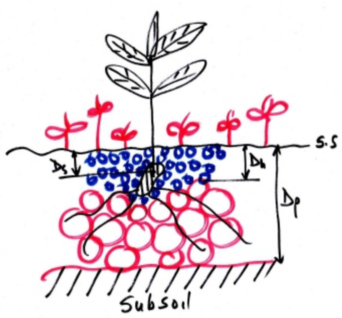
Global Farm Power Typology and Hunger Map

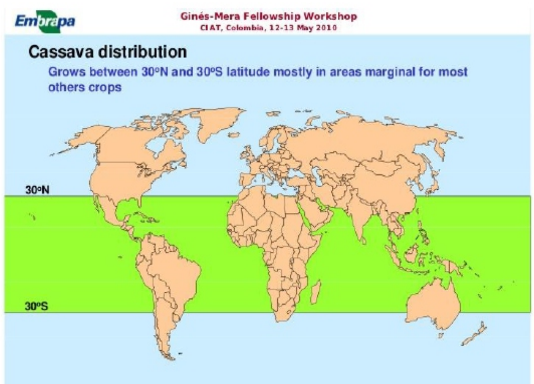
Farm power typology – Developing Countries (L Clarke

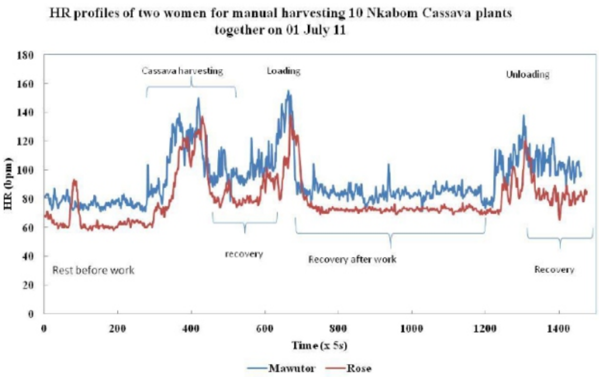


Cross-section of a conventional field ploughed, harrowed and planted

Language	Term
English	Land
Ewe	NYIGBA (Lick – first)
Akan	Asaase
Kiswahili	Arthi or Ardhi
Namibia Ovambo (Oshidongo)	i. Evi
Zambia Tonga & Bemba	Nyika
Malawi i. Chichewa & Tumbuka	Munda
Uganda Mugisu, Baganda & Basoga	Litaaka, Etaaka & Eitaaka
Ga /GaDangbe	Shikpong/Zugbaan
Zulu or Xhosa, Sotho, Tswana & Venda	Mhlaba, Lizwe,
Mole Dagbani	Tindaa





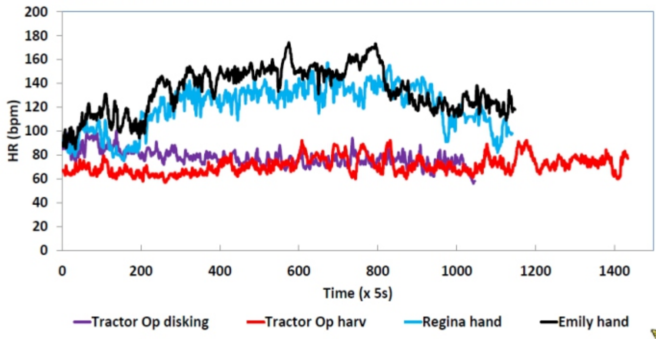


KNUST Solution

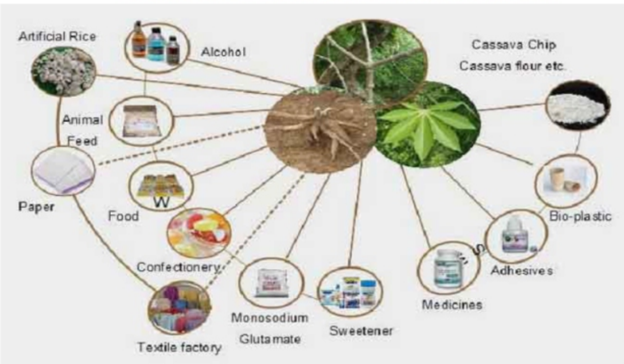
- An efficient TEK mechanical cassava harvester invented at KNUST (*OAPI patent 17219*).
- Harvester takes 1 sec/plant to dig out compared with 5- 10mins/plant manually.
- 30 prototypes deployed in Ghana, South Africa, Nigeria & Jamaica.
- Capacity exists to manufacture to satisfy continental demands

PATENT AND AWARDS

- 1ST Excellence Award, GIE (2014)
- APEI shortlist (2016)
- IPA shortlist (2018)
- 2014 ASABE publication has 3500^{+} reads in April 2021.



Some Industrial Cassava Products



Mechanical Harvesting Demo Video Clips

After mechanical harvesting, the field is ploughed

Mechanical yam harvesting with the TEK MCH

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DURABLE BLADES – THE ONLY SPARE PART

Planting on ridges is recommended as the FUTURE

RIDGING & CA BENEFITS FOR CASSAVA (SDG 13)

Recommended inter-row and intra-row spacings of mechanised cassava production

The future

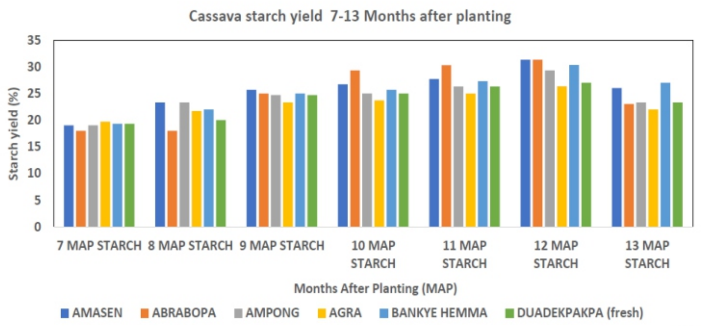
KNUST Cassava farm planted on ridges to facilitate mechanical operations

Drone view of KNUST Cassava Farm planted to 22 elite varieties

MPhill Student prototype double row disc ridger for cassava Cultivation

Field Testing KNUST Prototype Ridger

2021/04/18



Harvest demonstration in Nelspruit, South Africa, June 2015

Inspecting mechanically harvested cassava at UNIVEN, RSA

2021/04/18

Demonstrating Mechanised Cassava Harvesting in UNIVEN, South Africa

2021/04/18

Inspecting harvested cassava to assess tuber damage

2021/04/18

Displaying mechanically harvested cassava

21/04/18

Cassava Harvesting Demonstration in Nigeria, October 2018

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VISIT BY FAO DELEGATIONS

GHANA Vice President and Minister of Agriculture at my stand during the 33rd National Farmers' Day in December 2017

Ghana Agric Minister Hon Kofi Humado commissioned harvesters in 2013

Conclusion

- First commercial mechanical cassava harvester developed at KNUST for Ghana and Africa
- Africa must to develop cassava from food crop to become industrial & export crop.
- Well developed cassava value chain represents a multi- $billion market.
- The TEK Mechanical Cassava Harvester will unlock the huge potential of the crop on the continent
- Research team needs support to train farmers and tractor operators to adopt the mechanised production methodology to reduce drudgery, create employment and wealth in sub-Saharan Africa.

Closing Remarks

Africa has the land and the people and must adopt agricultural mechanisation technologies to attract the youth and turn agriculture into a multi $trillion industry on the continent.

Thanks for your time

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WORKSHOP A PRESENTATIONS

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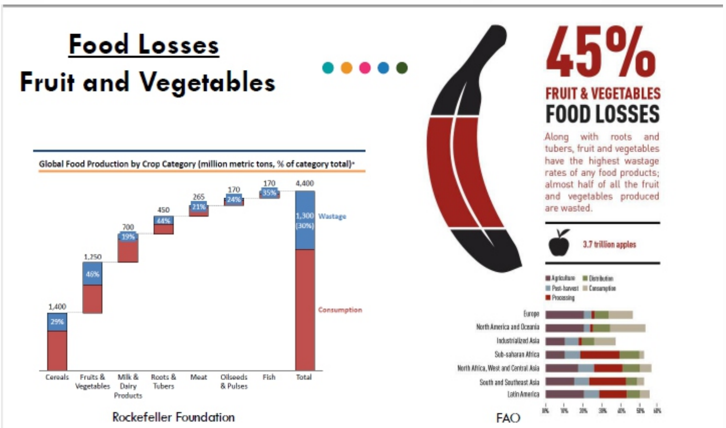
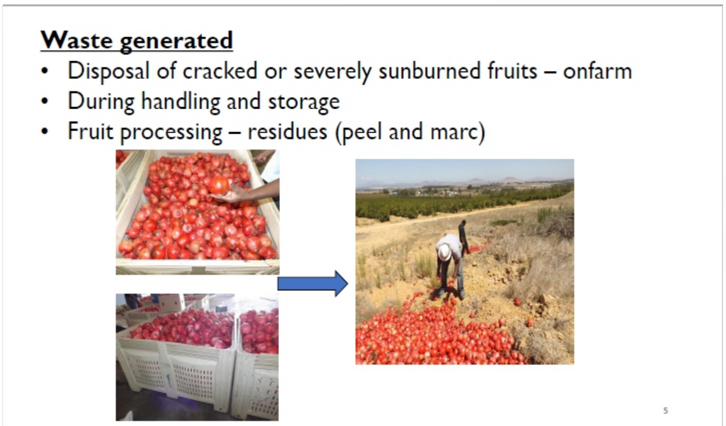
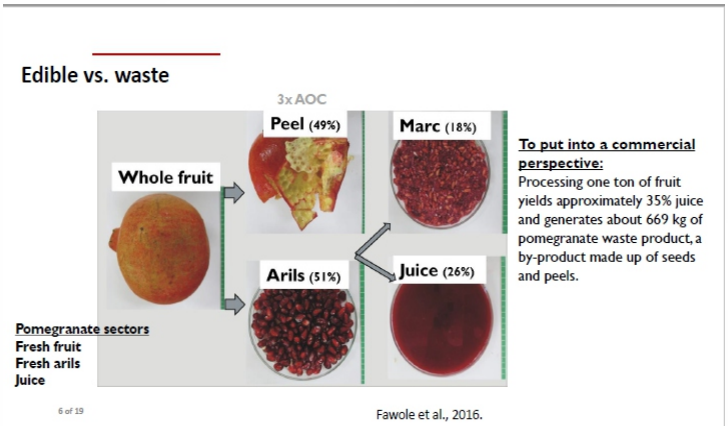
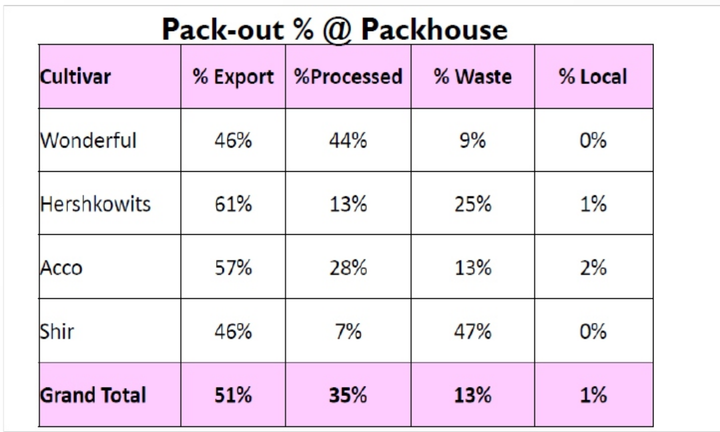
Prof. Olaniyi Fawole
University of Johannesburg, SA








Pack-out % @ Packhouse

Cultivar	% Export	%Processed	% Waste	% Local
Wonderful	46%	44%	9%	0%
Hershkowits	61%	13%	25%	1%
Acco	57%	28%	13%	2%
Shir	46%	7%	47%	0%
Grand Total	**51%**	**35%**	**13%**	**1%**

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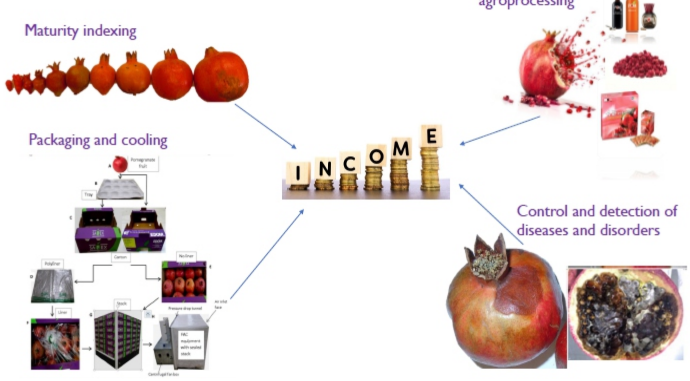
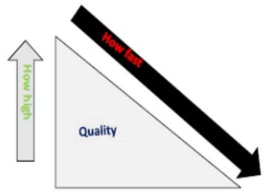
Our contribution



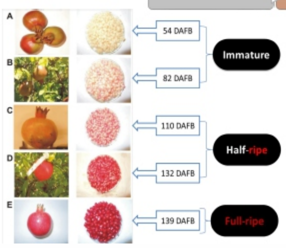
Example 1: Development of maturity index for S. African pomegranate fruit

✓ The moment a crop is removed from the its parent plant, it begins to deteriorate



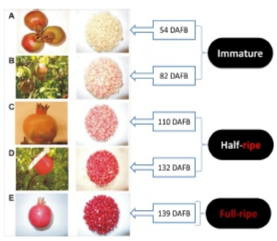
Example 1: Development of maturity index for S. African pomegranate fruit

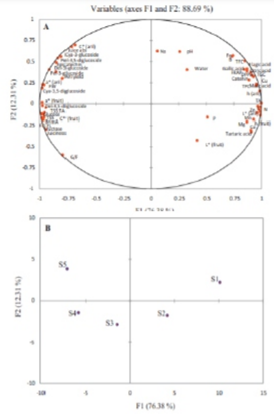
Step 1 Growth studies → Step 2 Evolution of quality indices → Step 3 Harvest index



- ✓ Non-climacteric – does not ripen off the tree
- ✓ Peel colour ≠ Aril colour
- ✓ Fruit ripens 5 – 8 months after fruit set, depending cultivar

A science-based tool for fruit quality evolution was developed for the industry



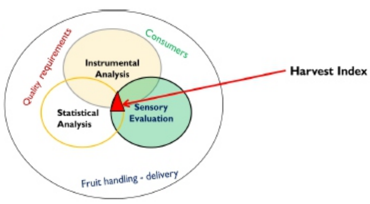


Fawole and Opara, 2013

When to harvest?

Science-based

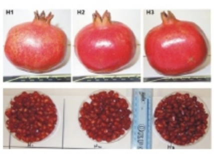
- Maturity indexing
- Cold chain requirements
- Whole fruit packaging
- Postharvest treatment
- Export market

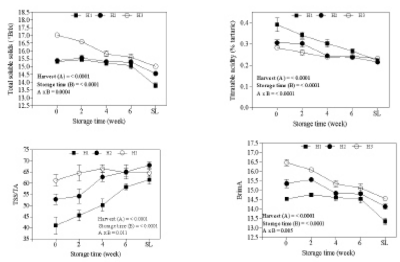


Science-based - the supply chain

Point-to-point	Time to export markets (Day)
Orchard to Packhouse	3 – 7
Packhouse build-up for container	3 – 7
Stacks to departure	3
Voyage	24
Arrival to de-stuffing	1 – 5
Warehouse/Depot to supermarket	3 – 5
Best before days/Shelf life	5 - 7
Total days	42 - 58

Investigated quality changes for different harvest windows





Chemical changes in 'Bhagwa' pomegranate fruit harvests during a simulated shipping condition at 5°C and shelf life. H1, H2 and H3 = Harvest dates 1, 2 and 3. Simulated storage lasted for 6 weeks at 5°C plus subsequent shelf life of 5 days at 20°C.

Sensorial attributes of different harvests were also investigated

Matching instrumental quality attributes with what do consumers want.

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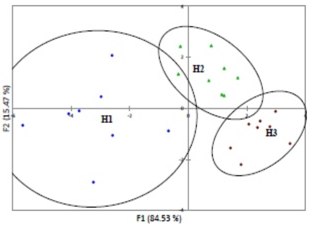
Statistical rigor – making sense of it all

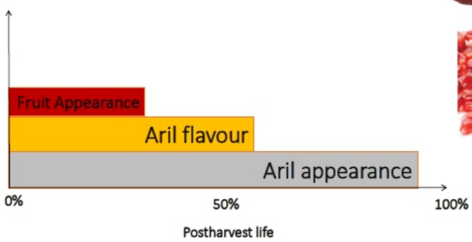


Predictor	Harvest time (DAFB)
TSS	H3 (175)
Juice content	H2 (167)

Harvest time (DAFB)	Determinant
167 - 175	TSS: ≥ 16ºBrix
	Juice content: ≥ 65 mL/100 g aril

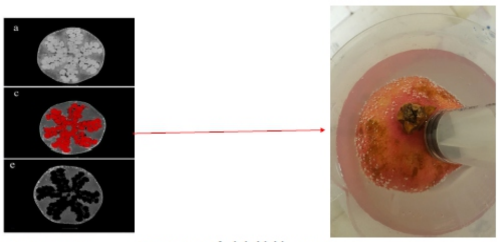
Example 2: Packaging and cooling for export-oriented fruit

Postharvest life of pomegranate fruit



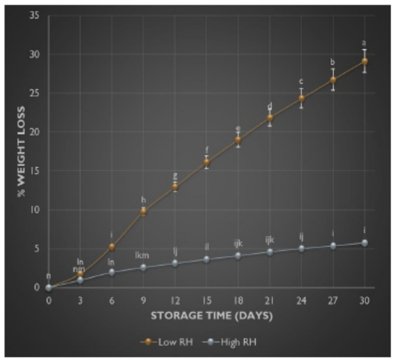
Relative humidity (RH) management – for weight loss control

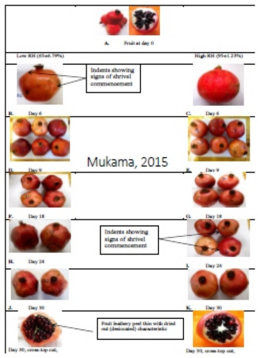
- ✓ Control of RH is critical in storage of pomegranate
- ✓ Low RH (<85%) – rind desiccates quickly, thanks to the porous skin – vapour pressure difference



Arendse et al., 2016 Pomegranate fruit is highly porous

Optimum relative humidity was established



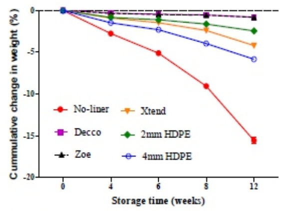


A protocol for RH during harvest and handling before storage was developed

- ✓ Time between fruit harvest and cooling is crucial – start of the cold chain management at the farmgate!
- ✓ Provide shading – fruit on top of bins can reach 50 °C
- ✓ 24 hours at 20 °C after harvest is equivalent to >1% weight loss
- ✓ Improper handling can lead to losses (25-30%)

Our research enabled the industry in decision-making on different packaging liners – efficiency, cost and return on investment

Fruit packaging – type of packaging liners

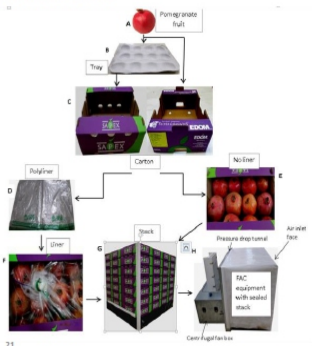


Financial loss after 12 weeks of storage at 5°C, 95% RH

Treatment	% weight loss	Per kg (USD)	Per kg (ZAR)
No-liner	15.6	0.546	7.753
Decco	0.79	0.028	0.393
Zoe	0.82	0.029	0.408
Xtend	4.17	0.146	2.072
2mm HDPE	2.44	0.085	1.213
4mm HDPE	4.17	0.146	2.072

Lufu, 2016

A protocol for fruit packaging systems was developed for export-oriented fruit



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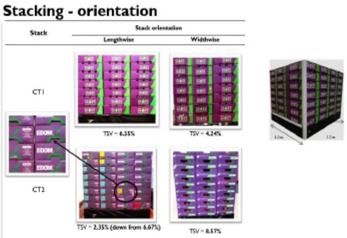
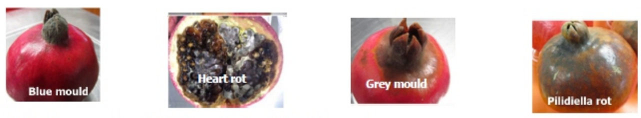
- ✓ Packaging and rapid cooling – prevents moisture loss

Stacking - orientation



Disease management in South Africa pomegranate



- ✓ Mostly preventative and limited to cultural and chemical protection

Preharvest

- Orchard sanitation
- Copper oxychloride, carbendazim, mancozeb, copper oxychloride and captan

Postharvest

- ✓ SA packhouse operation followed a combination of sanitation treatments with chlorine and Scholar (Fludioxonil) to minimise decay caused by fungi
- ✓ However, it is important to maintain optimal temperature and RH through postharvest handling
- ✓ Edible coatings

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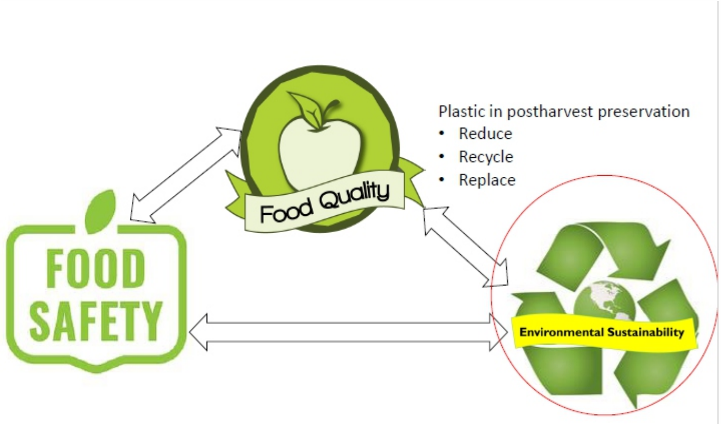
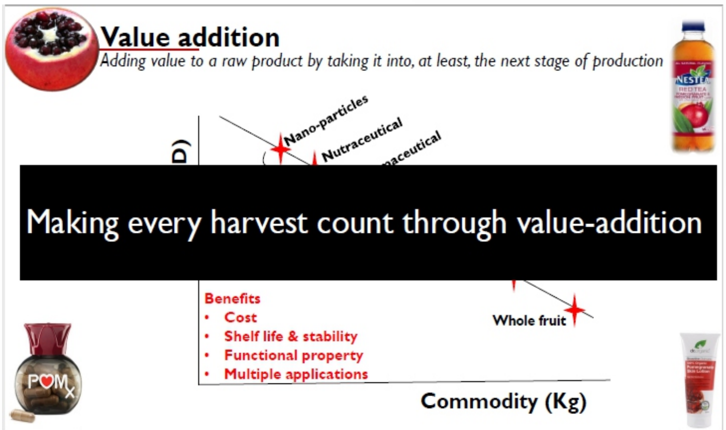
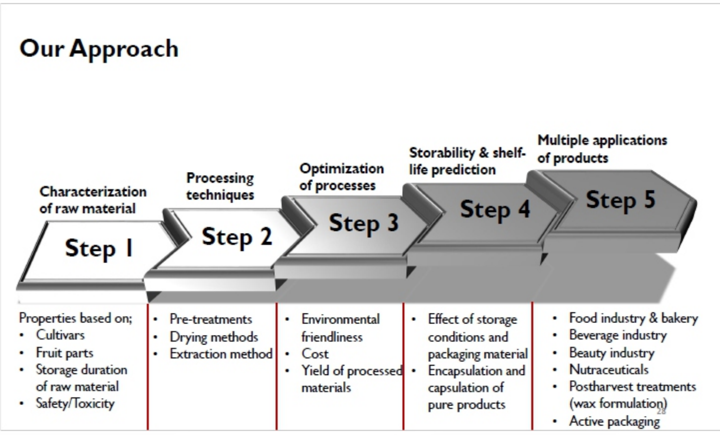
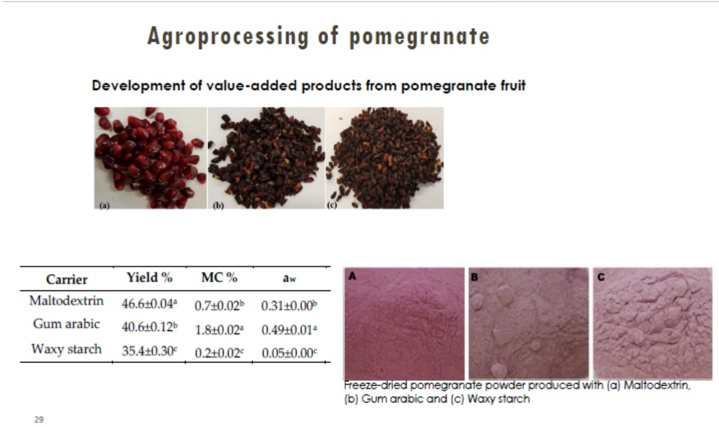
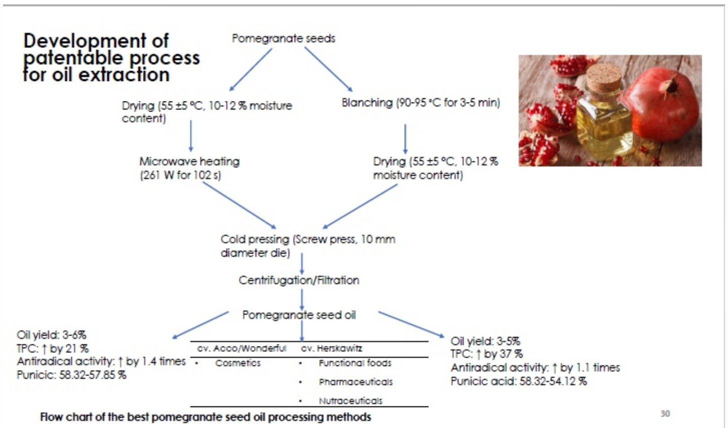


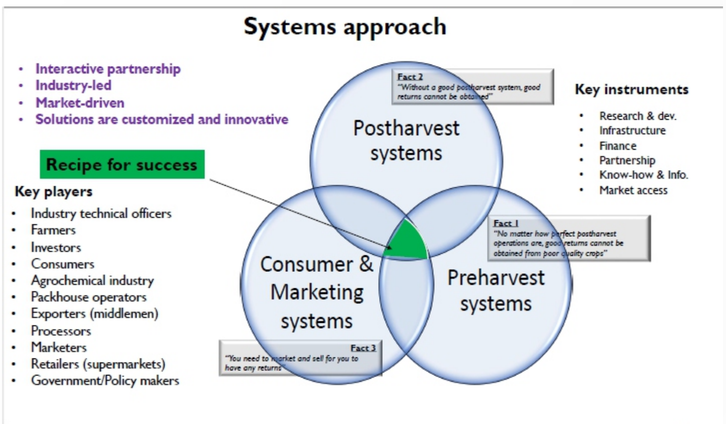




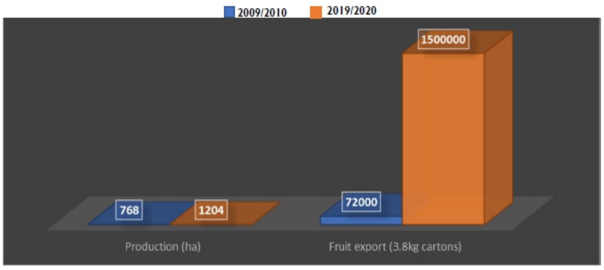


Carrier	Yield %	MC %	aw
Maltodextrin	46.6±0.04ᵃ	0.7±0.02ᵇ	0.31±0.00ᵇ
Gum arabic	40.6±0.12ᵇ	1.8±0.02ᵃ	0.49±0.01ᵃ
Waxy starch	35.4±0.30ᶜ	0.2±0.02ᶜ	0.05±0.00ᶜ





- South African pomegranate industry.
- One decade.
- 57% increase in production area.
- A 20 fold increase in fruit export.
- Knowledge production– >20 postgraduate students



The Sustainable Development Goals

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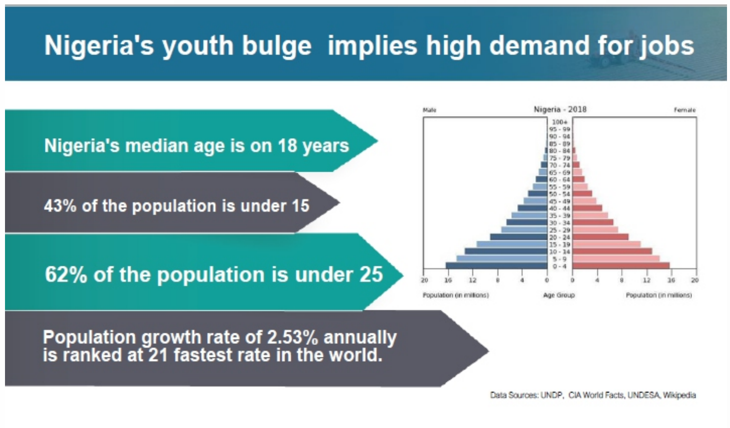
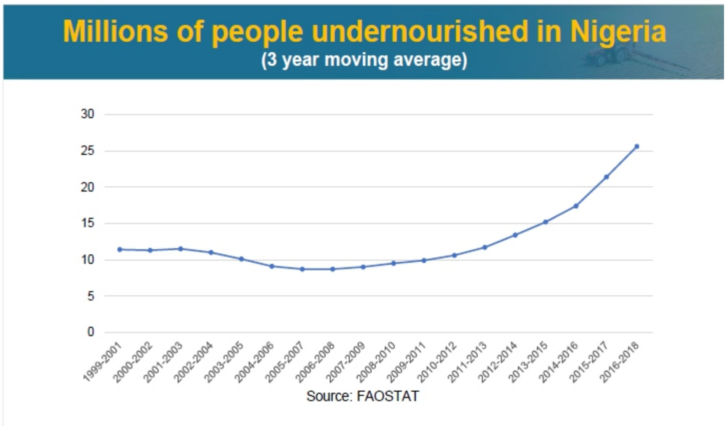
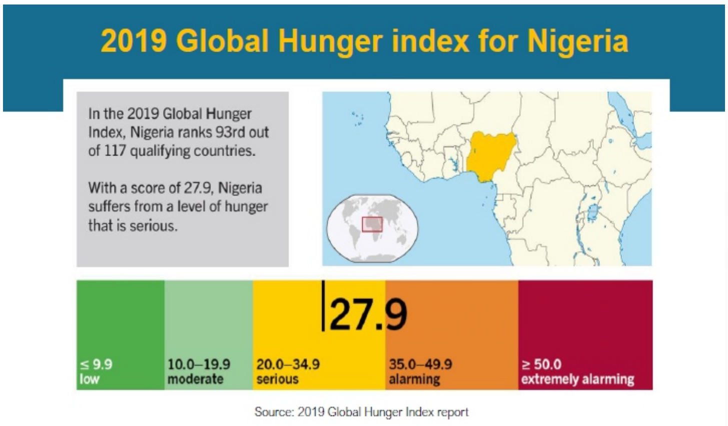
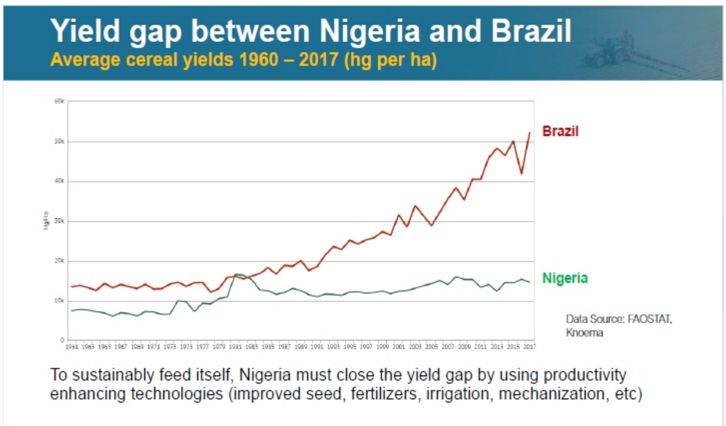
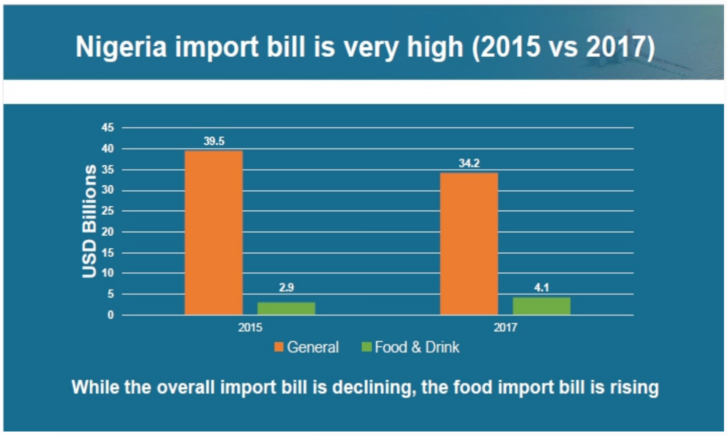
Ms. Monde Nyambe
African Development Bank (AfDB)











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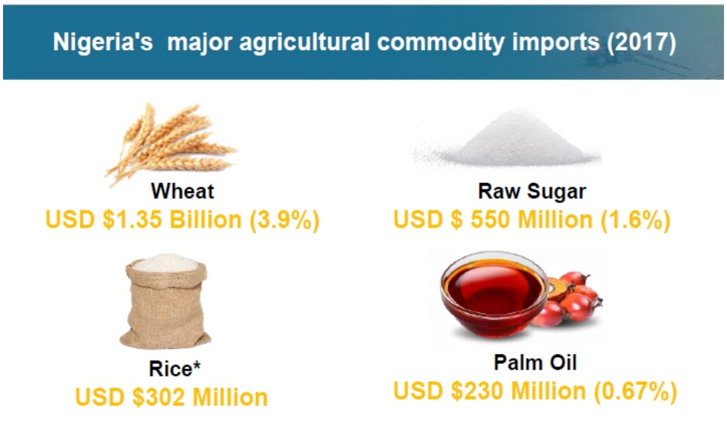

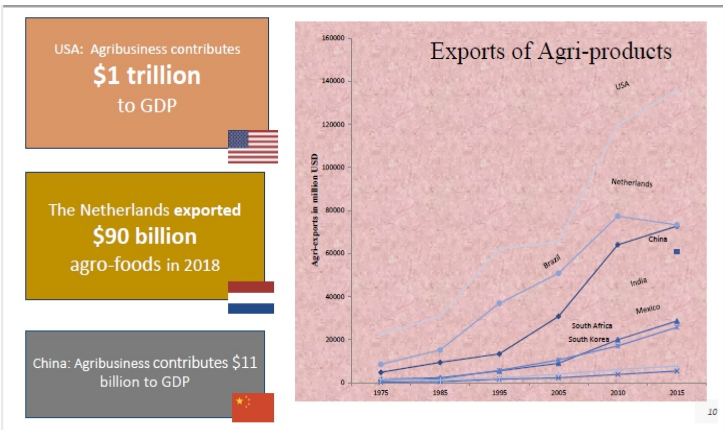

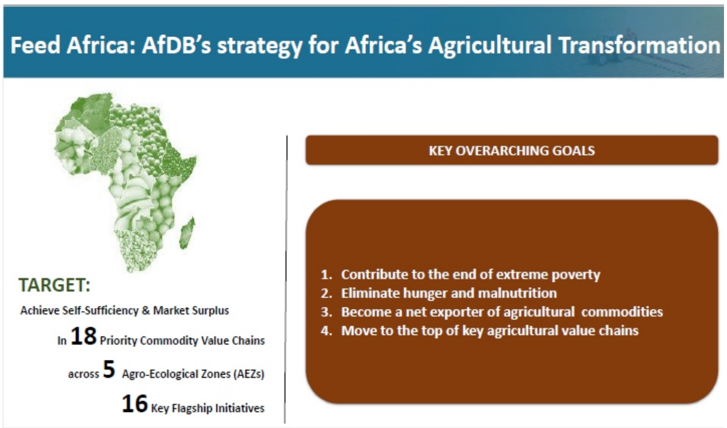

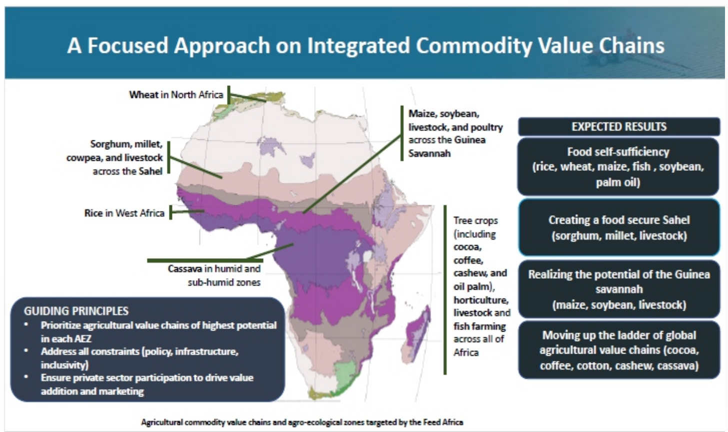

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What are Special Agro-Industrial Processing Zones (SAPZs)?

Agro-based spatial development initiatives designed to **concentrate agro-processing activities within areas of high agricultural potential** to boost productivity and integrate production, processing and marketing of selected commodities.

Shared facilities, to enable *agricultural producers, processors*, aggregators and distributors to operate *in the same vicinity* to reduce transaction costs and share business development services for ***increased productivity and competitiveness***.

By bringing adequate infrastructure (energy, water, roads, ICT) to rural areas of high agricultural potential, they attract private investments

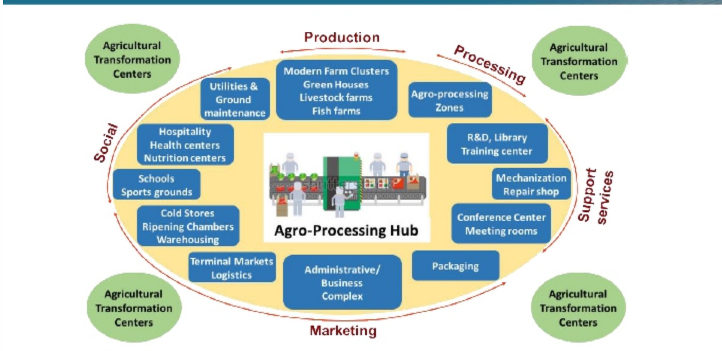
Components of an SAPZ: Agro-Processing Hub

A **centrally managed tract of land developed** and dedicated to supporting firms and other stakeholders engaged in agro-processing and related activities located throughout the production area surrounding the hub. (FAO, 2017);

The hub offers adequate infrastructure, logistics and specialized facilities and services (e.g. electricity, water, cold chain facilities, laboratory and certification services, business services, ICT, waste treatment, etc.) required for agro-industrial activities.

The ownership and management of the hub is controlled by a dedicated and independent entity, often in a public-private partnership arrangement.

Schematic Presentation of an Agro-processing Hub



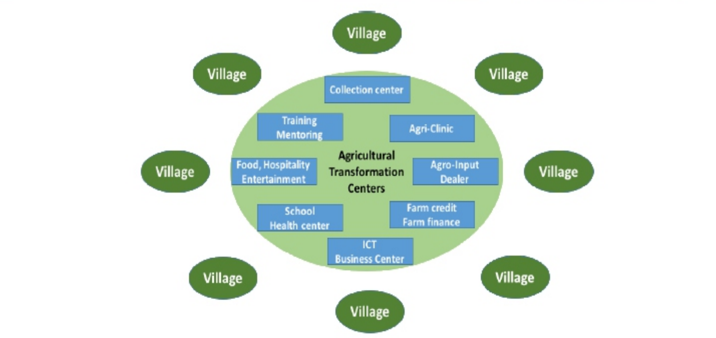
Components of an SAPZ: Agricultural Transformation Centres (ATCs)

For each SAPZ, ATCs are located within the production area to serve as **aggregation points** of products from the community to supply the Agro-Processing Hub for further value addition or to be directly marketed to distribution and retail centers.

The ATC is a physical complex of facilities located in a farming community, where required services are offered to farmers.

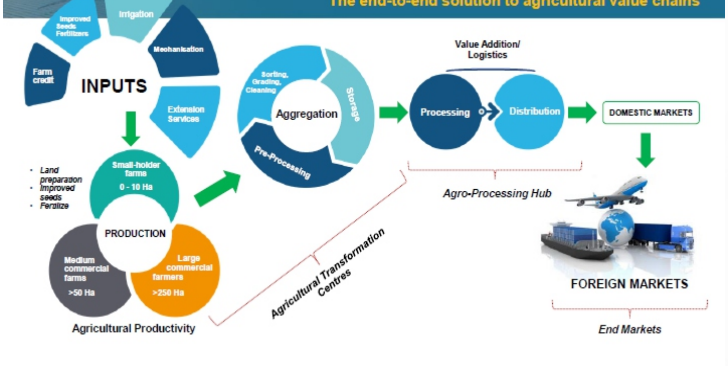
Includes crop drying facilities, cold stores and warehouses, farm equipment rental and maintenance services, crop handling, grading, storage, and processing for increased shelf life; livestock, fish handling, slaughtering and meat packing; food quality and safety control and certification; distribution and marketing platforms, etc.

Schematic Presentation of Agricultural Transformation Centers (ATCs)

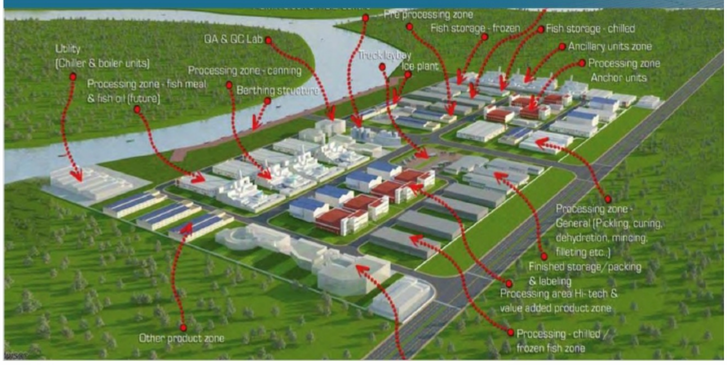


Components of an SAPZ

The end-to-end solution to agricultural value chains



SAPZ Facilities – the blue prints



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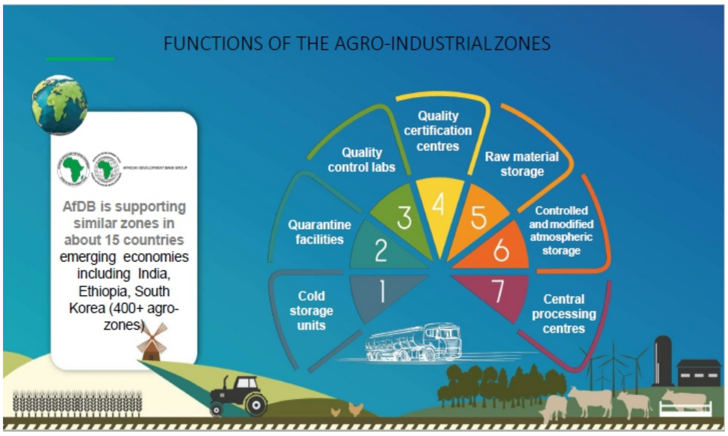

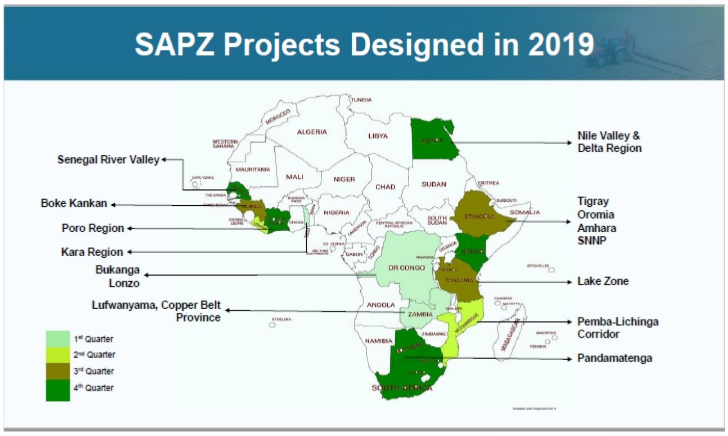

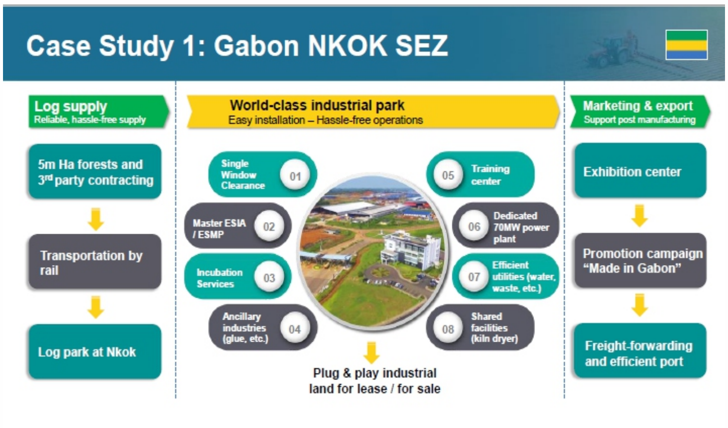

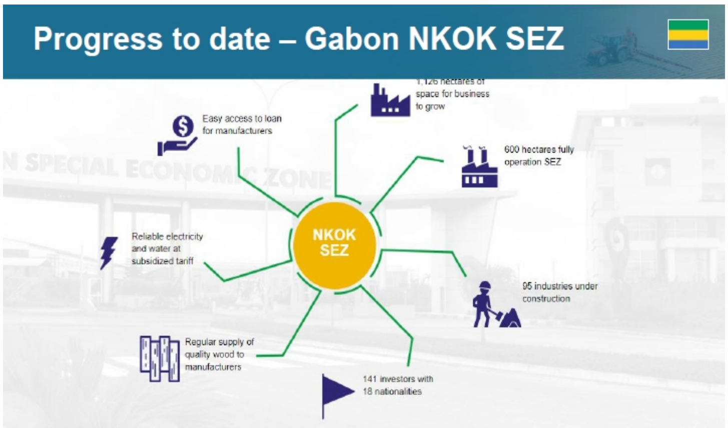

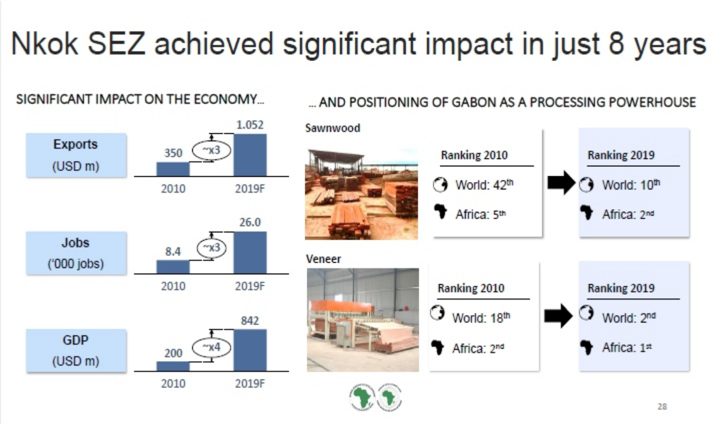

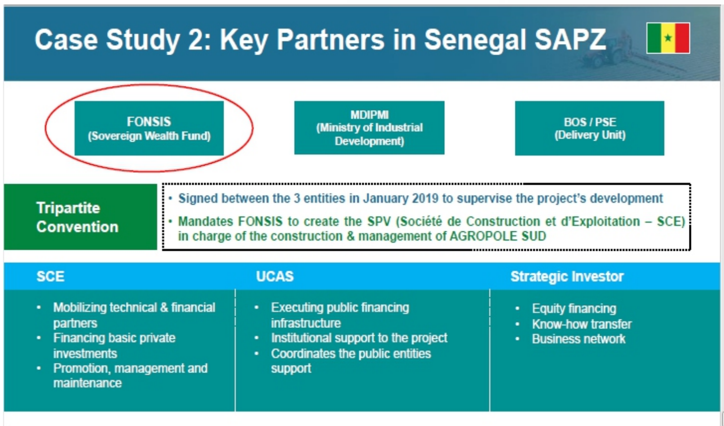

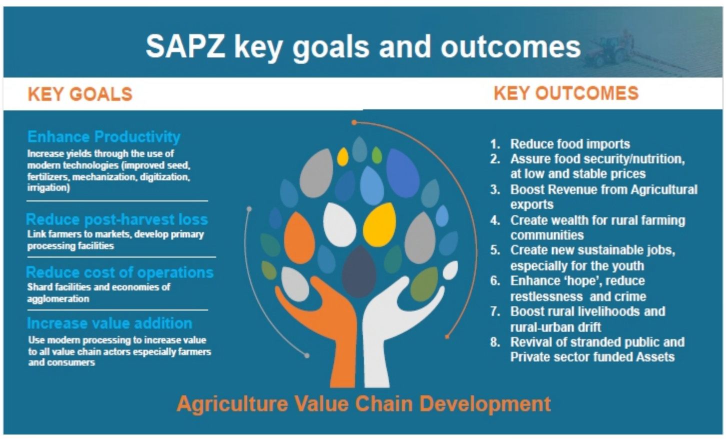

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FARM POWER AND MACHINERY

DEVELOPMENT AND PERFORMANCE EVALUATION OF 16HP (8KVA) FUELLESS GENERATOR TO POWER AGRICULTURAL MACHINES

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Abstract
Power generation and distribution has been an indispensable factor in the progress of an economy, ranging from manufacturing, banking, media, health care, aviation, etc. Environmental pollution which leads to degradation or depletion of ozone layer is one of the major problem caused by the use of generator with fossil fuels. This paper focuses on emergence of fuel less engine as a free energy electric motor with estimated capacity of 16HP using 16 N52 Neodymium magnet and 8 coils made with 17AWG wire properly arranged on disk array connected in series and parallel to 4 HV capacitors of 50mfd by 440vac connected in series. The result of the performance evaluation of the fuel-less power generating set shows that the machine has an average efficiency of 65.26% and lowest efficiency of 63% at load of 600W for continuous operation. The peak efficiency of the constructed fuel-less power generating set was 89% at load of 100W.

Keywords: Generator, Fuel-less, Efficiency, Power.

1. Introduction

Power generation and distribution has been an indispensable factor in the progress of an economy, ranging from manufacturing, banking, media, health care, aviation, etc. (Ulaby, 1999). It has however been proved that power skyrocket the productivity of a country. Environmental pollution which leads to degradation or depletion of ozone layer is one of the major problems caused by the use of generator with fossil fuels (Ajav, 2012). The famous Faraday energy generator can be modified for perpetual electrical current maintenance (Adiyat et.al, 1993). The basic components the fuel-less engines consisted of are a set of fast spinning discs placed between two electromagnets. The fuel-less engine usually runs very smooth and quiet and the best part of the design is that it is free from air pollution, since there is no emission of dangerous gas like Carbon monoxide (CO), carbon-dioxide (CO2).

The aim of this project is to develop and determine the performance evaluation of a 16HP (8KVA) fuel-less generating set to power agricultural machines.

2. Methodology

2.1 Experimental materials

The materials used for this research are shown in Table 2.1

Materials	**Quantity**
Carbon brush	2
HV motor run Capacitors 50mfd by 440VAC	4
5/16” D by 36”L stainless steel long bolts	3
Mounted ball bearings	2
(8)1/2 “ washers and nut	8
1” Ball Bearing	2
27 copper wire	27
Stainless steel washers 32 by ½”	64

2.2 Design Procedure/method

2.2.1 Construction of stator coil disk using ply wood

Step1: The 0.75” thick ply wood was cut to a diameter of 14.5”
Step2: 0.50” thick was cut to a diameter of 14.5” into 2 parts which makes it a total of 3 disc to make the stator coil disc of which the three disc are connected together to make one.
Step3: A drill press circle cutter was used to cut large eight holes for the coils to fit into. With the first disc ¾” thick while the second and third ½” thick.

2.2.2 Construction of generator housing end using ply wood

Step1: Another ply wood of 0.75” thick was cut to a diameter of 14.5” into two parts for the generator housing.
Step2: Their bases was cut into a rectangular shape of sizes 1” base by 2 (7 7/8”) length connected to a height of 3” to the diameter disc.
Step3: A hole of 1” diameter was cut through the center of the disc for generator shaft to pass through it.

2.2.3 Construction of magnetic rotor disc using ply wood

Step1: Now for the N52 Neodymium magnet, a ply wood of 0.75” was cut to a diameter of 12.5” into two pieces/parts.
Step2: Holes of 2” diameter were drilled for the 2” diameter N52 neodymium magnets to fit into
Step3: 1” diameter hole was cut through the center of the disc for the shaft to pass through it.
Step4: Both the rotor disc, end disc and coil disc into 8 equal pie pieces were marked.

2.2.4 Carbon brush assembly

Step1: Carbon brush assembly was made from polyethylene plastic
Step2: ½” thickness of polyethylene plastic was used
Step3: The plastic length 4 7/16” and width ¾” was used

2.2.5 Commutator assembly

Step 1: polyethylene plastic of 2 1/8” diameter × ¾” thickness was used to make commutator collar with 1” diameter center hole drilled for 1”D to pass through
Step 2: Copper pipe of actual diameter size of 2 1/8” D was used as commutator
Step 3: Small holes were drilled all around the edge of the copper pipe so as the help the epoxy stick better to the copper pipe

2.2.6 The coil

Step1: 17 AWG copper wire was used for the coil
Step2: Bobbin/mold of 3 3/16” diameter × 2 5/8” outer length was used
Step3: Pvc pipe of outer 1 11/16” outer diameter × 1 5/8” length was used

2.3 *Design Calculation*

2.3.1 Commutator and Brush Design

Commutator Peripheral Velocity $V_c = \pi D_c N/60$………………………………..2.1
$V_c = 1.40 m/s$
=Frictional torque in Nm × angular velocity

=Frictional force in Newton × distance in meter
=2πN60
=9.81μPbAball × Dc / 2× 2πN / 60
=9.81μPbAballVc……………………………………………………………2.2
μ= coefficient of friction and depends on the brush material. Lies between 0.22 and 0.27 for carbon brush
Fball Brush frictional loss = 2158.2N
Pb= Brush pressure in kg/m2 and lies between 1000 and 1500
Aball = Area of brushes of all the brush arms in m^2
Aball= Ab × 2 in case of wave winding
Aball= 990.6mm^2
Ab = cross sectional area of the brush/brush arm
Ab= $t_b w_b n_b$……………………………………………………………………2.3
Ab= 495.3mm^2
t_b= thickness of the brush
w_b= Width of the brush
n_b= number of sub divided brush

2.3.2 Stator/rotor Disc Design

De= Exterior diameter = 3175mm
He= Entire thickness = 44.45mm
Dy= yokes internal diameter = 50.8mm
Nm= Pole number = 8
Nc= Coil number = 8
Bg= Air gap density = 646.05kg/m^2
Lg= Effective coil length in magnetic field = 75.4mm

$3k = \frac{Nc}{(GcD(Nc,Nm))}$…………………………………………………………2.4

K= Arbitrary positive Integer
Gcd= Greatest common factor= 8
K = 0.0208
Flare angle for permanent magnet Ɵm

$\theta m = \frac{360°}{Nm}$……………………………………….....................................2.5

Ɵm = 45°
Permanent Magnetic thickness Lm = 12.7mm
Carter's Coefficient= Kc

Kc = $\left(1 - \frac{1}{\frac{Ts}{Ws}(\frac{Sg}{Ws}+1)}\right)^{\wedge} - 1$…………………………………………………......2.6

Kc = 1.638
Lg = 2×δg + Lc……………………………………………………………….2.7
Lb= Coil width = 44.45mm

2.3.3 Coil design

Coils have a property called inductance. When electrical current changes as it flows through the wire of a coil, it produces a changing magnetic field that induces a voltage or emf (electromotive force), in the wire that opposes the current which is called induction and inductance is a value quantifying the ability of the coil to induce/produce that voltage.

$L = \frac{\mu r \times turns^2 \times Area \times 1.26 \times 10^{-6}}{Length}$...2.8

L=Inductance
Inductance=0.0082H
Table 2.2 shows parameter of the design component

Table 2.2: Parameters of design calculation components

Parameters	Description	Value
μ	Coefficient of friction for carbon brush	0.22
p_b	Brush pressure	1000kg/m^2
tb	Thickness of brush	13mm
wb	Width of brush	19.05mm
Ab	Cross sectional area of brush arm	495.3mm^2
Nb	Number of subdivided brush	2

2.4 Working Principles of a 16hp (8kva) Fuel-less Generator

The Fuel-Less engine puts out far more than it takes to run it! It is considered a Free Energy Perpetual motion machine. So then the electrolytic capacitor bank is now fully charged and the spark plug gap is set to fire at 1,000 volts, It then ignites and a complete circuit is made to the magnets which are facing one another north pole to north pole, An explosive amount of magnetic power then takes place and both magnets repel one another, You can use that power to do work, to power a generator to keep up the batteries and to supply power to your entire home.The fuel-less generator will consist of 8 molded air coils which will require proper winding with 17 AWG magnet wire connected in series and 16 pieces of 2inches diameter N52 neodymium magnets needed for rotor magnet disc.
Figure 2.1 below is the first figure in this section which shows the assembly drawing of a Fuel-less generator while Figure 2.2 shows the labelled componentassembly drawing of a Fuel-less generator.

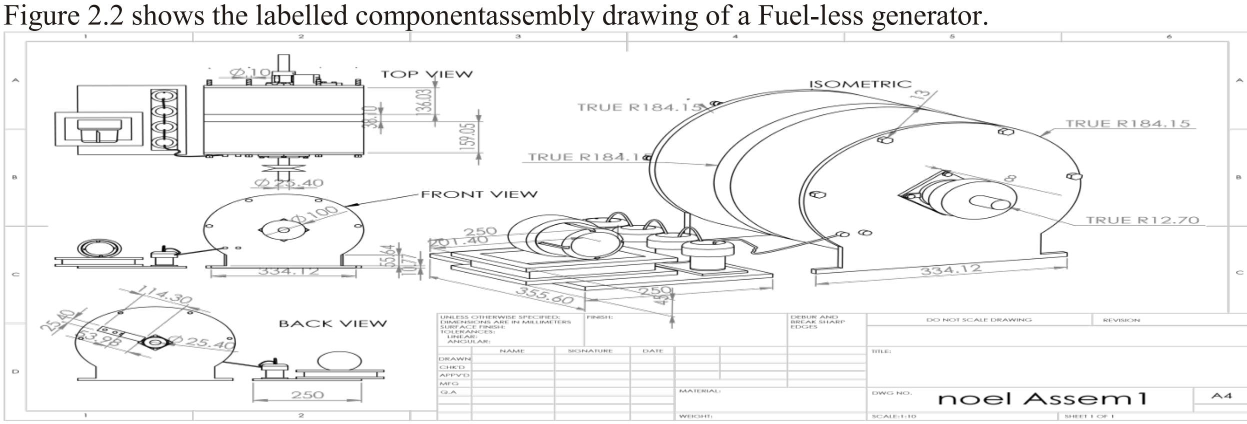

Figure 2.1: Assembly Drawing of a Fuel-less Generator

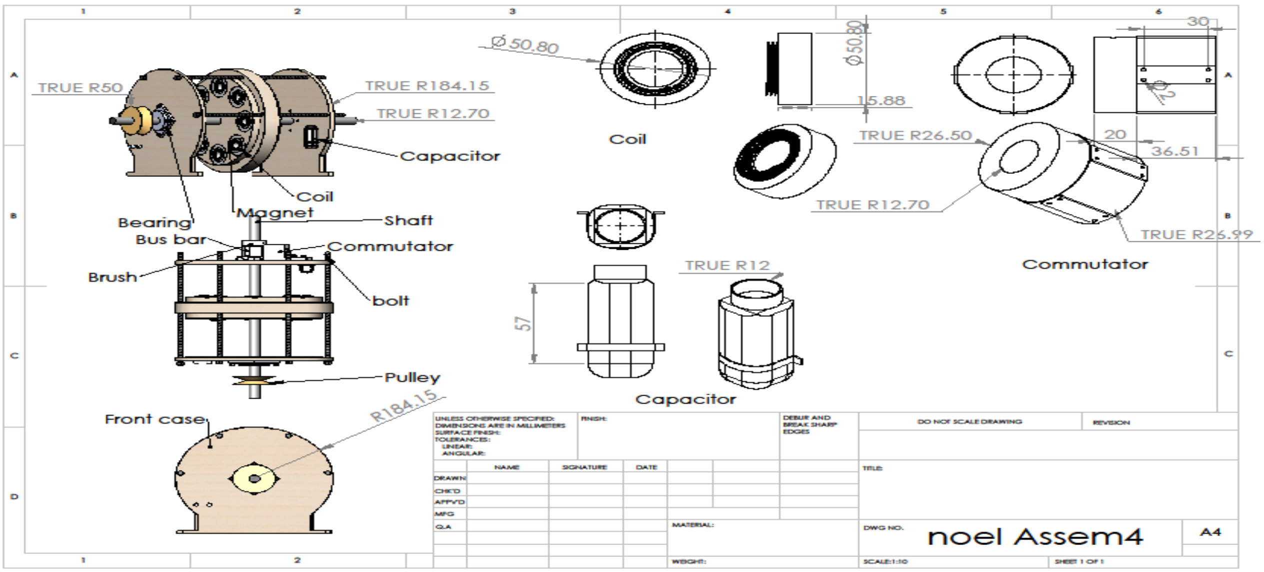

Figure 2.2: Labelled component assembly drawing of a Fuel-less Generator

2.5 *Performance Evaluation and Machine Efficiency*

This will include response to variations in input power, input and output voltage as revealed by Sandia (2004) according to IEEE standard. The evaluation of the machine will be calculated using the formula below as stated by Akintundeet *al* (2004); Efficiency = $\frac{Output\ power}{Input\ power} \times 100$

3. Results and Discussion

3.1 *Output Efficiency for fuel-less Power Generator*

Table 3.1 below shows the average result of performance evaluation for the 16HP (8kva) fuel-less power generating set. Five different type of Agricultural machines of different load capacity were connected to the fuel-less engine. The machine was tested by subjecting to a load appliance rating of 100W within a stipulated time frame of 40 minutes at a fragment of 5 minutes each to determine the load in wattage, input voltage, output voltage, input current in Ampere, output current in Ampere, input power in wattage, output power in wattage and efficiency. After subjecting the machine for 40 minutes, the average values when subjected to 100W were input voltage at 12.6V, output voltage was 218V, input current 7.3A, output current was 0.38A, input power was 91.98W, output power 82.41W and efficiency 89.1% respectively. The same process was repeated respectively when subjected to a load of 200W, 300W, 400W, 500Wand finally for the load of 600W, we have the values of 12.7V, 145V, 8A, 0.4A, 101.60W, 63W and 63% efficiency respectively. It was deduced that when subjected to a higher load in ascending order the efficiency kept decreasing. The highest efficiency of 89% was recorded at load 100W and the lowest efficiency of 63% was recorded at load 600W which followed the same trend as that of the research experiment carried out by (Ajav, 2014).

Table 3.1 Average performance evaluation for 8kva fuel-less generating set.

Trials	Load	Input	Output	Input	Output	Input	Output	Efficiency
		Voltage	Voltage	Current	Current	Power	Power	

1	0	12.662	225	0	0	0	0	0
2	100	12.6	218	7.30	0.38	91.98	82.41	89.1
3	200	12.65	200	7.80	0.43	98.67	83.90	85
4	300	12.8	212	7	0.40	89.60	74.1	82.5
5	400	12.9	190	8.2	0.50	105.78	74	72
6	600	12.7	145	8	0.4	101.60	63	63

4. Conclusions

The following conclusions were drawn from the design, construction and performance evaluation of 8KVA (16HP) fuel-less power generating set;

i. It can be deduced that the machine (fuel-less power generating set) had the peak efficiency of 89% at a load of 100W and the lowest efficiency of 63% at a load of 600W with voltage output of 145V.

ii. It was also revealed that there is a decrease in the output of the machine when there is a high increase in the load.

iii. The machine has an average efficiency of 65.26%.

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OPTIMISATION OF THE MIXING RATIO OF ADMIXTURE OF PYROLYZED JATROPHA SHELL WITH *EUCALYPTUS CAMALDULENSIS* WOOD SHAVING FOR BRIQUETTES PRODUCTION

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Abstract
Wastes from the forest and urban centres represent huge amount of renewable sources of energy. This study focused on optimisation of mixing ratio of admixture of pyrolyzed jatropha shell and Eucalyptus camaldulensis wood shavings with Acacia senegal as the binder. Response Surface Methodology was applied in the optimisation of the mixing proportions. Bio-char of jatropha shell-cum-Eucalyptus camaldulensis wood shavings and Acacia senegal were considered as the independent factors while the response variable were calorific value and hardness of the briquette. The experimental design adopted was five factors, five levels Central Composite Rotatable Design (CCRD) of second order polynomial model. Five mixing ratio having a mass of 1200g of pyrolyzed jatropha shell to Eucalyptus camaldulensis wood shaving proportions viz. 0/100, 25/75, 50/50, 75/25 and 100/0 % with 50, 60, 70, 80 and 90 g of Acacia senegal as the binder respectively were selected. The hardness and calorific values of briquettes produced were determined as the responses using universal testing machine and bomb calorimeter respectively. The optimum mixing ratio and mass of binder were found to be 25/75% and 64.02g with corresponding response for calorific value and hardness being 19.37 MJ/kg and 3.83 kN, respectively. The hardness of the briquette followed an increasing trend with the binder while it decreased with increase in proportion of jatropha shell in the mix. However, the calorific value was found to increase with proportion of jatropha shell in the mix while it decreased with the binder. The briquette was found to have good handling qualities and also suitable as solid bio-fuel both for domestic and industrial uses.

Keywords: Briquette, mixing ratio, jatropha shell, *Eucalyptus camaldulensis* and *Acacia senegal*

1. Introduction

Briquettes represent a viable and sustainable source of renewable energy for industrial and family level use. It is a compressed form of solid fuel produced from biomass (Zheng *et al*., 2010). In Nigeria biomass accounts for 51% of total energy consumption while other sources such as natural gas, hydroelectricity and petroleum products constitute 5.2%, 3.1%, and 41.3% of energy consumption (Akinbami, 2001, Olorunnisola, 2007). It is obvious from the foregoing that biomass remains an indispensable source of renewable energy in this part of the world. It is estimated that about 2.7 billion people worldwide, who do not have access to modern fuels depend on biomass for domestic use (UNDP/WHO 2009, Grimsby and Borgenvik, 2013). Dependence on biomass has resulted to depletion of trees in some of the forest reserves when trees are being felled for fire wood. The demand for fuel wood is projected to increase to 213.4 x10^3 metric tonnes, with decrease in supply to about 28.4 x10^3 metric tonnes by the year 2030 (Adegbulugbe, 1994). Green house gas emission as of one the adverse impact of indiscriminate felling of trees is here with us today. Studies on the utilization of rejected or undesirable forest and agricultural wastes such as straws, leaves, wood shavings, pods, shells and so on in production of briquettes has been conducted and found to be a veritable means in reducing emission of greenhouse gases (Shiferaw et al. 2017,Rajaseenivasan et al. 2016, Olorunnisola, 2007).

Forest and agricultural waste could be pyrolyzed and converted into briquettes. This area of research has been carried out in the past with positive outcome (Prasityousil and Muenjina, 2013). In production of briquette, parameters such as compression pressure, pyrolysis temperature, moisture content, particles sizes of feedstock, mixing ratio and the type of binder determines the effectiveness and suitability of the briquette for fuel (Maschio*et al*., 1992). Gonzalez *et al.* (2004) studied the optimisation of mixing ratio for four different categories of pellets. The optimum mixing ratio was established to be75:25 using tomato and forest residues, with thermal efficiency of 92.4% when applied in a boiler. Previous studies have shown that optimisation of the mixing ratio of the feed stocks in briquette production is important for quality and efficient solid fuel. The production of briquette involves the utilization of binders which interfere with some of its thermal properties. The cost of binders is another factor that must be considered since they are freely available. It is therefore necessary minimize the quantity of binders in briquettes production without affecting its stability. .In this study, the optimisation of the mixing ratio of constituting components (binder, jatropha shell and *Eucalyptus camadulensis*) of a briquette was carried out in a bid to produce more quality and effective briquettes using lesser quantity of binder.

2. Materials and Methods

2.1 Sample Preparation

In the production of the briquettes some undesirable forest and agricultural waste such as *Eucalyptus camaldulensis* wood shavings and jatropha shell recovered from jatropha nut shelling process, were collected from within Federal College of Forestry Mechanisation and Trial Afforestation Research Station Kaduna, Nigeria. The *Eucalyptus camaldulensis* wood shavings and jatropha shell were pyrolyzed separately in an improvised kiln with chimney and charring chamber. The bio-chars recovered from the kiln were screened using a sieve to obtain finer bio-char particles. The bio-chars recovered were cooled and kept in polythene sacks at room temperature (28±2 ºC). An organic binder, such as *Acacia senegal* was selected for the production of the briquette. This type of binder is more preferable because it is environment friendly.

2.2 *Optimisation of Mixing Proportion*

The optimization of the mixing ratio was carried out using experimental design plan in Table 1. The experimental design plan comprises of two independent factors i.e. jatropha shell-cum-*Eucalyptus camaldulensis* wood shavings proportions ranging from 0/100, 25/75, 50/50, 75/25 to 100/0 % with the binder from 50, 60, 70, 80 to 90g. Response Surface Method (RSM) was adopted for the optimisation process. The plan of experimentas shown in Table 2 was generated using a statistical package such as Design-Expert 10 by applying Central Composite Rotatable Design. The response variables were hardness and calorific values of the briquettes produced while the independent variables were jatropha shell-cum-*Eucalyptus camaldulensis* wood shavings proportions and mass of binder. These were analyzed using two factor interaction and quadratic models. The analysis of variance was also carried out for jatropha shell-cum-*Eucalyptus camaldulensis* wood shavings proportions and mass of binder. The experimental design adopted was two factors, five levels Central Composite Rotatable Design (CCRD) as shown in Table 1. This comprises three major design points which include axial, central and factorial points. Full CCRD was adopted for the experimental design (Montgomery and Runger, 2003; Fadele and Aremu, 2018). The total number of experimental runs was evaluated in Equation 1 as follow:

$$N = (2^k) + 2k + c \qquad 1$$

Where: N is the number of runs; k is the number of independent parameters; c is the centre point.
The experimental design plan comprises of 4 factorial points, 4 axial points and 5 replications at the centre point. In the optimization process, 13 runs were generated in all as shown in Table 2.

Table 1. Experimental Design for Jatropha-cum-Eucalyptus Camaldulensis and Binder Mixing

Factors	**Levels**				
	1	2	3	4	5
Mass of Binder (g)	50	60	70	80	90
Jatropha: Eucalyptus	0:100	25:75	50:50	75:25	100:0

Table 2.Plans of Experimental Design for the Mixing Ratio

S/No	Jatropha Shell-cum-*Eucalyptus camaldulenis* Wood Shaving (%)	Mass of Binder (g)	Responses	
			Calorific Value (MJ/kg)	Hardness (N)

1	50/50	70	18.95	4.2
2	50/50	70	19.56	3.8
3	75/25	60	15.37	5.3
4	75/25	80	17.23	4.6
5	50/50	70	15.66	3.6
6	50/50	90	16.75	7.5
7	25/75	60	14.05	3.5
8	50/50	70	27.33	3.1
9	50/50	70	21.49	4.7
10	0/100	70	14.64	7
11	100/0	70	15.09	4.6
12	25/75	80	9.66	6
13	50/50	50	31.15	2.6

2.3 Determination of Calorific Value of the Briquette

The calorific value of the briquette was determined using a bomb calorimeter (ZDHW-2000) in Leather Research Institute Zaria, Kaduna Nigeria. Thirteen samples of briquettes produced from mixing proportions in Table 1 were tested. Figure 1 shows the diagram of the bomb calorimeter used for the test.

Figure 1.Test for the calorific value of the briquette using a bomb calorimeter

3.3 Determination of Hardness of the Briquette

The hardness of the briquette was determined using a Universal Testing Machine (Techquipment SN1000) as shown in Figure 2. Thirteen samples of the briquettes were tested and values for hardness and deformation were logged and plotted into a curve on the system. The hardness of the briquette was also optimized.

Figure 2.Test for the compressive strength of the briquette using a Universal Testing Machine

3. Results and Discussion

3.1 Effect of Mixing Proportion on the Calorific Value of Jatroph-cum-eucalyptus Briquette

The calorific property of the briquette was found to be insignificantly influenced by variation in the mixing proportion of the bio-char of jatropha and *Eucalyptus camaldulensis* with the mass of binder as shown in Table 3. This is an indication that variation in all the mixing constituents of the briquette does not have any effect on the calorific value of the briquette which could be as a result of application of constant compressing pressure for all the briquettes. The maximum value obtained was found to be 31.15MJ/kg which is agreement with that of charcoal and jatropha pods bio-char (Openshaw, 2000; Mallika *et al.,* 2015). However, the minimum value was found to be 9.66 MJ/kg while the average value was 18.23 MJ/kg. The optimum calorific value was 19.37 MJ/kg with desirability of 0.55. The calorific value was found to increase and then decrease with proportion of jatropha shell in the mix which could be due to the bulk density of jatropha shell which contributed to the energy density of briquette when its proportion increases as shown Figure 3. This is in support of findings by Grimsby and Borgenvik (2013); while it decreases and then increases with the proportion of *Eucalyptus camaldulensis* wood shaving in the mix as shown in Figure 3. The calorific value also decreased with increase in the mass of the binder as shown in Figures 3. Equation 2 shows the mathematical relationship that exist between calorific and the mixing proportion of jatropha shell-cum-Eucalyptus wood shavings with the mass of binder.

$$C = 87.4 - 0.159A - 1.604B + 0.00625AB - 0.00245A^2 + 0.00736B^2 (R^2 = 0.48) \quad 2$$

where: C is the calorific value; A is the proportion of bio-char of jatropha shell to eucalyptus wood shaving; B is the mass of binder

The Model F-value of 1.27 implies the model is not significant relative to the noise. There is a 37.14 % chance that a F-value this large could occur due to noise. The lack of fit F-value of 2.37 implies that the lack of fit is not significant relative to the pure error. There is a 21.13% chance that a lack of fit F-value this large could occur due to noise. Non-significant lack of fit is good since it shows that the observed data fit to the model. The coefficient of determination (R^2) obtained was found to be 0.48. This shows the variation in the constituting components of the briquette to accounts for 48% of the total responses in the calorific value of the bio-char jatropha shell-cum-*Eucalyptus camaldulensis* wood shaving briquette.

Table 3. Analysis of Variance for Relationship between Calorific and Briquette Constituents

Source	Sum of Squares	Df	Mean Square	F-Value	p-value Prob > F	
Model	187.79	5	37.56	1.27	0.3714	not significant
A-Jatropha	*7.99*	*1*	*7.99*	*0.27*	*0.6189*	
B-Binder	*81.80*	*1*	*81.80*	*2.77*	*0.1398*	
AB	*9.77*	*1*	*9.77*	*0.33*	*0.5831*	
A^2	*54.02*	*1*	*54.02*	*1.83*	*0.2181*	
B^2	*12.41*	*1*	*12.41*	*0.42*	*0.5373*	
Residual	206.50	7	29.50			
Lack of Fit	*132.21*	*3*	*44.07*	*2.37*	*0.2113*	*not significant*
Pure Error	*74.29*	*4*	*18.57*			
Cor Total	394.29	12				

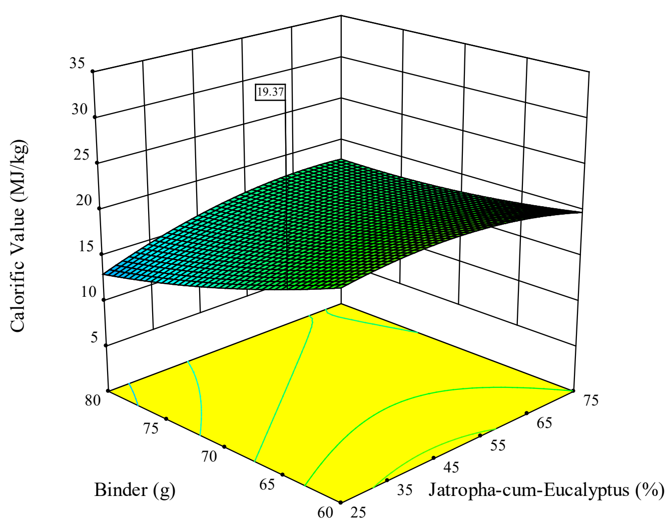

Figure 3. Calorific value against binder and jatropha-cum-eucalyptus bio-char

3.2 Effects of Mixing Proportion on the Hardness of the Briquette

The hardness of the briquette was found to be significantly affected by the mixing ratio as shown in Table 4. This shows that variation in one or more of the mixing constituents of the briquette have an effect on the hardness of the briquette. The maximum value obtained was found to be 7.5 kN which is acceptable for stability of briquette during handling, transit or utilization. However, the minimum value was found to be 2.6 kN while the average value was 4.65 kN. The optimum value obtained for the hardness was 3.83 kN. The hardness was found to decrease with jatropha-cum-*Eucalyptus camaldulensis* wood shaving mixing ratio while it increases with the binder as shown in

Figure 4. The hardness value was found to decrease with the proportion of bio-char of jatropha shell in the mix while it increases with that of *Eucalyptus camaldulensis* wood shavings. However, the hardness of the briquette increased with increase in the mass of the binder as shown in Figures 4. Equation 3 shows the mathematical relationship that exists between the hardness and jatropha-cum-Eucalyptus wood shavings proportion with the mass of binder.

$$H = 3.134 + 0.132A - 0.158B - 0.0032AB + 0.00077A^2 + 0.00296B^2 \ (R^2 = 0.83) \quad 3$$

where: H is the calorific value

A is the proportion of bio-char of jatropha shell to eucalyptus wood shaving

B is the mass of binder

The Model F-value of 6.67 implies the model is significant as shown in Table 4. There is only a 1.36% chance that an F-value this large could occur due to noise. The lack of fit F-value of 2.74 implies that the lack of fit is not significant relative to the pureerror. There is a 17.75% chance that a lack of fit F-value this large could occur dueto noise. Non-significant lack of fit is good since it shows that the observed data fit to the model. The coefficient of determination (R^2) obtained was found to be 0.83. This shows that the variation in the constituting components of the briquette to accounts for 83% of the total responses in the hardnessof the bio-char jatropha shell-cum-*Eucalyptus camaldulensis* wood shaving briquette.

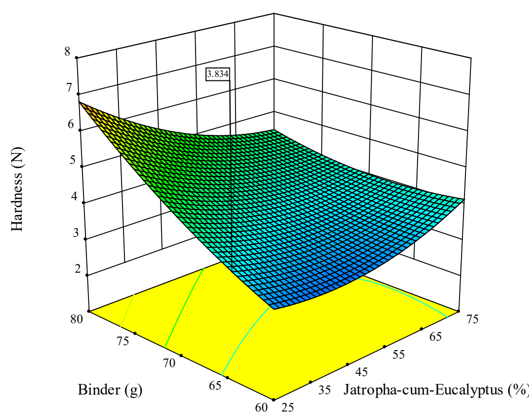

Figure 4. Hardness against binder and jatropha-cum-eulayptus bio-char

Table 4. Analysis of Variance for Relationship between Hardness and Briquette Constituents

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	21.37	5	4.27	6.67	0.0136	significant
A-Jatropha	*1.61*	*1*	*1.61*	*2.52*	*0.1565*	
B-Binder	*11.21*	*1*	*11.21*	*17.51*	*0.0041*	
AB	*2.56*	*1*	*2.56*	*4.00*	*0.0857*	
A^2	*5.35*	*1*	*5.35*	*8.36*	*0.0233*	

B^2	*2.01*	*1*	*2.01*	*3.13*	*0.1201*	
Residual	4.48	7	0.64			
Lack of Fit	*3.02*	*3*	*1.01*	*2.74*	*0.1775*	*not significant*
Pure Error	*1.47*	*4*	*0.37*			
Cor Total	25.85	12				

4. Conclusion

The effects of mixing ratios on some engineering properties of pyrolyzed jatropha shell-cum-*Eucalyptus camadulensis* shaving briquette were determined.The optimum mixing ratio of the pyrolyzed jatropha shell-cum-*Eucalyptus camadulensis*wood shaving briquette were 25/75% jatropha shell to *Eucalyptus camaldulensis* wood shavings and 64.02g for mass of binder with corresponding calorific value and hardness of 19.37 MJ/kg and 3.83 kN, respectively. The mean, minimum and maximum values for the calorific value and hardness were 18.23, 9.66 and 31.15 MJ/kg and 4.65, 2.6 and 7.5 kN, respectively. The hardness of the briquette followed an increasing trend with the binder while it decreased with increase in mixing proportion. However, the calorific value was found to increase with jatropha-cum-wood shaving mixing ratio while it decreased with the binder. The briquette was found to be stable and suitable as solid bio-fuel both for both domestic and industrial uses.

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EFFECTS OF TILLAGE PRACTICES ON SOME PHYSICAL PROPERTIES OF SOIL IN RESEARCH FARM OF FEDERAL COLLEGE OF AGRICULTURE IBADAN

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Abstract

Drainage, tillage, and intensive land use lead to drastic alteration in physical, biological, and chemical properties of soil. This experiment was conducted to evaluate the effects of tillage practices on some physical soil properties in the research farm of Federal College of Agriculture Ibadan. Five tillage practices as treatment were imposed in a randomized complete block design (RCBD) with three replications. These treatments are; Plough tillage (PT), Harrow tillage (HT), Hoe tillage (L), No-tillage (NT) and Plough plus Harrow tillage (PHT) at various tillage depths of 0-15cm and 15-30cm respectively. These physical properties include soil moisture content, soil porosity, soil bulk density and soil texture. The result of the study indicates that depth of tillage significantly affected the physical properties of the soil. The soil particle size analysis reveals that the soil textural class falls on sandy loam with 45.16% - 47.35% sand, 3.68% - 5.83% clay and 46.83% - 51.17% silt. The result showed significant difference in soil texture due to imposed variation in tillage depth ($p < 0.05$). Moisture content was observed to be significant for both depths while bulk density and soil porosity shows no level of significance. Highest moisture content mean value of 9.40% was recorded at 0-15cm tillage depth of plough tillage while the lowest moisture content value of 7.80% was recorded at 0-15cm tillage depth of harrow tillage. The plough and harrow tillage operation was found to be more appropriate in improving the soil physical properties. Therefore, farmers and land users in and around the study area should be encouraged to adopt this recommended tillage practice for optimum crop production.

Keywords: Soil physical properties, Tillage, Bulk density, Porosity, No-tillage, Moisture content

1. Introduction

Tillage, according to Davies (2003), is a terminology that is applied to creation of enabling environment for the germination and growth of crops. Technically according to Makanjuola (2003), tillage refers to the mechanical stirring of the soil to provide a suitable soil environment for growth of crops. In general, the purpose of tillage include providing a good tilt which will be suitable for the operation of subsequent machinery and growth of crop, to provide for the land the necessary preparation for irrigation and drainage operation and to mix fertilizer, crop residue and other soil amendments into the soil (Onwualu *et.al.,* 2006).

Soil tillage is among the important factors affecting soil properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et.al.,* 2006) and affects the sustainable use of soil resources through its influence on soil properties (Lal and Steward, 2013). The judicious use of tillage practices overcomes edaphic constraints, whereas inopportune tillage may cause a variety of undesirable outcomes, for example, soil structure destruction, accelerated erosion, loss of organic matter and fertility, and disruption in cycles of water, organic carbon, and plant nutrient (Lal, 1993).

Soil physical properties are important for favourable conditions for crop growth and maintaining soil quality (Rachman *et al*., 2003). The suitability of a soil for sustaining plant growth and biological activity is a function of physical and chemical properties (Mulumba and Lal, 2008).

Soil is a key natural resource and soil quality is the integrated effect of management on most soil properties that determine crop productivity and sustainability (Anikwe and Ubochi, 2007). Tillage practices profoundly affect soil physical properties. It is essential to select a tillage practice that sustains the soil physical properties required for successful growth of agricultural crops (Jabro *et al*., 2009). Seedbed preparation is crucial for crop establishment, growth and ultimately yields (Atkinson *et al*., 2007). Tillage systems create an ideal seedbed condition for plant emergence, development, and unimpeded root growth (Licht and Al-Kaisi, 2005). Soil physical and biological characteristics are influenced by tillage practice, which in turn lead to alter plant growth and yield (Wasaya *et al*., 2011, Rashidi and Keshavarzpour 2007).

Soil bulk density, penetration resistance and water movement in the soil, all indices of soil compactness and porosity, depend on depth and method of tillage (Mulumba and Lal, 2008). Therefore, assessing the effect of tillage depth and method on these soil properties may explain variability in growth, crop development, yield and quality. (Mulumba and Lal, 2008). Generally speaking, all the tillage methods reduce soil bulk density and penetration resistance to the depth of tillage..

Tillage method affects the sustainable use of soil resources through its influence on soil properties (Schwartz et al., 2010). The proper use of tillage can improve soil related constraints, while improper tillage practices may cause a range of undesirable process e.g., destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption of organic matter. Therefore, currently, there is a significant interest and emphasis on the shift to the conservation and no-tillage method for the purpose of controlling erosion. (Igbal *et al.,* 2005).

The knowledge of relationships between different soil physical properties is necessary for the evaluation of the possible consequences of tillage practices on soil conditions and crop production. The changes in soil physical characteristics induced by tillage may persist for varying lengths in various soil types and is strongly related to climatic conditions. The deterioration of soil structure as a result of continuous cropping can affect crop growth adversely. The choice of suitable tillage systems will be useful to control soil degradation (Busscher *et al.,* 1995).
Both adverse and beneficial effects occur as a consequence of intensive tillage. The adverse effects include soil compaction, soil erosion, and loss of soil organic matter (Unger, 1992) and ultimately destruction of internal drainage. The possible beneficial effects include increased water conductivity in the soil profile through macro pores in minimum tillage systems and soil organic matter stabilization in certain tillage and residue management systems (Unger, 1992). The protection of soil erosion and soil moisture conservation for crops should be major objectives of conservation tillage (Allen and Fenster, 1986).The objective of the study was to study the effect of different tillage practices on some physical properties of soil and to determine the tillage depth that best suit soil for crop production.

2. Materials and Methods

2.1 Study Area

The experiment was carried out at the research site of Federal College of Agriculture, Moor Plantation, Ibadan. The location lies between 7.2^{0}C to 21^{0}C in longitude and latitude respectively. The climate is characterized by two distinct reasons, dry and wet, while the temperature range from 32^{0}C to 21^{0}C and average relative humidity is about 75%. The experiment was carried out in May, 2018.

2.2 Experimental Design

Five tillage practices were divided on the plots using a Randomized Complete Block Design (RCBD) with three replicates. These treatment methods were; Plough tillage (PT), Harrow tillage (HT), Hoe tillage (L), No-tillage (NT) and Plough plus Harrow tillage (PHT). The size of each plot was 10.0m by 6.0m. Ploughing involved the use of a disc plough mounted on a 70Hp tractor to adequately pulverize the soil to a level sufficient for seed germination and seed establishment. Plough plus harrow was carried out using a disc plough followed by a disc harrow.

2.3 Soil Sampling and Analysis

The experiment have five (5) plots in all and two sample were collect at different depth of 0-15 cm and 15-30 cm from each of the plots, days after the treatment were applied. The parameters tested in this study were soil texture, bulk density, soil density, soil moisture, and soil porosity.

2.3.1 Determination of Soil Texture

The soil texture of the study area was determined by hydrometer method (Gee and Bauder, 1986) and the soil was classified according to United State Department of Agriculture (USDA) soil texture classification. Particle size distribution of soil from two depth (0-15 and 15-30cm) in the selected plots was determined and the soil texture using soil textural triangle as described by Gee and Bauder (1986).

2.3.2 Determination of Soil Bulk Density

Density of the soil was determined following the procedure suggested by FAO (1977). Soil core samples from the 0-15 cm and 15-30cm depths were collected using core sampler of known volume which was driven into the soil and carefully dug out. The soil samples were collected, weighed and reweighed after oven drying for 24 hours. Soil bulk density was determined from the ratio of mass of dry soil per unit volume of soil cores.

2.3.3 Determination of Soil Moisture Content

A weight of empty can was recorded as W_0 and a known weight of sample (100g) was weighed on a meter weighing balance as W_1. The sample was weighed in the can W_1 and put inside an air hot oven set at 105^0C overnight after drying; the whole content was weighed and recorded as (W_2). The gravimetric moisture content was calculated as the mass of moisture in the soil sample divided by the mass of the dry soil multiplied by 100 (ASABE Standards, 2008).

$$MC = \frac{W1 - W2}{W2} \times 100 \quad (1)$$

2.3.4 Determination of Soil Porosity

The total porosity of the soil in the 0– 15 cm and 15–30 cm layers were calculated from the values of the dry bulk density and an assumed particle density of 2.65 Mg m^{-3} using the following Equation (Chancellor, 1994). The result was multiplied by 100:

$$\text{Soil porosity} = \left(1 - \frac{\ell b}{\ell p}\right) \times 100 \quad (2)$$

Where; ℓb = bulk density; ℓp = Particle density

2.3.5 Data Analysis

Statistical data analyses were performed on all data collected using the Balanced Analysis of Variance (ANOVA) Model of SPSS Software using the Duncan Multiple Range Test (DMRT). The mean values of dry bulk density, moisture content and porosity were compared on treatment basis using the least significant difference test at $p<0.05$.

3. Results and Discussion

3.1 *Soil Texture*

The result in Table 1 showed that sandy loam was dominant textural class across various tillage depth (0-15 cm and 15-30 cm) ;silt ranges from 46.83% -51.17%, sand ranges from 45.16% - 47.35% while clay ranges from 3.68% - 5.83%. The soil at the five experimental plots was homogeneous with sandy loam texture at depth 0-15 cm and 15-30 cm. The soil textural class was determined using soil textural triangle.

3.2 *Bulk density*

The bulk density of a soil gives an indication of the soil's strength and thus resistance to tillage implements or plants as they penetrate the soil. Soils with higher proportion of pores to solids have lower bulk densities than those that are compact and have fewer pores (Brady and Weil, 1999). The mean bulk density values of the various treatment plots are provided in Table 2. The plot with treatment, Hoe tillage (L), Harrow tillage (HT), Plough tillage (PL), No tillage (NT), and Plough plus Harrow tillage (PHT), have recorded bulk density values of 1.43, 1.19, 1.24, 1.71, and 1.23 Mg/M^3 respectively. From the result, it could be seen that the No-tillage (NT) have the maximum bulk density while the Harrow tillage (HT) plot have the minimum bulk density, this agree to the findings of (Aikins and Afuakwa, 2012). The result finding shows that there is no significant difference in the experiment base depth of 0-15 cm and 0-30 cm depth. Bulk densities in excess of $1.6 Mg/M^3$ can restrict root growth and result in low levels of water movement into and within the soil (Smith, 1988).

Table 1: Means of soil textural class at different tillage depths and tillage operations

Treatment	% Silt	% Sand	% Clay	Soil texture
Depth				
0-15 cm	51.17^a	45.16^b	3.68^b	Sandy loam
15-30 cm	46.83^b	47.35^a	5.83^a	Sandy loam
Tillage				
No Tillage	11.83^e	81.55^a	6.64^a	Sandy loam
Hoe	19.39_d	74.49_b	6.13^{ab}	Sandy loam
Plough	78.03^a	20.43^d	1.55^d	Sandy loam
Harrow	66.61^c	27.58^c	5.81^b	Sandy loam
Plough and Harrow	69.13^b	27.24^c	3.67^c	Sandy loam
D*T	*	*	*	

*- significant. Means with same letter (s) in a column are not significantly different at 5 % level of probability by DMRT

TABLE 2: Means of bulk density, moisture content, and soil porosity as affected by tillage operations

Treatment	Moisture content	Bulk Density (mg/m3	Soil porosity
Depth			
0-15 cm	8.63^b	1.34^b	38.48^b
15-30 cm	8.69^a	1.39^a	41.43^a

Tillage			
No Tillage	8.09[c]	1.71[a]	25.18[e]
Hoe	9.10[a]	1.43[b]	29.47[d]
Plough	8.96[b]	1.24[c]	40.81[c]
Harrow	8.19[c]	1.19[d]	47.81[b]
Plough and Harrow	8.97[b]	1.23[c]	56.51[a]
D*T	*	Ns	Ns

ns - Not significant; *- significant. Means with same letter (s) in a column are not significantly different at 5 % level of probability by DMRT

3.3 *Porosity*

Soil porosity and organic matter content play a critical role in the biological productivity and hydrology of agricultural soils. Pores are of different sizes, shapes and continuity and these characteristics influence the infiltration, storage and drainage of water, the movement and distribution of gases and the ease of penetration of soil by growing roots (Kay and VandenBygaart, 2002). Soil porosity result is presented in Table 2. No-tillage (NT) plots recorded a significant lower porosity level (25.18%) compared to other treatments. The effect of different tillage depth of soil is presented in Table 2. Soil porosity across tillage depth are closely related as Pagliai and Vignozzi (2002) stated that, soil porosity characteristics are closely related to soil physical behavior, root penetration and water movement. Highest soil porosity was recorded at 15-30 cm tillage depth for the period of the study as compared to other tillage depth; this is closely related with the report of Ahaneku and Dada (2013). This may be attributed to less pulverization of soil provided by later tillage depths. Porosity can be said to decrease with increase in soil depth due to the natural increase in packing density with depth. Overall, in 15-30 cm produced the highest total porosity, while No-tillage (NT) gave the lowest porosity level, this result is closely related with that recorded by Aikins and Afuakwa (2012) who stated that overall, in both the 0-15 cm and 15-30 cm soil layers, the disc plough plus disc harrow followed by disc harrow treatment produced the highest total porosity while the No-tillage gave the lowest total porosity.

3.4 *Moisture content*

Soil moisture is the source of water for plant use in particular in rainfed agriculture (Mweso, 2003). Soil moisture is highly critical in ensuring good and uniform seed germination and seedling emergence (Arsyid *et al*., 2009), crop growth and yield. Different tillage depth significantly affected soil moisture during the study. The highest soil moisture content (9.78 %) was obtained from tillage depth 15-30 cm and the lowest moisture content was from No-tillage (NT) as showed in Table 3. Result shows that No- tillage (NT) have the lowest moisture content compared to other tillage depth. The value of moisture content associated with No- tillage is due to decrease pore space, increase shear strength and stable aggregates. The result obtained was almost in line with what was presented by (Mitchell *et al.,* 2007). Another reason attributed to low moisture content with No-tillage (NT) soil is the level of compaction known with the conserved soil. The result obtained correlate with the findings of (Cambell *et al.,* 1974) that No-tillage gives lower moisture content.

Table 3: Means of soil texture and moisture content at different tillage depth and tillage operations.

Depth (cm)	Tillage	% Silt	% Sand	% Clay	Moisture content
0-15	No tillage	12.41^{i}	82.40^{a}	5.24^{c}	8.28^{f}
15-30	No tillage	11.26^{j}	80.70^{b}	8.05^{a}	7.89^{g}
0-15	Hoe	19.97^{g}	76.15^{c}	3.88^{d}	8.43^{ef}
15-30	Hoe	18.80^{h}	72.82^{d}	8.38^{a}	9.78^{a}
0-15	Plough	75.20^{c}	24.50^{g}	0.30^{f}	9.40^{b}
15-30	Plough	80.85^{a}	16.36^{j}	2.79^{e}	8.52^{e}
0-15	Harrow	70.80^{d}	22.50^{h}	6.70^{b}	7.80^{g}
15-30	Harrow	62.43^{e}	32.65^{f}	4.93^{c}	8.58^{de}
0-15	Plough and Harrow	77.45^{b}	20.25^{i}	2.30^{e}	9.23^{c}
15-30	Plough and Harrow	60.80^{f}	34.22^{e}	5.03^{c}	8.71^{d}

Means with same letter (s) in a column are not significantly different at 5 % level of probability by DMRT

4. Conclusions

The effects of tillage practices on some physical properties of soil were studied. Results revealed that the soil textural class of different tillage depth was dominated by the sandy loamy. Result obtained shows that tillage depth of 0-15 cm gives the most favorable soil physical properties. The No tillage system does not sufficiently improved soil physical properties required for optimum crop growth and yield. The most favorable soil physical properties (the lowest bulk density and highest total porosity) were recorded under conventional tillage system (Harrow followed by Plough) while a moderate change in soil physical properties was under reduced tillage system (Plough or Harrow only). Result shows that Plough and Harrow tillage system gave the highest total porosity. Also, Hoe tillage (15-30cm) recorded the highest amount of soil moisture content while Harrow tillage (0-15cm) recorded the lowest amount of soil moisture content. The result findings shows that every tillage operation involved had effect on the soil physical properties but Plough and Harrow tillage operation was found to be more appropriate in improving the soil physical properties

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ASSESSMENT OF ECONOMIC VIABILITY FOR *JOJOBA* SEED BIODIESEL PRODUCTION IN NORTH CENTRAL NIGERIA

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Abstract

This study determined biodiesel demand for Nigeria for 2008-2025, analyzed the project scope for Jojoba biodiesel production, and assessed the economic viability for jojoba biodiesel production.
Secondary data were used for the study. The study area was some states in Nigeria's North Central geo-political zone comprising Niger, Kogi, Nasarawa States and the Federal Capital Territory (FCT). National diesel consumption data from 2008 to 2018 were obtained from the Nigerian National Petroleum Corporation (NNPC), and the data was projected to 2025. The process variables for jojoba production in the selected States and FCT like jojoba crop feedstock, landmass, water, and infrastructure availability were obtained from reports of the Federal Ministry of Agriculture and Rural Development, Federal Capital Development Authority (FCDA), the Federal Ministry of Industry, Trade and Investment; as well as the Ministries of Agriculture, Industry and Commerce in each of the three selected States. Further secondary data such as industrial process conversion factors for feedstock demand, water and landmass requirements, and CO_2 emissions savings were elicited from the International Energy Agency (IEA). The data obtained were analysed using industrial process calculations and CO_2 emissions. The economic variables obtained included biodiesel production capital and operations costs, interest rates, and project time duration amongst others. The data obtained were analysed using life cycle costs and engineering economy analyses. The result showed diesel demand projections in Nigeria to be 4.75 – 5.79 billion litres from 2017 to 2025 with total diesel consumption projections of 47.3 billion litres. Biodiesel demand projections were 949.92 – 1158.11 million litres with total projections of 9.46 billion litres. Jojoba oil projections were 1.19 – 1.78 billion litres from 2017 to 2035, with total projections of 28.14 billion litres. Jojoba seeds projections were 1.88 – 2.82 billion kg over the timeframe, with total projections of 44.46 billion kg of seeds. Water requirement projections for jojoba cultivation were 2.09 to 3.14 trillion litres/year, with total projections of 49.52 trillion litres over the timeframe. Landmass projections were 6531.34 – 9809.73 sq. km over the timeframe, with total projections of 154,795 sq. km. The landmass projections were estimated to be 2.69 – 4.05% of North Central Nigeria's total landmass of 242,425 km^2. Jojoba biodiesel production total operating costs were estimated to be ₦8,226.26 per litre.
The study concluded that technically, based on the current price of diesel, Jojoba biodiesel substitution may not be recommended for implementation due to high level price deficit though it can find useful application in the Cosmetic and Pharmaceutical industries.

Keywords: Biodiesel Demand, *Jojoba* Seed, economic viability, agro-energy, feedstock, Oil Yield.

1. Introduction

Energy assumes a fundamental role in the political, monetary and social advancement of any country. The sufficient, reliable and affordable supply of energy is critical to economic activities in this day and age – including manufacturing and industrial processes, transportation, correspondence, agribusiness and food production, power supply, housing, education and total well-being (da Silva *et al*., 2009). In this manner, energy is the backbone of present day progress, and energy utilization per capita is a major indicator for estimating the way of life of a general public. Contrarily, the insufficient, untrustworthy and unaffordable supply of energy diminishes present day social orders, constraining monetary yield and antagonistically influencing the general public's way of life. Energy assumes a fundamental role in national techno-economic advancement, and a country's stature in the comity of nations is directly related to its ability to acquire and control a robust energy base for its industrial and power projections.

Globally, energy resources are categorized into two forms – non-renewable energy sources (coal, petroleum and gas) and renewable energy sources (biomass, hydro, solar, wind, sea wave and tides, and geothermal power). Renewable energy resources are so called because they can be readily replenished by nature. Energy development has greatly benefited from the global village status of the world because shift in major sources of energy from wood to coal to petroleum to complex renewable energy interventions has enjoyed an un-parallel shift in human history. Since the global energy crises of the 1970s, the focus in energy thinking has shifted towards energy conservation, national energy security; environmental considerations on fossil fuel production and consumption, and affordable/adequate energy provision (Spalding-Fecher *et al*., 2005).

Fossil fuels make up approximately 92 per cent of the total business electricity consumed in Nigeria and are the only energy source for the transport industry (CBN, 2015) with total of 4.75 billion liters of diesel consumed in 2017 (NBS, 2018). With a population of over 198 million individuals increasing at an average rate of 2.7 percent per year and an economic growth rate of 2.1 percent in 2018, the market for refined petroleum products in Nigeria has so far been established, expanding and sustainable. Like other responsible nations in the world, Nigeria identifies the environmental and energy security implications of fossil fuel / transport fuel consumption (Agba *et al*., 2010). The government consequently launched the Biofuel Policy which called for 20% biodiesel substitution in gasoline (Automotive Gas Oil or AGO) (NNPC, 2007). The country's prevalent thinking presupposes that renewable energy, especially biofuels, can improve fuel supply, decrease demand on oil reserves, and help mitigate ecological issues (Agba *et al*., 2010). The execution method of biofuel policy (NNPC, 2007), however, has not been sufficiently mandated by two main Government Energy Agencies (the Nigerian Energy Commission (ECN) and the Nigeria National Petroleum Corporation (NNPC)) (Ogundari, 2014). One critical factor is the constraints to guide the execution of the biofuel policy in the project planning premises. Acceptable feedstock must be explored for the implementation of biofuel policy as non-edible crops are deemed more suitable than food crops with regard to food vs. fuel concerns (Ogundari *et al*., 2012). An interest in development of *Jojoba* as an appropriate biofuel feedstock has been expressed by the Federal Ministry of Agriculture. The rejuvenation of the National Biofuel Program (2007) inculcates integrated non-edible crop biofuel production and rural development programmes. Studies on the cultivation of non-edible crops for biofuels in Nigeria are severely restricted and there is no project planning assessment of the development of jojoba crops for biodiesel, hence this study. The study provides the project specifics for *Jojoba crop* biodiesel production. This data is critical to the successful implementation of Nigeria's biofuel policy. The study determined biodiesel demand estimations for Nigeria till 2025, analyzed the project definitions specifications for biodiesel production and assessed rural development benefits and project economics of sustainable biodiesel production in North Central Nigeria as input to National biofuel policy review and sustainable rural development.

2. Materials and Methods

2.1 *Study Area and Population*

The study was carried out in the North Central geopolitical zone of Nigeria, covering about 242, 425 km^2 comprising six States (Kwara, Kogi, Benue, Niger, Nassarawa, and Plateau) and the Federal Capital Territory (FCT). The area has an estimated population of about 25.4 million people, and forms one of the major agricultural zones of the country with farming as its major occupation. The study was limited to Kogi, Nassarawa, and Niger States as well as the Federal Capital Territory (FCT), due to ongoing integrated agriculture, non-edible crop biofuel production and rural development initiatives.

Institutions sampled in the study area included the Federal Ministry of Agriculture and Rural Development, the Federal Capital Development Authority (FCDA), the Federal Ministry of Industry, Trade and Investment; the Nigerian National Petroleum Corporation (NNPC); and the Ministries of Agriculture, Industry and Commerce in each of the three selected States. Furthermore, two Research Institutes and three Universities in the study area were purposively selected in recognition of their expertise in bioenergy/biotechnology and agricultural/rural development research. These were the National Research Institute for Chemical Technology (NARICT), Zaria, the Federal University of Technology (FUT), Minna, Nassarawa State University, Lafia, Kogi State University, Ayingba, and the National Biotechnology Development Agency (NABDA), Abuja.

2.2 *Methods of Data Collection*

Data for the study were obtained through primary and secondary sources. Secondary data were obtained from the official documents of the Federal Ministry of Agriculture and Rural Development, the Federal Capital Development Authority (FCDA), the Federal Ministry of Industry, Trade and Investment; the Nigerian National Petroleum Corporation (NNPC); and the Ministries of Agriculture, Industry and Commerce in each of the three selected States. Data obtained included land availability for crop cultivation, feedstock availability, investment profiles, and infrastructure provision.

Primary data were obtained using two sets of questionnaires and interview schedules. One set of questionnaire was administered to the Ministries, Departments and Agencies (MDAs) previously mentioned. The data obtained included technical and economic specifications like national diesel consumption, *jojoba* crop feedstock availability in the study areas, landmass and water availability, and infrastructure availability, as well as capital investment parameters like cost of land, labour and utilities. Information on the project scope and economic parameters for biodiesel production were obtained from the two Research Institutes and three Universities previously stated. The information obtained included industrial process conversion factors for parameters such as feedstock demand, water and landmass requirements for feedstock cultivation, and CO_2 emissions savings. Project economics data obtained included biodiesel production capital and operations costs, interest rates, and project time duration.

2.3 Questionnaire Design and Administration

One questionnaire set was designed and administered on purposively selected technical experts in the focus firms and government institutions. The questionnaire elicited information on factors such as availability of raw materials, labour, power, utility services and transport facilities, waste disposal facilities, and proximity to markets; rating regional industrial chemicals production capabilities; as well as rating the technological constraints to sustainable industrial chemicals production development in Nigeria.

2.4 Study Variables and Measurements

The different variables analysed in the study and the means by which these variables were measured. One set of structured questionnaire and database/publications searches were employed to address the study objectives.

Variables for the determination of biodiesel demand up to 2025 in Nigeria

The identified variables were:

i. National diesel demand as at 2017 (measured in thousand tonnes).
ii. Biodiesel percentage policy directive in national diesel consumption (Measured in percentages)
iii. Time (Measured in Years)

Variables for the analysis of project scope definitions for Jojoba crop biodiesel production

The variables for this analysis were:

i. Feedstock and oil (measured in tonnes)
ii. Landmass requirements (measured in Sq. Km),
iii. CO_2 capture and sequestration (measured in tonnes),
iv. Water utilization (measured in litres)
v. Critical technological issues related to sustainable biodiesel production including technological constraints to biofuel industry development (measured in percentages); and the 'food vs fuel' concern, analysed by comparing landmass utilization for fuel to national total, arable, and cultivatable land (measured in percentages).

Variables for assessing the project economics of biodiesel production and its rural development benefits

i. The variables for assessing the project economics were:
ii. Fixed and variable costs for biodiesel production (measured in Naira),
iii. Item replacement time (Measured in Years)
iv. Interest rates and Discounting factors (Measured in %)
v. Selling price of diesel (measured in N/litre), and
vi. Poverty reduction potential (measured by number of potential jobs that can be created)

2.5 Data Analysis

The data obtained were analysed using energy planning analysis, industrial process calculations, life cycle cost analysis, and descriptive statistics.

The data collected were analysed using different analytical methods:

i. Energy planning analysis to determine diesel demand and biodiesel substitution by 2025 and subsequently up to 2035;

ii. Industrial process calculations to determine input raw materials

iii. Net present value to assess the process economics and cost evaluation of jojoba biodiesel production and determine capital, operational and production costs per tonne.

3. Results

3.1 *Biodiesel Demand Estimates for Nigeria till 2025*

Table 1 presents the estimations for biodiesel demand in Nigeria from 2017 to a projected future being Year 2025. From this table we see that diesel consumption over the years is directly related to population growth by a diesel consumption/capita ratio of 24.88 litre/capita. The table revealed estimated diesel consumption of 4.75 – 5.79 billion litres from 2017 to 2025, and total diesel consumption of 47.3 billion litres over the period. This consumption pattern is of grave concern to Nigeria and of a necessity raises strategic considerations. The Nigerian State is unable to adequately refine national crude oil production, and is dependent on foreign oil refineries for its domestic petroleum product needs. Nigeria is reported to import 70% of its petroleum products annually (Adeosun and Oluleye, 2017).

Needing to import about 70% of the 47.3 billion litres of diesel (33.11 billion litres of diesel) over the 9-year period from 2017 to 2025 thus constitutes a huge national security risk.

Table 1: Biodiesel Demand Estimates for Nigeria till 2025

Year	Population	Diesel Consumption/Capita (Litre/capita)	Diesel Consumption (Million Litres)	Biodiesel Demand (Million Litres)
2017	190,900,000	24.88	4,749.59	949.92
2018	195,700,000	24.88	4,869.41	973.88
2019	200,600,000	24.88	4,991.33	998.27
2020	205,615,000	24.88	5,116.11	1,023.22
2021	210,800,000	24.88	5,245.13	1,049.03
2022	216,070,000	24.88	5,376.25	1,075.25
2023	221,500,000	24.88	5,511.36	1,102.27
2024	227,040,000	24.88	5,649.21	1,129.84
2025	232,720,000	24.88	5,790.54	1,158.11
	TOTAL		47,298.93	9,459.79

In line with the biofuel policy guidelines of 20% biodiesel substitution in diesel consumption, Table 1 also presents biodiesel demand estimates and projections from 2017 to 2025. The results were 949.92 – 1158.11 million litres of biodiesel demand over the 9-year timeframe. Estimated total demand over the period was 9.46 billion litres.

3.2 *Technological Inputs to Jojoba Biodiesel Production*

It was shown in Table 2 that the jojoba oil and seeds requirements for the production of jojoba biodiesel in North Central Nigeria. The Table 2 also showed the landmass required to grow the required jojoba seeds. Jojoba oil requirements were estimated to be from 1.19 billion litres in 2017 to 1.78 billion litres in 2035. This gives a total of 28.14 billion litres of jojoba oil required for the estimated biodiesel production requirements from 2017 to 2035 (i.e. 22.5 billion litres of biodiesel). Moreover, from Table 2, it was deduced that the jojoba seeds required to produce this amount of oil is in the range of 1.88 – 2.82 billion kg of seeds for the study period (a total of 44.46 billion kg of seed). These seeds would require between 6531.34 and 9809.73 sq. km of land over the study period, and require total landmass of 154,795 sq. km over the study timeframe.

In Table 3, it was revealed that other technological inputs to jojoba biodiesel production. The jojoba seeds would require 1.19 – 1.78 billion trees for cultivation. Over the study time frame, an estimated 28.13 billion trees would have to be grown. The total amount of water required for the cultivation of the jojoba crop would be 2.09 to 3.14 trillion litres/year, giving a total of 49.52 trillion litres of water required over the entire time frame (Table 3).

3.3 *Landmass Requirements as a Percentage of the Landmass of North Central Nigeria*

The Jojoba crop cultivation landmass requirements as a percentage of total landmass of Nigeria's North Central region was as presented in Table 4. This amounted to 2.69 – 4.05 percentage of the North Central geopolitical zone's total landmass of about 242,425 km^2 (Table 4). These statistics are strategic as it provide reliable evidence that jojoba crop as a feedstock option for biodiesel production in the region would not create food or land security concerns.

Table 2: Jojoba Oil, Jojoba Seeds and Jojoba Seeds Landmass Requirements for Jojoba Biodiesel Production in North Central Nigeria

Year	Diesel Consumption (Billion Litres)	Biodiesel Demand (Million Litres)	Jojoba Oil demand (Million Litres)	Jojoba seed requirements (Billion kg)	Landmass requirements (hectares)	land mass (Sq Km)
2017	4.75	949.92	1,187.40	1.88	653,134.2	6531.34
2018	4.87	973.88	1,217.35	1.92	669,610.5	6696.11
2019	4.99	998.27	1,247.83	1.97	686,376.4	6863.76
2020	5.12	1,023.22	1,279.03	2.02	703,535.8	7035.36
2021	5.25	1,049.03	1,311.28	2.08	721,276.9	7212.77
2022	5.38	1,075.25	1,344.06	2.12	739,308.8	7393.09
2023	5.51	1,102.27	1,377.84	2.18	757,888.2	7578.88
2024	5.65	1,129.84	1,412.30	2.23	776,844.0	7768.44
2025	5.79	1,158.11	1,447.64	2.29	796,278.7	7962.79
2026	5.92	1,184.01	1,480.01	2.34	814,088.3	8140.88
2027	6.06	1,210.98	1,513.72	2.39	832,631.0	8326.31
2028	6.19	1,237.95	1,547.43	2.45	851,173.7	8511.74
2029	6.32	1,264.92	1,581.14	2.50	869,716.4	8697.17

2030	6.46	1,291.88	1,614.86	2.55	888,259.1	8882.59
2031	6.59	1,318.85	1,648.57	2.61	906,801.9	9068.02
2032	6.73	1,345.82	1,682.28	2.66	925,344.6	9253.45
2033	6.86	1,372.79	1,715.99	2.71	943,887.3	9438.87
2034	7.00	1,399.76	1,749.70	2.77	962,430.0	9624.30
2035	7.13	1,426.73	1,783.41	2.82	980,972.8	9809.73
			28,140.00	44.46	15,479,559.0	154,795.00

Table 3: Jojoba Trees Requirements, Water Needs to Grow the Trees, and CO_2 Emissions Mitigation for Jojoba Biodiesel Production in North Central Nigeria

	Biodiesel substitution (Million Litres)	CO_2 emissions mitigation (Billion kg)	Jojoba seed requirement (Billion kg)	Trees (Billion)	Water requirement (Trillion Litres/Year)	Landmass (Sq. km)
2017	949.92	2.55	1.88	1.19	2.09	6531.34
2018	973.88	2.61	1.92	1.22	2.14	6696.11
2019	998.27	2.68	1.97	1.23	2.20	6863.76
2020	1,023.22	2.74	2.02	1.28	2.25	7035.36
2021	1,049.03	2.81	2.08	1.31	2.31	7212.77
2022	1,075.25	2.88	2.12	1.34	2.37	7393.01
2023	1,102.27	2.95	2.18	1.38	2.42	7578.88
2024	1,129.84	3.03	2.23	1.41	2.49	7768.44
2025	1,158.11	3.10	2.29	1.45	2.55	7976.79
2026	1,184.01	3.17	2.34	1.48	2.60	8140.88
2027	1,210.98	3.25	2.39	1.51	2.66	8326.31
2028	1,237.95	3.32	2.45	1.55	2.72	8511.74
2029	1,264.92	3.39	2.50	1.58	2.78	8697.17
2030	1,291.88	3.46	2.55	1.61	2.84	8882.59
2031	1,318.85	3.54	2.61	1.65	2.90	9068.02
2032	1,345.82	3.61	2.66	1.68	2.96	9253.45
2033	1,372.79	3.68	2.71	1.72	3.02	9438.87
2034	1,399.76	3.75	2.77	1.75	3.08	9624.30
2035	1,426.73	3.82	2.82	1.78	3.14	9809.73
				28.13	49.52	154,795.00

Table 4: Jojoba Seeds Landmass Requirements and Corresponding percentage of the Landmass of North Central Nigeria

	Landmass (Sq. Km)	Percentage of the Landmass of North Central Nigeria
2017	6531.32	2.69
2018	6696.11	2.76
2019	6863.76	2.83
2020	7035.36	2.90
2021	7212.77	2.98
2022	7393.09	3.05
2023	7578.88	3.12
2024	7768.44	3.20
2025	7962.79	3.28
2026	8140.88	3.39
2027	8326.31	3.44
2028	8511.74	3.51
2029	8697.16	3.59
2030	8882.59	3.66
2031	9068.02	3.74
2032	9253.45	3.82
2033	9438.87	3.89
2034	9624.30	3.97
2035	9809.73	4.05

The results also indicate that the North Central region could be a biodiesel production powerhouse, with the potential to be a major player in the global biofuel industry.

3.4 Engineering Economic Analysis of Jojoba Biodiesel Production

Table 5 presents estimated costs for the production of *jojoba* biodiesel in the North Central region of Nigeria. Capital Investment costs were estimated to be ₦16 per litre of jojoba biodiesel production, while total operating costs were determined to be ₦8226.26 per litre. With the current price of diesel being ₦250 per litre, the study determined a price deficit of almost ₦8,000 per litre and established that the production of biodiesel from jojoba oil would not be viable.

3.5 Discussion

It is critical to note that Nigeria does not currently have a domestic biodiesel industry, and national biodiesel production is zero. It is imperative for the country to develop this industry for its energy security as well as employment generation capabilities. Furthermore, the results which show increased demand for diesel and increased potentials for biodiesel production are consistent with demand projections for countries in the Far East, Sweden and the United States (IEO, 2010). The estimates for diesel and biodiesel demand are consistent with the results determined by Ogundari (2014) even though a different methodology was used for determination. It is important to note that Nigeria has no official figures for petroleum products consumption, and government policy and planning are based on guess estimates (Adenikinju, 2018).

Total diesel consumption projections for Nigeria provide other strategic concerns for the country – the huge consumption projections have implications for Nigeria's carbon footprint and Green House Gas emissions. With estimated diesel consumption of 112.57 billion litres from 2017 to 2035, and at the conversion factor of 2.63 kg of CO_2 produced per litre of diesel consumed (Dale *et al.*, 2010), Nigeria would be emitting a massive 295.88 million tonnes of CO_2 over the study time. This could have significant implications for the nation's environment and health considerations.

Table 5: Engineering Economic Analysis of Jojoba Biodiesel Production

Fixed Investments	Naira/Litre
Machinery	12.64
Buildings/land	3.36
Total Investment	16.00
Operation Costs/Litre	Naira/Litre
Feedstock (jojoba oil)	3697.01
Labour	132.29
Chemicals, enzymes, yeast	253.86
Electricity	2464.67
Steam	500.33
Water (fresh)	23
Wastewater treatment	9.86
Labour cost (transportation)	200.46
Diesel cost (transportation)	63.26
Maintenance (building & machinery)	584.95
Various costs e.g. insurance	296.68
Total Operating Costs	8226.26

Total Cost of Production (Net Operation Costs + Total Investments)/Recovery Price for Biodiesel	8242.26
Current Selling Price of Diesel	250
Deficit (Selling Price – Production Cost)	7992.26

Source: Ogundari (2014)

Also, this diesel consumption would cost an estimated N 28.14 trillion at current prices of N 250 per litre.

The total volume of diesel substitution with biodiesel over the study period (22.5 billion litres) is huge and although has exceeded available national projections (Ogundari, 2014), they are consistent with the projections by Ogundari (2014). The huge biodiesel demands serve as a good incentive for the development of the national biodiesel industry. The feedstock jojoba seed and jojoba oil estimates were unique and unprecedented. The growth of these total jojoba seeds would require 154,795 sq. km of land. It is important to note that this huge jojoba oil output would require less than 5% of North Central Nigeria's landmass. These figures enable policy makers at the state and federal governments understand that jojoba oil and seeds cultivation should not have any negative implications for food or business usage of land in the area. China, one of the world's leading biofuel production country, requires an estimated 350 to 760 Thousand Sq.Km. of land (about 3.66% of China's total landmass) to meet its biofuel demands (GSI, 2008). Brazil used 36 Thousand Sq.Km (1% of total arable land) while the US used 100 Thousand Sq.Km (3.7% of total arable land).

The largest by-product of the combustion of fossil fuel and the second most abundant, globally warmed, greenhouse gas is carbon dioxide (CO_2). Cardiovascular deaths, improving the air condition, and fast and extensive circulation of deadly infectious diseases, including malaria, dengue and yellow fever, constitute environmental concerns and issues related to CO_2 (World Bank, 2008). Biodiesel substitution in diesel consumption is expected to reduce CO_2 emissions and limit these environmental and health concerns (Ogundari *et al*., 2012). It is pertinent to note that Nigeria's CO_2 emissions savings were not included in the National Biofuel document prior to publication (Ogundari, 2014).

The water demand for the cultivation of the jojoba seed is very large and has serious implications for policy. The water requirement for the national biofuel initiative had not been determined prior to the gazetting of the National Biofuel Policy (NNPC, 2007) hence no policy strategies were developed for the provision and management of suitable crop water. This is a serious lapse in policy planning and would likely have negative implications on national water resources planning and the provision of irrigation projects in the North Central region. Furthermore, the non-availability of a robust water resources planning framework could negatively impact on other development areas like manufacturing, energy, food, health and environmental initiatives in Nigeria (Ali, 2013).

The recovery cost for jojoba biodiesel production as determined by the study would have to be ₦8242.26 per litre. This is not feasible in Nigeria today. Consequently jojoba crop is not an economically viable option for biodiesel production in the country. The production of jojoba oil however could still be viable if hit could be used for other means. The international cosmetics industry has found the use for this oil as a critical input to beauty products. Interestingly, jojoba oil sells for an estimated ₦20,000.00 per litre as a beauty-product input. This study has shown that the Nigeria's North Central region has the technological capacity to produce a substantial amount of jojoba crop for the production of oil. The use of this oil can be shifted from the energy sector to the cosmetics industry.

4. Conclusion and Recommendation

The study provided general project planning parameters for biofuel production in the North Central (NC), Nigeria. It also revealed the positive environmental effect of biofuel production adoption in the region. One of the recognised global challenges of biofuel production is the debate over national agricultural landmass diversion for biofuel utilisation. This study helps provide a critical policy perspective to this debate. In the NC, Nigeria, total landmass is 242,425 Sq. Km., arable landmass in the same region is 90,497.25 Sq. Km., while actual cultivated landmass is 38,008.85 Sq. Km. From the study, it can be seen that total land requirement for production at the highest point of demand (High demand scenario at 20% substitution level in year 2017 to 2025 and extended to 2035) requires only 6,531.32 Sq. Km, 7,962.79 Sq. Km, and extended to 9,809.73 Sq. Km of land in 2017, 2025 and 2035 respectively. This is far less than 3.0%, 3.50% and 4.50% of total landmass available for farming in NC, Nigeria respectively.

The cost of industrial-scale Jojoba oil production using Jojoba feedstock is estimated to be $22.90/litre (₦8,242.26/litre). At the current official domestic diesel price of US$0.69/litre (₦250/litre), a deficit of US$22.2/litre (₦7992.26litre) would occur.

This study therefore concludes that the production of biodiesel from Jojoba feedstock is technically not feasible but economically viable with respect to the focus of this study. From the findings of this study, although Jojoba oil for biodiesel substitution may not be recommended for implementation due to high level price deficit, the oil however found useful application in the Cosmetic and Pharmaceutical industries as the price of a litre of Jojoba oil cost $55.56/litre (₦20,000.00/litre) in Nigeria local market leaving a high level marginal profit of $32.66/litre (₦11,757.74/litre). This outcome is an essential component of this study. Consequently, this option would find application in the long awaiting stimulation of agricultural sector for job creation indirectly in the cosmetic and pharmaceutical industries in the country thus creating an economic potential for Jojoba oil production.

The study provides general planning premises for biofuel production in the country. More detailed techno-economic assessments need to be carried out systematically over time so as to fine-tune the forecasts. The study also focused on only a few universities & research institutes with recognised expertise on bio-energy related R&D. The study could be extended to all the universities and research institutes in the country so as to have a clearer picture on national R&D capabilities in the bioenergy sector.

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FAILURE ASSESSMENT OF SOME SELECTED TILLAGE IMPLEMENTS IN BAUCHI, NIGERIA

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Abstract
This study was carried out to assess the failure of disc plough, disc harrow and mouldboard plough in Bauchi metropolis. In order to achieve this, fifty five (55) target operators were identified and twenty six (26; 47.27 %) were used as the sample population. A structured questionnaire was designed and administered. Data obtained were analyses using descriptive statistics. Selected implements' component failure and causes were investigated. The results show that disc harrow has the highest frequency of components failure with 81 (49.39 %) followed by disc plough and mouldboard with 74 (45.12 %) and 9 (5.49 %) frequency of components failure, respectively. The results further revealed that shaft, bearing, bolt and share are the components that failure occurs most. It was also observed from the results of the study that poor land clearing and poor routine maintenance are most causes of the implement failure.

Keywords: tillage, implements, failure assessment, mouldboard plough, disc plough, disc harrow.

1. Introduction

Tillage operation is an agricultural preparation of the soil by mechanical agitation of various types to provide most effective condition for crop production (John *et al*., 2016). Tillage operations could either be primary or secondary. Primary tillage constitutes the initial major soil working operation which is normally performed to reduce soil strength, cover plant materials and rearrange aggregates. Secondary tillage operations are lighter and finer operations following primary tillage, performed on the soil to create proper soil tilth for seeding and planting (Sahay, 2006). This is achieved through the use of tillage implement (John *et al*., 2016). A tillage implement consists of a single tool or a group of tools, together with the associated frame, wheels, hitch, control and protection devices, and any power transmission components (Hills**,** 2000). Tillage implements use for primary and secondary tillage operations are called primary and secondary tillage implement, respectively. During soil engagement these implements are expected to perform their task optimally without failure under desirable conditions.

However, implement failure occurs when it experiences a stress that exceeds its strength while performing its task (Viswanadham and Singh, 1998). The causes of failure are many. It could be due to manufacturing defects, unsuitable choice of implement to match certain conditions, poor routine maintenance among other factors. (*Pontius*, 2019; Viswanadham and Singh, 1998). According to Smith (2011) failure is defined as non-conformance to some defined performance requirements while Rausand and Hoyland, (2004) defines failure as the termination of the ability of an item to perform a required function. Failure of tillage implements introduces delay in operation due to time of repair, increase in operational cost and generally affects production costs. Hence, the need to investigate the causes of implements failure in order to prevent its unnecessary occurrence.

Therefore this study aimed to assess the failure of disc plough, disc harrow and mouldboard plough and make recommendation to reduce consequences that arises due to their failure to enhance overall production benefits.

2. Materials and Methods

2.1 Materials

The material used for this study is structured questionnaire together with verbal interview and personal observations.

2.2 Study Area

The study was conducted in Bauchi metropolis of Bauchi state of Nigeria. The map of the study area is as shown in Figure 1.

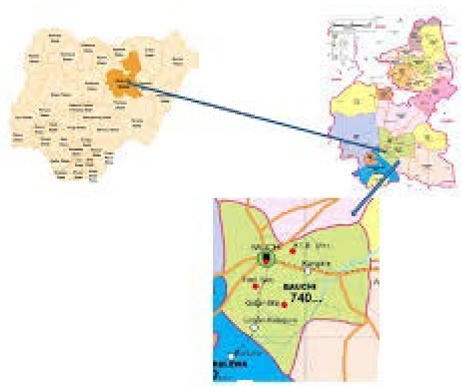

Figure 1: Map of the study area
Source: Bauchi state Ministry of Land and Survey, 2015

2.3 Data Collection and Analysis

2.3.1 Data Collection

Fifty five (55) target operators were identified and twenty six (26; 47.27 %) were used as the sample population. Structured questionnaire was designed and used as the essential instrument for data collection. Information requested includes; availability of the selected implements, parts of the implements that fail most, possible causes of the failure etc. The questionnaires were administered and retrieved during scheduled visits to the respondents Verbal interview and personal observation were used to compliment questionnaires as means of data collection where the respondent cannot provide relevant information through the questionnaires.

2.3.2 Data Analysis

Generated data were arranged and grouped according to relevant study objectives in a simple frequency distribution table. Pareto diagrams were also generated.

3. Results and Discussion

3.1 Availability of the Selected Tillage Implements

Table 3.1 shows the results for the availability of the selected implements in the study area. It can be seen that the entire selected implements were found in the study area. However, disk harrow which a secondary tillage implement is mostly available for tillage operation as indicated by the highest frequency of 26 followed by disc plough and mouldboard plough which are primary tillage implements; with a frequency of 24 and 6, respectively.

Table 3.1: Availability of the selected implements

S/No	Implements	Frequency
1	Disc plough	24
2	Disc harrow	26
3	Mouldboard plough	6

Highest frequency of disc harrow indicates that it's the implement that is frequently used for tillage operations. This can be attributed to the fact that most farmers within the study area adopt minimum tillage (Eniolorunda, 2016). The frequent use of Disc plough over Mouldboard plough for primary tillage operation can be due to its ability to: penetrate into soil which is too hard and dry for working with a mouldboard plough, works well in sticky soil in which a mouldboard plough does not scour, be used in stony and stumpy soil without much breakage etc. (Dogra, 2019)

3.2 *Components Failure of the Implements*

Tables 3.2 and 3.3 show the frequency of failure for the components of disc plough and disc harrow. These are also illustrated in Appendix I. It can be observed from these tables that Bearing, bolt and Shaft are the components that have highest failure with a frequency of 48, 32 and 21, respectively. The frequent failure observed in bearing for the Disc Plough and Disc harrow could be due to excessive stress that the component is being subject to beyond its bearing capacity (Falau, *et al*., 2014). More so, it can be attributed to poor routine maintenance (lubrication and improper adjustment) (Radu, 2010) and indicated by the respondent in Table 3.5 that lubrication poor adjustment are some of the causes of implement component failure.

Table 3.2: Components failure for disc plough

S/No	Components failure	Frequency
1	Bearing breakage	23
2	Plough bolt breakage/worn	17
3	Disc edge damage	16
4	Bearing hub damage	13
5	Cracking/bending of scraper	5
	Total	74

The occurrence of bolt failure for the disc plough and disc harrow can be attributed to severe vibration when the implement had an impact with a non-compliant object such as stony surface or stump due to poor land clearing. It could also be due to lack locking mechanism. Machinery and implements that are subject to vibratory environments usually are equipped with some sort of locking mechanism. If the locking mechanism is not applied to during manufacture or replacement due to failure, further failure may occur (Roberts, n.d).

The incidence of shaft failure in Table 3.3 can be seen to have a frequency of 21. This can be attributed to excess stress that the component is subjected beyond it bearing capacity (overload) when the implement strikes against hard surface. Thus, when the shaft experience extreme overload, it twist and distort. Additionally, incessant bearing failure may keep the shaft away

Table 3.3: Components failure for disc harrow

S/No	Components failure	Frequency
1	Bearing breakage	25
2	Shaft bending	21
3	Bolt breakage/ Worn	15
4	Spacer breakage	11
5	Cracking/bending of scraper	9
	Total	81

from position and consequently causes shaft bent (Shaft Failure Mode, 2011). Disc edged damage has a frequency of 16. This damage could be as result of the implement working in non-workable field (field with poor moisture) or when ploughing on poorly cleaned land with presence of stones and stump.

Scraper is the component that fails the least for both the disc plough and disc harrow. According to Kaul and Egbo, (1985) as cited by Falalu, *et al*., (2014) failure of disc scrapers are mostly attributed to improper attachment.

Table 3.4 shows components failure for mouldboard plough. It can be observed from the table that the total frequency of failure for the entire components is 9. This is because mouldboard plough is not widely used in the study area as indicated by the respondent in Table 3.1. This could be attributed to the advantages of using other implement for minimum tillage as most farmers adopt minimum tillage within the study area (Eniolorunda, 2016).

Table 3.4: Components failure for mouldboard plough

S/No	Components failure	Frequency
1	Share blunting	4
2	Bolt breakage/worn	3
3	Coulter damage	2
	Total	9

However, share blunting is usually experience when using mouldboard similar to disc edge damage when using disc plough. Share blunting can be due to abrasive wear when the implement strikes hard soil particle or when tilling in stony field (Horvat *et al.,* 2008; Kumi, 2011)

3.3 Possible Causes of the Failure

Table 3.5 shows the possible causes of tillage implements failure as indicated by the respondent. It can be observed from the table that poor land clearing account for the highest frequency of 26; it usually subject the implements to stress beyond its design capacity when the implement strikes against non-compliant object such stump, stone etc. Consequently result to damage and failure.

Table 3.5: Causes of Tillage Implement Failure

S/No	Causes of failure	Frequency
1	Poor land clearing	26
2	Poor lubrication	19
3	poor implement selection	17
5	Traveling too fast	15
5	Poor adjustment	13
Total		90

Poor lubrication and adjustment are aspect of poor routine maintenance. Maintenance services are required in order to keep farm machine/implement in operable condition. Where this is not done at specified intervals as may be recommended by manufacturers or where unsatisfactory services are carried out, the risks involved include reduction in the life of the machine/implement, increase in frequency of failures, increased expenditure for owning or operating such a machine/implement.

poor implement selection could be attributed to adoption of minimum tillage by most farmers in the study area (Eniolorunda, 2016); in an attempt to reduce cost of tillage operations wrong tillage implement may be used. For instance in a situation where the field is too hard or dry which requires the use of sub-soiler or chisel plough before another primary implement is used disc plough or mouldboard plough is directly used thereby subjecting it to excessive stress beyond its designed capacity.

4. Conclusion and Recommendations

4.1 *Conclusion*

Failure assessment of disc plough, disc harrow and mouldboard plough was carried out in Bauchi metropolis. The results show that disc harrow has the highest components failure followed by disc plough and mouldboard. The results further revealed that shaft, bearing, bolt and share are the components that failure occurs most. It was also observed from the results of the study that poor land clearing, poor lubrication and wrong implement selection are most causes of the implement failure.

4.2 *Recommendations*

Observing the results from the information gathered it's hopeful that the following recommendations could reduce the frequency of failure when adhere to.

i. Machinery/implements owners and tractor operators should adhere to routine maintenance specifications as recommended by machinery/implements manufacturers.
ii. All stake holder concerned should make appropriate provision for personnel and quality spare parts for effective repair and maintenance when the need arises.
iii. There is the need for proper awareness through extension service to the farmer on tillage operation(s) required for particular crop after considering the field conditions.
iv. Effort should be made in selecting proper implement for certain task and matching the implement with the field conditions.
v. Similar studies should be extended to other locations in order to make general and most justifiable decisions.

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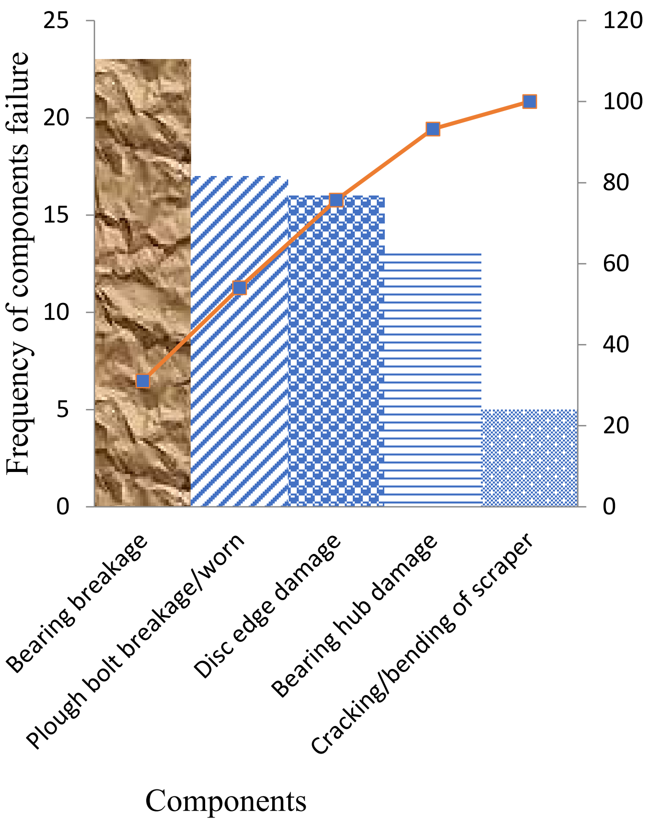

Figure 2: Pareto Chart Showing the Components Failure for Disc Plough

APPENDIX I

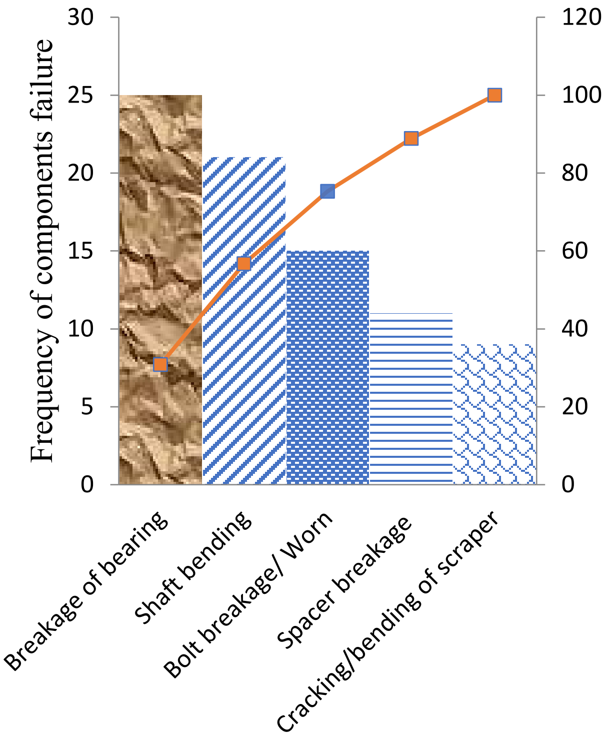

Figure 3: Pareto Chart Showing the Components Failure for Disc Harrow

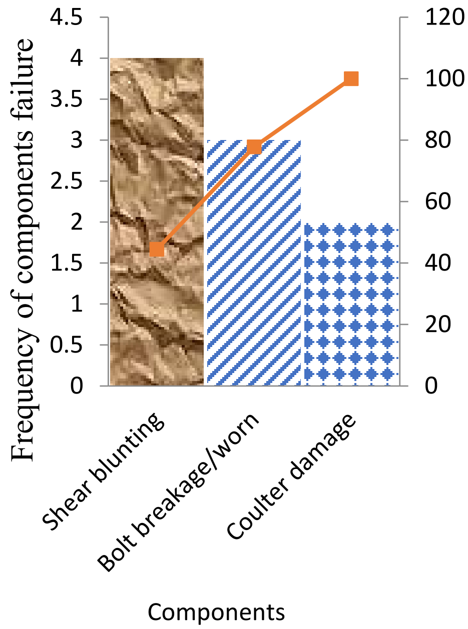

Figure 4: Pareto Chart Showing the Components Failure for Mouldboard Plough

PERFORMANCE RATE EVALUATION OF METERING SPEED AND HOPPER CAPACITIES OF A LOCALLY DEVELOPED SOYBEAN PLANTER

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Abstract

Soybean has tremendous potential to improving the nutritional status and welfare of resource-poor people particularly in a developing country of ours. Soybean can also contribute to providing useful residues for feeding livestock. This research was aimed at determining the effect of metering speed and hopper capacity on the working parameters of a soybean planter. The pre-design experimentation was carried out on TGX 1740-IF-Seed soybean (Glycine max) and the evaluation of the planter was carried out in the respect of the dependence of the application and discharge rates on metering speed and hopper capacities. The geometric mean diameter and cell diameter of 6.52 mm and 8 mm with groove depth 6 mm were recorded for the soybean grains. It was also revealed at all hopper capacities that the discharge and application rates had uniform trends which showed that the effect of hopper capacities is not significant ($P<0.05$). The effect of metering speed on these parameters is highly significant ($P<0.05$). The damage on the seeds was not significant at low speed of between 10 rpm and 45 rpm. However, at speeds greater than 45 rpm, significant and visible damages were observed on the seeds. The planter has seed damage efficiency of 98% at an optimum metering speed of 45 rpm. The field capacity of the planter is 0.28 ha/h with the average discharge and application rates of 8.60 kg/h and 30.74 kg/ha respectively. The regression analysis showed that the discharge and application rates were not significantly affected by hopper capacities but the metering speed has significant effect on both the discharge and application rates at probability level of 0.05.

Keywords: Application rate, discharge rate, grain crops, metering speed, soybean planter.

1. Introduction

Soybean has been described in various ways. Some call it the "miracle bean" or the "golden bean" because it is a cheap, protein-rich grain. It contains 40 per cent high quality protein, 20 per cent edible vegetable oil, and a good balance of amino acids (Gungula and Garjila, 2005). It has therefore, tremendous potential to improve the nutritional status and welfare of resource-poor people particularly in a developing country like Nigeria (Sajo and Kadams, 1999). Soybean can also contribute to enhanced sustainability of intensified cropping systems by improving soil fertility through nitrogen fixation, permitting a longer duration of ground cover in the cropping sequence, and providing useful crop residues for feeding livestock. However, soybean is a relatively new crop in Africa. Until recently, it was seen as being appropriate only for large-scale commercial farming where the crop can be utilized industrially and for formulation of livestock feed (Dugje *et al*., 2009). A commonly held view however is that soybean is of little or no importance in sub-Saharan Africa because it has not attained the status of one of the popular staple foods.

With improvement in breeding and processing research however, soybean cultivation, domestic marketing, processing and utilization has grown considerably in Nigeria. Soybean has been recognized in the country as an important oilseed crop, as well as in indispensable source of protein in animal feeds (Ajeigbe *et al*., 2014). Industrial and domestic processing of soybean has given rise to numerous products utilized as food for both human and livestock. Soybean is gaining prominence in Nigeria as over 200,000 ha of land were devoted to its cultivation as far back as 2000 (Ajani and Olayemi, 2000). Soya is cultivated extensively, among small scale farmers, which may account for its low yields. Despite this, Nigeria's experiment in the use of Soya as a food crop offers a lot of promise. Women in Northern Nigeria have come up with the idea of using the beans to make "*daddawa*", a local condiment which is usually made from the seeds of Locust bean (*Parkia biglobosa*), a leguminous tree from the savanna regions.

Food insecurity and poverty among others are the major problems facing this country (Nigeria). Eliminating these prevailing problems on the entire populace, conducive condition for massive production of agricultural produce would be useful. The global importance of grain crops to the human diet and agriculture cannot be over emphasized. Studies in grain crop production in different parts of Nigeria have shown an increasing importance of the crop amidst growing utilization by food processing industries and livestock feed mills (Ogunsumi *et al*., 2005; Khawar *et al.*, 2007; Abdulrahaman and Kolawole, 2008).

The traditional way of sowing still predominates the cropping system in the country, especially the peasant farming methods. Since that is the principal farming system of the country, about 95% of the Nigerian farmers have small land holding and are much below living standard. It is very difficult for them to have costly agricultural machinery and equipment (Odumal *et al.*, 2014). These traditional sowing methods adversely affect the production and seed requirement per unit area. They also result in improper placement of the seed into the soil at the correct soil depth, failure to properly keep the seed firmly in the soil, uneven placement of the seeds at correct interval in a row, and incidence of bird and rodent attack on improperly planted seeds (Olaoye and Bolufawi, 2001).

2. Materials and Methods

2.1 Materials

The materials used for the experiment are; TGX 1740-IF-Seed soybean (*Glycine max)* that was procured at the Institute of Agricultural Research and Training Obafemi Awolowo University, Nigeria. A pair of vernier caliper was used to measure the axial dimensions of the material including the length, breadth and thickness. The model used is the Gilson Vernier Caliper with calibration of 20 cm with error of 0.05 mm. Two measuring cylinders (Spyrex EX 20ºC with calibration of 250 ml ± 2 ml and a measuring cylinder with 100 ml; 20ºC) were used to determine the bulk volume of the materials. The weighing can was used to hold the materials in the oven when determinig the moisture content of the material. It was also used when weighing in bulk. The weighing balance was used to measure the weight of materials in gramms. The weighing balance used was The Electronic Precision Balance with model JA303P, number 1505601, Max weighing 310 g and readability 0.001 g.

2.2 Experimental Field Test Procedures

The soybean planter was designed bearing in mind the prevailing situation in Nigeria. - The designed planter is a motorised self-propelled machine that operates on the input data, with an electrically driven and controlled system - incorporated into the planter. -The working principle of the planter is tthat which an electric motor drives the seed metering device, reducing the influence of non-uniformity caused by ground wheel slippage. The seeder of the planter was considered to be constructed using two separate seed boxes, one for each row (Plate 1). Seeds were distributed and metered by vertically inclined seed plates with peripheral seed cells.

Plate 1. The Soybean Planter

The machine was experimented and tested in the Laboratory where experiments were conducted to test the metering mechanism. The planter was tested electrically by connecting a dc motor to the metering shaft using a chain and sprocket connection of ratio 1:1. The motor was allowed to rotate and the quantity of seeds received over a period time was weighed and recorded as displayed on the display screen. The seed visible damage was also estimated, by operating the planter at various speeds. The planter was also operated at different levels of seeds in the hopper. It was evaluated in the following hopper conditions;

i. When the hopper was filled with seeds at its full capacity
ii. When the hopper was filled with seeds at its 75% capacity
iii. When the hopper was filled with seeds at its 50% capacity
iv. When the hopper was filled with seeds at its 25% capacity

The effect of these hopper capacities on the seed discharge and application rate was noted, recorded and tabulated. At each instance, Equations 1 and 2 were used to calculate the discharge and application rates respectively. The experiment was repeated by noting and recording the number of seeds dropped over a period of time and the number of damaged seeds were also noted.

$$Discharge\ rate = \frac{Quantity\ of\ seed\ dropped}{Time\ taken} \qquad (1)$$

$$Application\ rate = \frac{Quantity\ of\ seed\ dropped}{Area\ of\ land\ covered} \qquad (2)$$

Field Capacity (ha/h) = (3)

Efficiency % = (4)

3. Results and Discussion

The discharge rate and application rate of the metering unit of the planter were the bases for the determination of the capacity of the planter, which were also used to determine the optimum operation conditions of the planter. Table 1 shows the average capacity of the planter at the hopper full capacity (100% hopper capacity). It was revealed from the table that the total seed discharged at the seed tube increased with decrease in the speed of the planter. This is due to the fact that at high speed the seeds do not have enough time to drop into the cell groove. Also, at high speed the seeds had high impact on the wall of the metering cells thereby resulting in the bouncing around of the seeds. The implication of operating the planter at these high speeds is that it results in high missing index on the field. It was revealed from the results that the planter has a steady and uniform discharge rate and application rate irrespective of the hopper capacity (level of seeds in the hopper) (Figures 1 and 2). It was shown from the figures that the discharge rate and the application are inversely related. The optimum speed of the planter was chosen to be the point of interception between the discharge rate and the application rate; it is taken to be 45 rpm. This point was justified by Figure 3 which shows the efficiency of the planter at different metering speeds and varying hopper capacities. It was revealed that at all the hopper capacities the highest efficiency of 98% was recorded at the metering speed of 45 rpm at the linear speed of 1.30 m/s. The field capacity of the planter was determined to be 0.28 ha/h with the average discharge and application rates of 16.02 kg/h and 58.82 kg/ha respectively. The result could be compared with what was recorded by Karim *et al.* (2015) when they evaluated a drum seeder with urea super-granule application and recorded an optimum roller speed of 23 rpm when the seeder was manually pulled. On the other hand, Hossein *et al*. (2012) recorded a metering speed of 41.5 rpm at the planter travel speed of approximately 1 km/h during the determination of some design parameters for roller type seed metering device such as roller speed, travel speed, length and depth of groove for tomato seeds precision planting.

Table 1. Machine performance at 100% hopper capacity in 60 seconds

Speed (m/s)	Speed (rpm)	Total seed dropped (kg)	Seed damage (kg)	Discharge rate (kg/h)	Application rate (kg/ha)	Efficiency (%)	Field Capacity (ha/h)
2.304867	80	0.155937	0.011328	9.35622	18.79321	92.73553	0.497851
2.016758	70	0.15222	0.009381	9.1332	20.96599	93.83721	0.43562
1.72865	60	0.156999	0.006195	9.41994	25.22826	96.05411	0.373388
1.440542	50	0.1593	0.003186	9.558	30.71761	98	0.311157
1.152433	40	0.126732	0.00177	7.60392	30.54696	98.60335	0.248926
0.864325	30	0.094872	0.001593	5.69232	30.49007	98.3209	0.186694
0.576217	20	0.06195	0.001239	3.717	29.86435	98	0.124463
0.288108	10	0.033276	0.000708	1.99656	32.08284	97.87234	0.062231

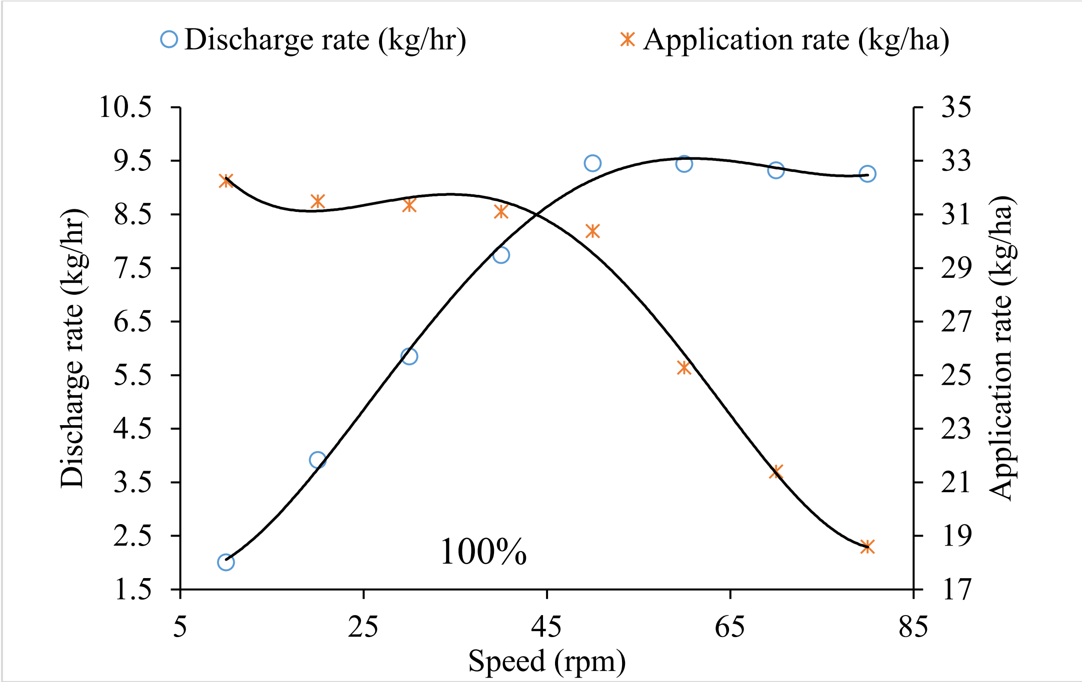

Figure 1. The discharge and application rates of the planter at 100% hopper capacity

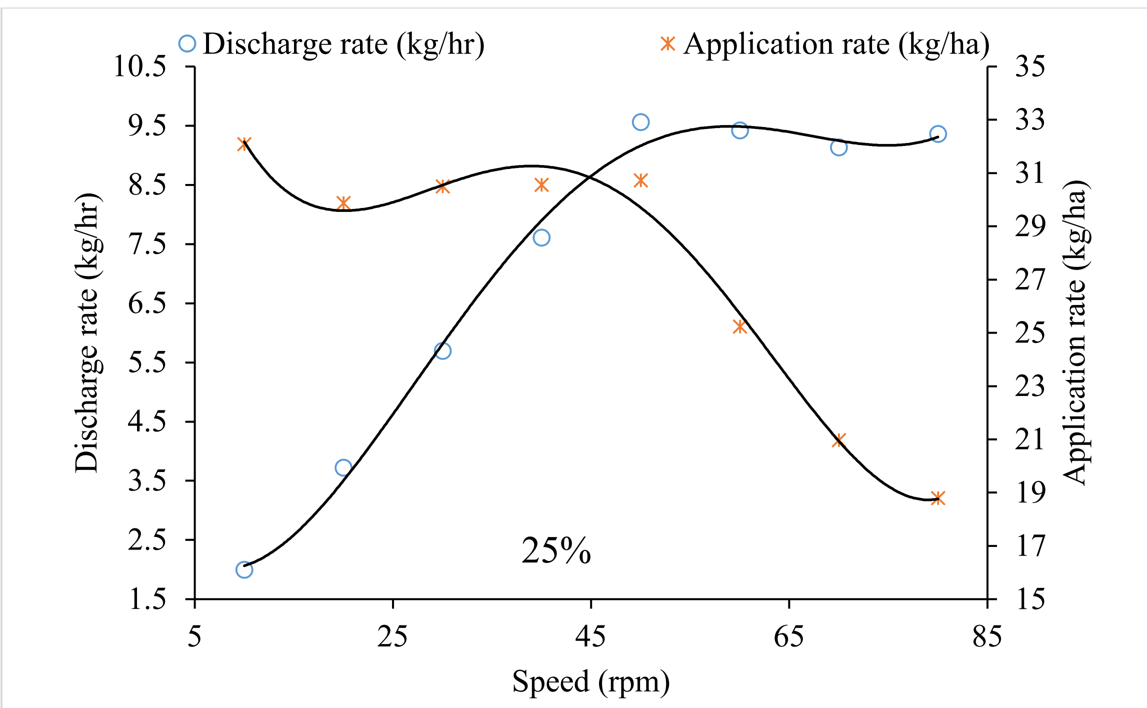

Figure 2. The discharge and application rates of the planter at 25% hopper capacity

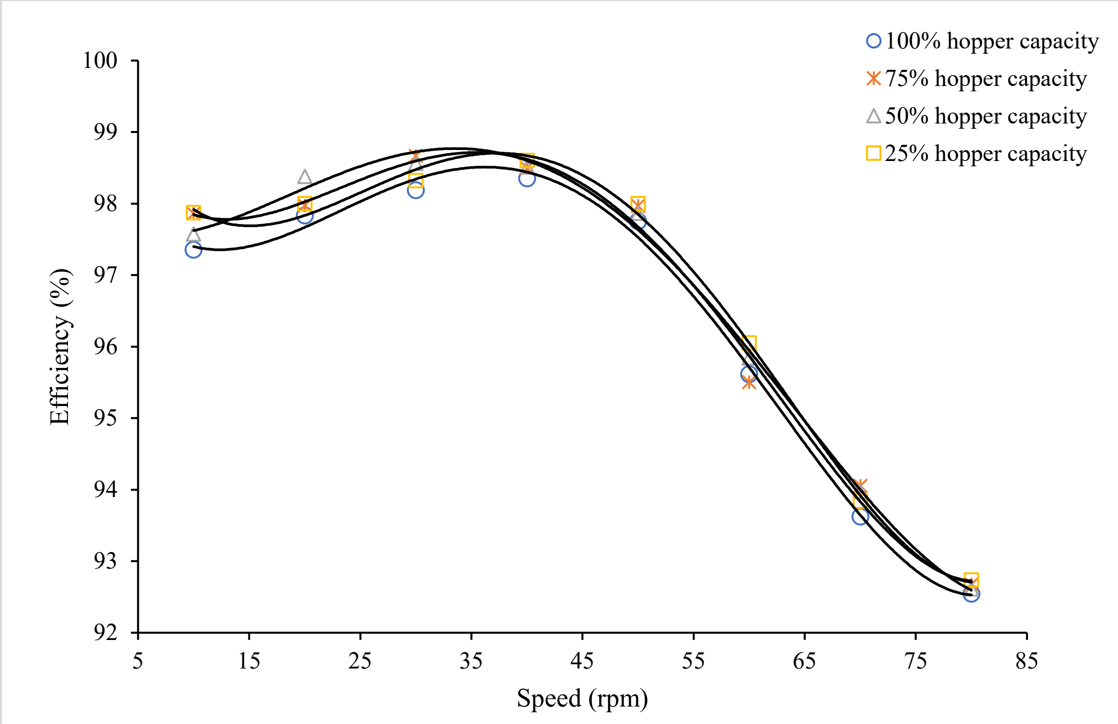

Figure 3. The efficiency of the planter at different hopper capacities

The effect of the metering speed on the application and discharge rates at different hopper capacities is shown in Figures 4 and 5. It was revealed from the Figures that both the application and discharge rates have an increasing trend at the initial (low rotational speed) stage. A decreasing trend was observed between 35 rpm and 45 rpm. The Figures also showed that at all hopper capacities, the application and discharge rates exhibit the same trend (uniform trend). This shows that the effect of hopper capacities is not significant at $P<0.05$. The theoretical field capacity of the planter was 0.28 ha/h with the average discharge and application rates of 16.02 kg/h and 58.82 kg/ha respectively for maize crop. The result is an improvement to what was recorded by Bamgboye and Mofolasayo (2006) when they carried out performance evaluation on a manually operated two-row okra planter by conducting field and laboratory tests where the discharge rate of 0.36 kg/h was recorded. Also, a field capacity of 0.260 ha/h was reported by Odumal *et al*. (2014). In the same trend, the planting rate of the template row planter that was designed by Adisa and Braide (2012) was found to be 0.20 ha/h.

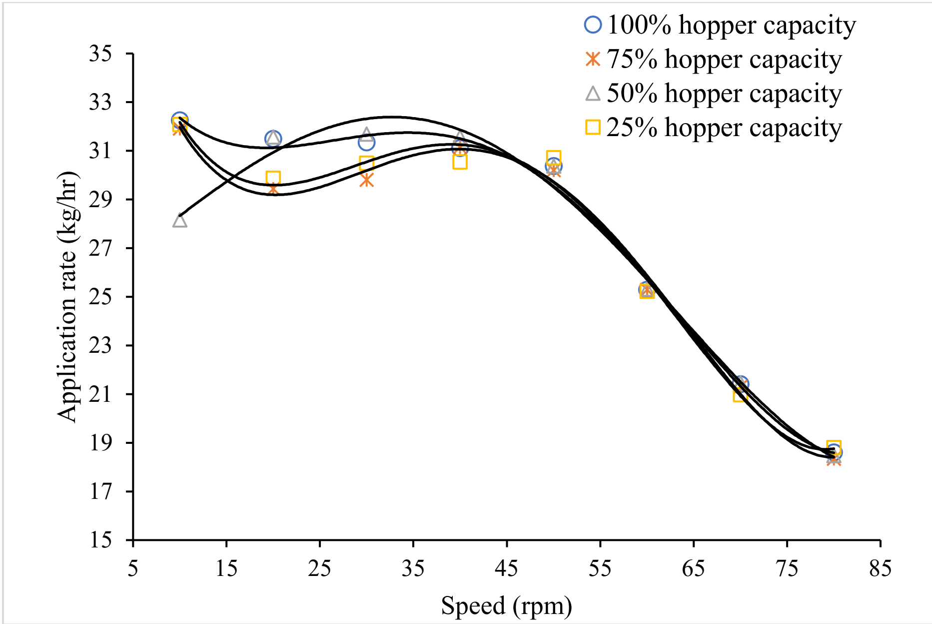

Figure 4. Effect of speed on application rate using four different hopper capacity

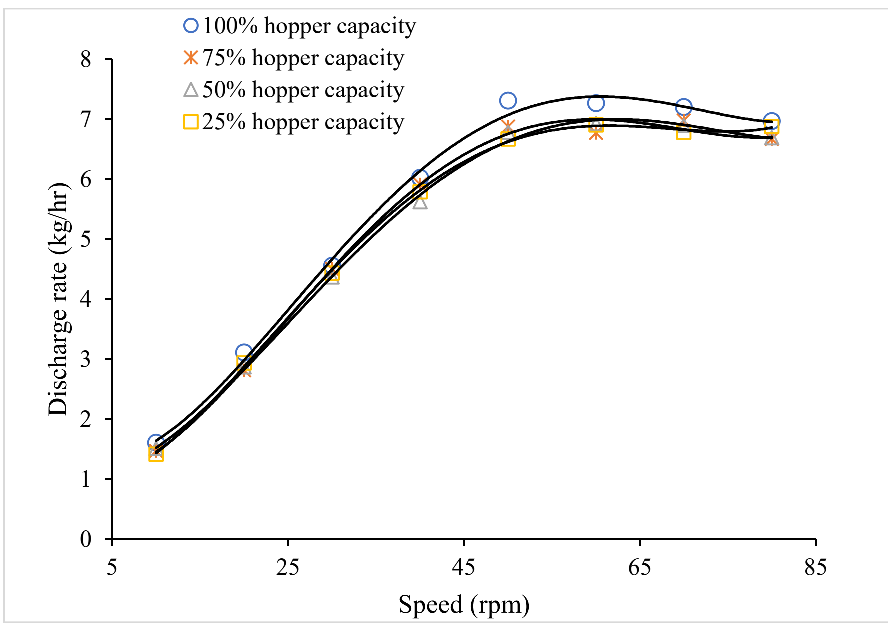

Figure 5. Effect of speed on discharge rate using four different hopper capacity

The surface plots in Figures 6 and 7 confirmed the results of the t-tests that the discharge and application rates are not significantly affected by hopper capacities but the metering speed has significant effect on both the discharge and application rates. This is because, the application and discharge rate displayed a constant trend at different hopper capacity irrespective of the metering speed on the surface plot (Figures 6 and 7).

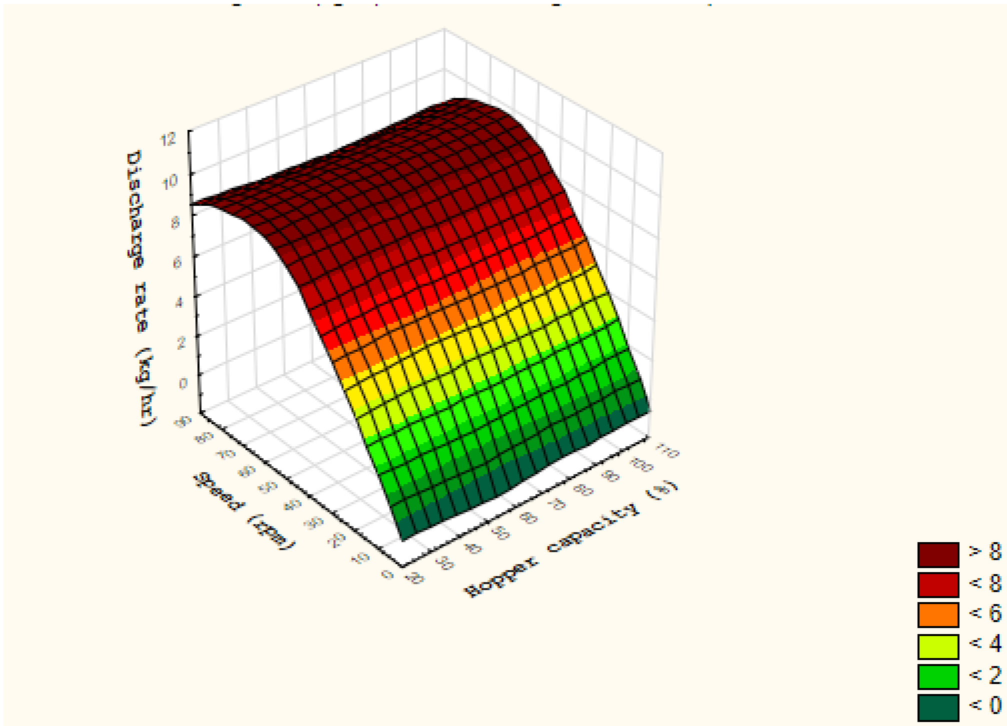

Figure 6. Effect of metering speed and hopper capacity on discharge rate

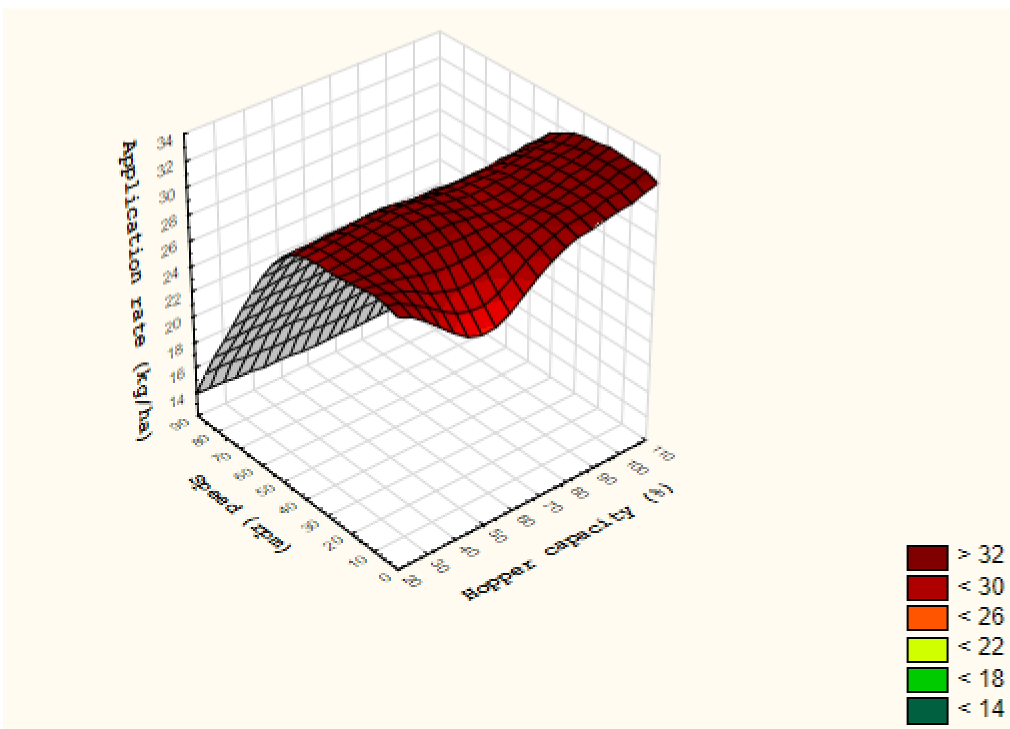

Figure 7. Effect of metering speed and hopper capacity on application rate

4. Conclusions

A locally made soybean planter was evaluated to determine its optimum working parameters and based on the results, the following conclusions were made.

i. Irrespective of the hopper capacity, the designed planter has uniform discharge and application rates. The discharge rate and application rate at all the hopper capacities exhibited the same trends.
ii. The field capacity of the planter is 0.28 ha/h with the average discharge and application rates of 16.02 kg/h and 58.82 kg/ha respectively.
iii. The effect of damages on the seeds was not significant at low metering speed of between 10 rpm to 45 rpm. At speeds greater than 45 rpm, significant and visible damages were done on the seeds at $P<0.05$.

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EFFECT OF AIR-VENT ON PERFORMANCE OF AN IMPROVED NATURAL-DRAFT BIOMASS COOKSTOVE

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Abstract
Air vents are essential components that improves overall performance of cookstoves. This study determines the effect of air-vent on performance of an improved natural draft biomass cookstove. An improved cookstove was developed for the purpose of this study in the Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University, Zaria. It is a double burner natural draft convection biomass stove which is fed in batch and constructed from locally available materials. Stainless steel was used as the major construction material as it possess lesser thermal conductivity (14.9 W/mk) compared with aluminum and mild steel which have 174.6 W/mk and 80.2 W/mk, respectively. A 2 cm thick detachaeble internal insulation made of fired clay was used to control conductive heat loss. Standard Water Boiling Test (WBT) version 3.0 was used to test the performance of the cookstove at three levels of air vent, (vent fully opened, vent half opened and vent closed). The experiment was conducted using Completely Randomized Design (CRD) and was replicated thrice. Statistical Analysis System (SAS) Software Version 9.3 was employed to analyze data obtained. The analyzed result revealed a maximum mean thermal efficiency of 25.1% at the high-power cold start phase under a fully opened vent setting, while the minimum thermal efficiency recorded was 20% when the vent was close at high power hot start phase. The lowest mean specific fuel consumption (best) obtained was 0.026 at fully opened vent under the low power phase while the average mean time spent in boiling per given weight of water was recorded as 0.213 kg/hr at fully opened vent with a mean fire power of 0.689 kW observed in the low power phase. The results obtained conforms to standard test codes and thus, revealed that the operation of the cookstove performs best under the fully opened vent setting. Hence, air-vents are essential components required in cookstove development.

Keywords: Cookstove, air-vent, biomass

1.0 Introduction

Improved Biomass Cookstove are solid-fuel stoves that improve on traditional baseline biomass technologies in terms of fuel savings via improved fuel efficiency (Thomson *et al.* 2016). They are designed to primarily improve fuel efficiency, reduce smoke and harmful emission associated with the combustion of fuels. Improved cookstoves comes in different forms. Some are designed to operate on natural draft, some on forced draft while some operates on both natural and supplemental air for effective fuel combustion. The choice of a particular design type and mode of operation depends on some factors which affects the overall performance, these factors are; environmental factors (temperature, air speed, humidity, etc.), stove factors (fuel/air ratio, temperature of flame and/or envelope, mode of fuel supply, primary and secondary air, mass of the stove, etc.), fuel factors (physical and chemical properties of fuel such as volatile matter, moisture content, ash content, etc.) and operational factors (burn rate/size of the fuel ratio, volume to surface ratio, mode of fuel supply, cooking time, etc.). Hence, for effective and efficient cookstove development, a careful study on the aforementioned factors remains key.

Most biomass cookstoves are designed with insufficient or excessive air inlets, this usually stems from low consideration of the overall input air requirement during designs and constructions. When the input air requirement is not sufficient for complete fuel combustion, it results to high particulate emission and prolonged cooking time. In line with this, Ndiema *et al*., (1998) as cited in Igboanugo and Ajieh, (2017), reported that energy losses as a result of incomplete combustion in cookstoves results in the emission of carbonmonooxide (CO), unburned hydrocarbons (UHC), nitrogen oxides (NOx), smoke and soot. In another survey conducted by ACCES (2014) on the global burden of disease, it was reported that nearly 600,000 Africans die annually and millions more suffer from chronic illnesses associated by air pollution that emanates from inefficient and dangerous traditional cooking fuels and stoves. On the other hand, when there is excessive air inflow in the combustion chamber, it results to high fuel consumption. In line with this, it becomes pertinent to design cookstoves that would yield a balance in terms of fuel-air ratio for effective performance.

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2.0 Materials and Method

2.1 *Material Selection*

The materials used for the construction process were selected based on cost, workability, thermal properties and availability. They are; 5mm mild steel sheet used for constructing the grate, 2cm thick ceramic insulation to control conduction heat loss, 1.5mm galvanize steel sheet used in constructing the ash deposit chamber, 3mm stainless steel sheet was selected for the stove cladding, cap, air compartment and pot stand, this is because it has lower thermal conductivity (14.9 W/mK) as compared to other class of sheet metals.

2.2 *Design Analysis*

2.2.1 Needed gap at the edge of combustion chamber

Figure 2.1 shows the needed gap required at the edge of combustion chamber (Gc).

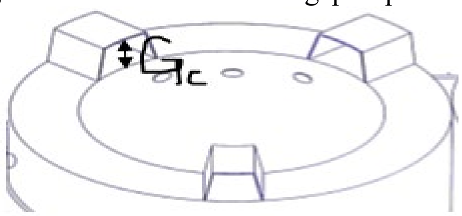

Figure 2.1 Stove cap showing the needed gap at the edge of combustion chamber

This is the needed gap between the bottom of the pot and the top edge of the combustion chamber which is equivalent to the effective height of the pot seat. The gap also serves as a secondary air inlet to the cookstove. To determine this, first the circumference of the area in which the hot gasses will pass through **Cc** (i.e. circumference of the area at the bottom of the pot) must be known. The circumference was determined by measuring the center of the combustion chamber outlet to the farthest edge, this is equivalent to the radius of combustion chamber (i.e. $\mathbf{r_c}$). Equation 2.1 as given by Mark *et al*. (2002) was used to determine the needed gap at the edge of combustion chamber.

$G_c = \frac{A_C}{C_c}$……………………………………………………………..(2.1)

Where,

G_c = needed gap at the edge of combustion chamber (mm)

C_c = Circumference of the stove hot gasses outlet (mm)

$C_c = 2.\pi.r_c$

$C_c = 2 \times \pi \times 63$ =395.9 mm

$$G_c = \frac{12{,}470.6}{395.9} = 31.5\ mm$$

Therefore, a gap of 31.5 mm at the edge of the combustion chamber was used in the design

2.2.2 Amount of air needed (AFR)

The amount of air required for combustion of fuel material was determined from equation 2.2 as given by Belonio (2005) and cited by Anil and Pushpendra (2016)

$AFR = \frac{\varepsilon \times FCR \times SA}{\rho}$…………………………………………………… (2.2)

Where,

SA = Stoichiometric air of biomass = 6 (Keche *et al.,* 2013 as cited by Aniland Pushpendra, 2016)

ε = Equivalence ratio = 0.3 (Keche *et al*., 2013 as cited by Anil and Pushpendra, 2016)

ρ= Air density = 1.225 kg/m^3 at 25 °C (Anil and Pushpendra, 2016)

$$AFR = \frac{0.3 \times 0.94 \times 6}{1.225} = 1.38\ m^3/h$$

2.2.3 Area required for primary air

The area required for desired amount of air flow rate as given by Belonio (2005) and cited by Anil and Pushpendra (2016) is express as:

$A = \frac{AFR}{V}$……………………………………………………………...(2.3)

V = velocity of air, m/s (indoor air velocity = 0.5 m/s = 1800 m/h) … (Anonymous, 2007) as cited by Anil and Pushpendra (2016)

Therefore,

$$A = \frac{1.38}{1800} = 0.000767\ m^2$$

2.3 *Experimental Procedure and Data Collection*

The stove was evaluated using the standard Water Boiling Test (WBT) Version 3.0 as suggested by Bailis *et. al* (2007). The test which was an open lid experiment was conducted in a well-ventilated laboratory with an average air temperature and relative humidity of 27ºC and 75.6%, respectively. It comprises of three (3) experimental phases; High power cold start phase, high power hot start phase and low power simmering phase. In order to assess the effect of air vent on the overall performance of the stove, the experiment was conducted at three levels of air vent setting, which are; vent fully opened (A1), vent half opened (A2) and vent closed (A3). Charcoal was used as the test fuel and its moisture content (7.8% wet basis) was determined using the standard oven dry test. Two (2) aluminum pots tagged pot 1 and 2 as shown in Plate 2.1, with capacities of 4.4 and 4.9 litres, respectively were used for the experiment. Water volume (two-thirds the pots capacity i.e. 2.93 and 3.3 litres) were filled and weighted prior to and after the commencement of each test phase. About 15ml of paraffin oil was sprinkled on the charcoal surface to initiate combustion. The initial water temperatures at the beginning of each phase were recorded and a wooden fixture was incorporated on the pot to hold the two thermometers at a height 5 cm above the pots bottom as shown in Plate 2.1. When the charcoal begins to combust, the pots were placed on the stove and the thermometers immersed in the water.

The data collected were; initial weight of fuel, initial weight of water, initial temperature of water, boiling temperature of water, time water reaches local boiling temperature, final weight of fuel and water, air or ambient temperature as well as relative humidity. The experiment was replicated three times. Statistical Analysis System (SAS) Software Version 9.3 (2019 Updated Version) was employed for the analysis. Duncan Multiple Range Test (DMRT) was used to further analyze the significant variables.

Plate 2.1: Experimental setup with pot 1 and 2 been operated on closed and moderately opened air vents, respectively

3.0 Results and Discussion

3.1 *Description of the Developed Prototype*

The developed prototype is batch fed natural draft cookstove which was made double burners to fast track cooking process. It comprises of a heat resistant handle, an insulated grate, a detachable refractory lining, **air vents**, ash deposit chamber and a cap comprising of pot seat.

The air vents were designed to serve as a primary air inlet for the cookstove, and were made adjustable as shown in Plate 3.1

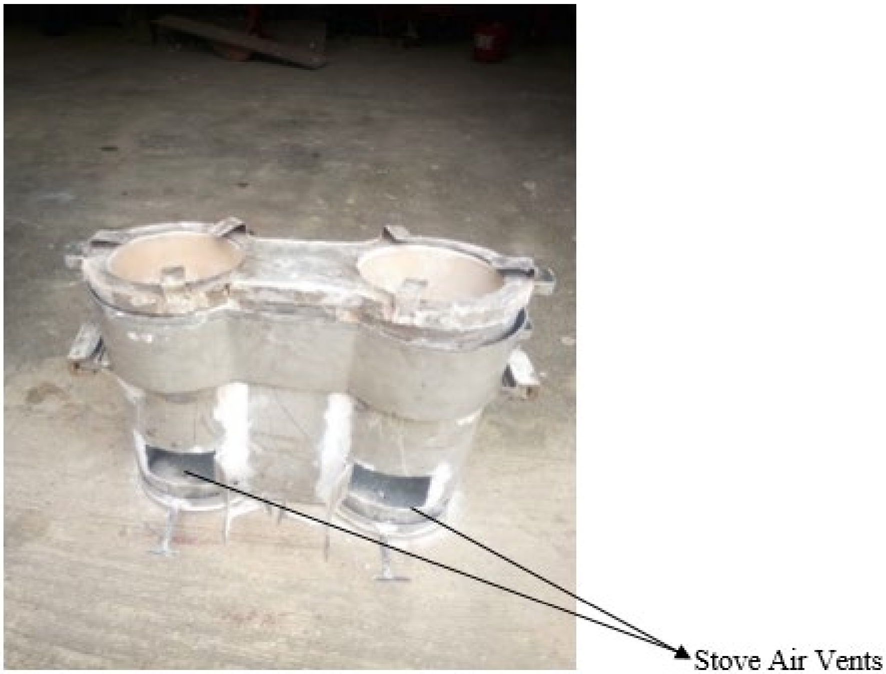

Plate 3.1: Pictorial view of the developed cookstove showing the stove air-vents

3.2 *Effects of Air Vent on Cookstove Performance*

Table 3.1 shows the effect of air vent on thermal efficiency at three levels of vent setting. The mean thermal efficiency at the three levels were found to be statistically different in the high-power phase but statistically at par when the air vent was fully opened (A1) and half opened (A2) at the low power phase.

The highest thermal efficiency was recorded at fully opened vent (A1) setting as 25%. This agrees to the 25% minimum thermal efficiency benchmark of natural draft cookstoves as reported in BIS 13152 test code (Part 1): 2013, and also conforms to the range obtained by Kulla (2011) as 20.96-39.65%, Joshi et al. (1991) as cited by Omini (2018) as 17-46% and Eronmosele (2008) as cited by Kulla (2011) as 11.51-35.38%. The maximum value recorded at A1 is attributed to the stove's ability to react with the air inflow at that level, thus, aids combustion.

Table 3.1: Effect of air vent on thermal efficiency

	Mean thermal Efficiency (Decimal)		
	Cold Start Phase	**Hot Start Phase**	**Simmering Phase**
Air Vent (ms^{-1}) A			
A1	0.251a	0.227a	0.234a
A2	0.233b	0.211b	0.240a
A3	0.206c	0.200c	0.217b
SE ±	0.0022	0.0018	0.0025

Mean followed by same letter(s) in the same column are not different statistically at P=0.05 using DMRT

Table 3.2 indicates the effect of air vent on specific fuel consumption. The mean specific fuel consumption at the three levels were found to be statistically different in the low-power phase (simmering phase) but statistically the same when the air vent was half opened (A2) and closed (A3) at high-power phase (cold and hot start phase).

The minimum (best) specific fuel consumption was recorded in the simmering phase when the vent was fully opened (A1) as 0.026. This is because the low power phase (simmering phase) occurs when the combusting fuel becomes weak in a manner that can lower the boiling point by 2 to 3^0C in order to simulate the actual cooking of legumes at very low fuel consumption. The highest specific fuel consumption was recorded at the hot start phase under A2 and A3 respectively. This may be attributed to the low air inflow rate at that level.

Table 3.2: Effect of Air Vent on Specific Fuel Consumption

	Mean Specific Fuel Consumption		
	Cold Start Phase	**Hot Start Phase**	**Simmering phase**
Air Vent (ms^{-1}) A			
A1	0.069b	0.068b	0.026c
A2	0.074a	0.076a	0.031b
A3	0.074a	0.076a	0.036a
SE ±	0.0014	0.0010	0.0012

Mean followed by same letter(s) in the same column are not different statistically at P=0.05 using DMRT

Table 3.3 shows the effect of air vent on time spent in boiling per given weight of water. The mean time spent in boiling at the three levels were found to be statistically different in the high-power phase but statistically at par when the vent was half opened (A2) and closed (A3) at the low power phase. The minimum (best) time spent in boiling was recorded in the cold start phase when the vent was fully opened (A1) as 0.213 hr/kg. This is because percentage heat utilization (PHU) is higher in the high-power phase than in the low power phase.

Table 3.3: Effect of Air Vent on Time Spent in Boiling Per Given weight of Water

	Mean Time Spent in Boiling Water per given weight of water (hr/kg)		
	Cold Start Phase	**Hot Start Phase**	**Simmering phase**
Air Vent (ms^{-1}) A			
A1	0.213c	0.227c	0.302b
A2	0.242a	0.258a	0.321a
A3	0.232b	0.241b	0.317a
SE ±	0.0033	0.0026	0.0017

Mean followed by same letter(s) in the same column are not different statistically at P=0.05 using DMRT

Table 3.4 indicates the effect of air vent on stove fire power at three levels. The mean stove fire power at the three levels were found to be statistically different in the low-power phase (simmering phase) but statistically the same when the vent was fully opened (A1) and half opened (A2) at the high-power phase (cold and hot start phase). The least (best) mean fire power was recorded at low power simmering phase at A1 as 0.689 kW. While the highest was recorded at the high-power cold start phase at A3 as 2.646 kW. This agrees to Ayo (2009) as 2.52 kW and Bello *et al.* (2015) as 2.26 kW.

Table 3.4: Effect of Air Vent on Stove Fire Power

	Mean Stove Fire Power (kW)		
	Cold Start Phase	**Hot Start Phase**	**Simmering phase**

Air Vent (ms^{-1}) A			
A1	2.591ab	2.426b	0.689c
A2	2.481b	2.441b	0.786b
A3	2.646a	2.597a	0.899a
SE ±	0.0545	0.0420	0.0270

Mean followed by same letter(s) in the same column are not different statistically at P=0.05 using DMRT

4.0 Conclusion

The study, which was aimed at assessing the effect of air vent in an improved biomass cookstove was successful. The analyzed result revealed a statistically different output as the performance varies significantly at variable air vent setting. The best performance was recorded when the air vent was fully opened, as a thermal efficiency, specific fuel consumption, time spent in boiling and fire power of 25%, 0.026, 0.213 hr/kg and 0.689 kW, respectively, were recorded. The performance of the cookstove at fully closed vent setting is similar to that of a cookstove without an air vent. Hence, this shows that cookstoves developed with air vents performs better than those developed without air vents.

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DESIGN, DEVELOPMENT AND PERFORMANCE TESTING OF A MUCUNA BEAN SEED CRACKER

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Abstract
A cracking machine was designed and developed for mucuna bean seed. Design considerations and calculations were made using relevant equations and data from some engineering properties of the seed. A 2hp electric motor running at a speed of 1400rpm was used to transmit power to the gear mechanism. The cracker was fabricated using locally available materials to promote possibility of replacing damaged parts. The performance of the machine was tested at various moisture levels, since traditional post harvest processing of the seed is moisture dependent. The feed rate of the machine decreased as moisture level increased. Significant decrease of 17.31% was observed across the various moisture levels tested as feed rate of the machine decreased from 8.01 to 6.59 kg/hr. At moisture content level 5.31% (dry basis), the throughput capacity of the machine was obtained as 12.02 kg/hr, while between 9.14 to 11.52% moisture content, it decreased by 3.5%. The efficiency of cracking of the seed increased from 56.6 to 66.1% as moisture level increased from 5.31 to 18.38% (dry basis). The percentage of seed breakage also increased with moisture level. The seeds were observed to had cracked more efficiently when moisture was reduced (dry basis). An average of 500 seeds was cracked within an hour, as against a minimum of 48 hours that would have been spent if the seeds were to be soaked in water before manual cracking. The cost of producing the machine was put at $200 (N80,100).

Keywords: Mucuna bean seed, moisture content, cracking, cracking machine, cracking efficiency

1.0 Introduction

Mucuna Bean seed is a tropical tree crop widely available in Africa and Asia. It is harvested and consumed as food and also used in production of traditional medicine for treatment of kidney related diseases, blood purification, expulsion of excessive gases, expelling of worms, menstrual cycle balance and blood pressure stabilization. The seed is harvested, processed and utilized as soap thickener, taste modifier and spice for confectionaries. After harvesting, the seeds are soaked in water for a period of two to four days, for effective moisture penetration and softening, before the can be manually cracked and utilized. The cumbersome process of traditionally processing the seed has resulted in increased loss of interest in processing and use of the oil seed, despite its huge nutritional and medical prospects.

A machine for cracking of the seed was considered for development based on values of some engineering properties of the seed obtained by Alonge and Etim (2015) and established machine design equations. The machine was designed to evaluate the efficiency of cracking of the seed in variation to moisture content,since moisture plays vital role in traditional method of cracking the seed. According to Ghafari *et al.* (2011), Agricultural seeds can either be cracked in wet or dry form, depending on specific function.

Many authors have developed machines for cracking of different seeds; Owolarafe *et al.* (2013); Dika Nut, Olalusi and Bolaji (2011); Bush Mango amongst others. Ojolo *et al.* (2019) developed a decorticating machine for Delonix regia, to advance course for research into the huge nutritional and medicinal benefits of the seed. Preliminary studies done revealed that the force required to break the pod was 1360N. The machine was of a power rating of 6 kw and the seed recovery efficiency was 98.4%, while the throughput capacity was obtained as 56.4 kg/hr. Marey *et al.* (2017) in designing an almond kernel extraction machine, used a compression test machine to determine the focre required to crack the seed. The compressive force measured, was used in designing the cracker.

Oduma *et al*. (2016) designed and fabricated a hand fed motorized oil bean slicing machine. Some of the materials considered were: physical and mechanical properties of the seed; mechanical properties of the construction materials; machinability of construction materials, availability of materials and cost. Alonge *et al.* (2017) modified a bambara groundnut Sheller earlier developed by Alonge *et al.* (2016). The modified machine saw the capacity and efficiency of the machine improve, as a result of incorporation of a separation unit to the system. Mild steel was also used as construction material.

A cracking machine was developed for walnut (Hussain et al., 2018). Relevant equations were deployed to design the frame, hopper, shaft, belt length, safe stress of the belt, and power required by the machine for operation. Ojolo and Ogunsinna (2007) developed a cashew nut cracking machine. The percentage of whole kernels produced and capacity of the machine were estimated as 66.60% and 18.3kg/hr respectively. Ojolo *et al*. (2009) also designed and developed a cashew nut shelling machine. The throughput capacity, shelling efficiency and whole kernel recovery were obtained as 15.57kg/hr, 95% and 70% respectively.

Kabir and Fadele (2018) reviewed shelling, threshing, dehulling and decortications machines for Agricultural products. Their findings revealed that the principles of construction of processing machines for pods, seeds and nuts were significantly dependent on the engineering properties of the material which is to be processed. Odewole and Ajibade (2015) fabricated a Thevetia Nut cracker. The overall cracking efficiency and throughput capacity of the machine were evaluated as 96.65% and 8.5kg/hr.

Sharifian *et al*.(2008) designed a walnut cracking machine based on some information from the mechanical properties of the fruit. The maximum cracking force and power required was 797N and 1.99Watts respectively. In designing and constructing a walnut cracker, Gharafi *et al*. (2011) fitted a flow rate control device to the hopper of the machine and obtained a percentage of whole kernel produced as 66.66%, while the capacity of the machine was estimated as 25.2kgg/hr. In designing of walnut cracker, Ghafari *et al.* (2011) reported that the cracking efficiency of the machine is a function of moisture content of the nut. Similar trend was reported by Onyenwoke and Simonyan (2013) in developing a Briquetting Machine for Plam Kernel. Aviaria *et al.* (2008) examined the effect of moisture content on performance indicators of Lanutus Seed cracker.

Bamboye and Sadiku (2003) designed and constructed a combined manual and motorized palm nut cracker and tested for performance at various moisture levels. The machine gave output capacities of 90.4Kg/hr for motorized and 19.8Kg/hr for the manually driven cracker. Oluwale *et al.* (2014) observed that the feed rate of shea nut into the chamber of its cracking machine varied with moisture content. The review extensively done on the subject revealed that the cracking of various Agricultural seed is dependent on moisture content (dry or wet basis).

In designing a shelling machine for moringa oliefera seed, Fadele and Aremu (2016) reported that as moisture level of the seed increased from 8.43 to 34.59% (wet basis), the maximum machine capacity, shelling efficiency and overall efficiency were obtained as 5.39kg/hr, 86% and 57.98% respectively. The selection of materials for construction for most of the machines aforementioned was based on durability, suitability, strength, availability and cost. The development of a suitable technology for cracking of mucuna bean seed is key to addressing challenges faced with its post harvest processing. Moisture also plays a key role in post harvest processing of the seed since it is usually soaked for days as shown in Figure 1, before could be manually cracked. Evaluation of the effect of moisture content on the performance of the machine is of essence.

Figure 1: Mucuna Bean Seed Soaked in water for Cracking Manually

2.Materials and Methods

2.1 *Design Considerations*

Some physical and mechanical properties of the seed were considered in designing of the hopper and discharge chute of the machine. The major, intermediate and minor diameters were obtained from a study conducted by Alonge and Etim (2017). The force required to crack the seed under static load was obtained through a compression test using a Universal Testing Machine (UTM – Instron 3382, 100KN Floor Model) at the central Engineering workshop, Akwa Ibom State University. The force required to break the seed on its major and minor axes were 1500 and 250N respectively. The cracker was fabricated using locally available materials to promote possibility of replacing damaged parts with ones locally available in the market. The total cost of producing the machine was ($200) N80, 100.

2.2 *Description of the Machine*

The cracker was made of two rotating drums, sprockets, belt, pulley and a gear mechanism. The gear mechanism served as an intermediary between the power transmission system and the drive mechanism. One of the drums was attached to a shaft and was rotational, while the other was stationary. The rotating drum had splines attached round its surface. Fifty percent of the major diameter of the seed (Alonge and Etim, 2017) was used as the thickness of each spline. The drums were mounted in such a way that enabled them rub against each other when rotating. The essence of employing the gear mechanism was to ensure control of the speed of the rotating drum, to limit impact when the two drums come in contact, thus mitigating against opportunity of increased damage to the seeds. Power was transmitted from the electric motor to the gear mechanism by a v-belt arrangement. The transmission between the gear train and the rotating shaft was aided by a chain drive. The main frame was made of mild steel. Exploded and orthographic views of the machine are as shown in Figures 2, 3 and 4.

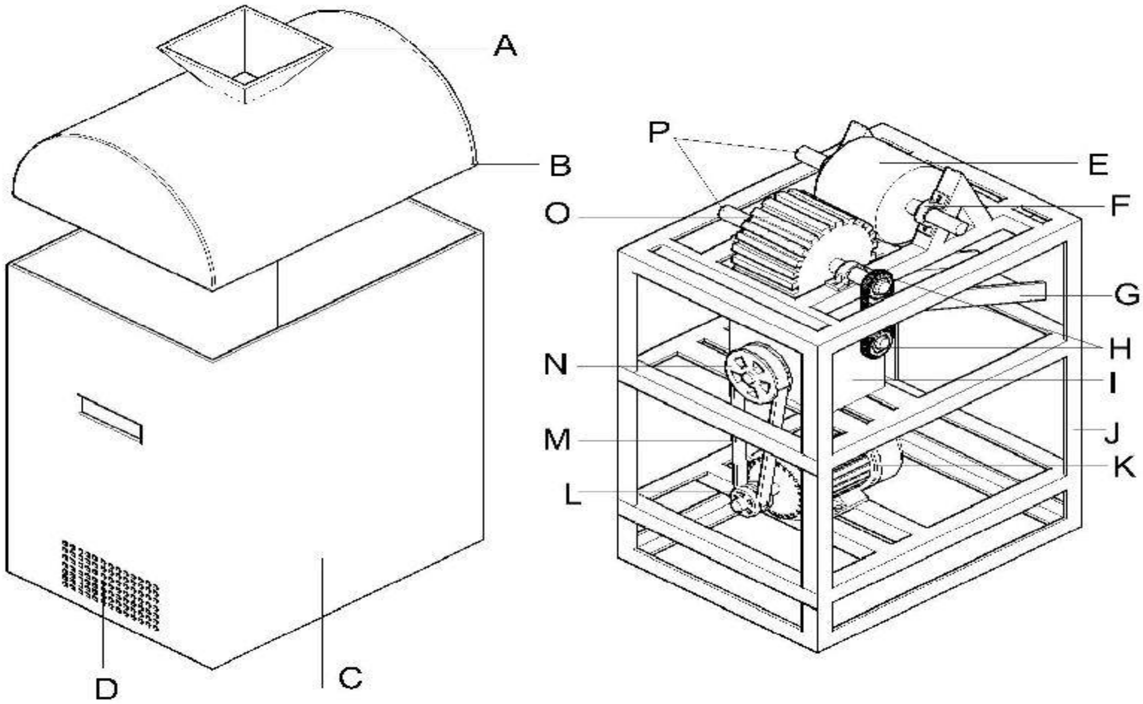

Figure 2: Exploded view of the machine

LEGEND:

A	Hopper	I	Gear
B	Rotating Drum Cover	J	Ankle Bar
C	Metal Sheet	K	Electric Motor
D	Air Duct	L	Driving Pulley
E	Stationary Drum	M	Belt
F	Coupling Flange	N	Driven Pulley
G	Discharge Outlet	O	Driving Drum
H	Sprocket	P	Shaft

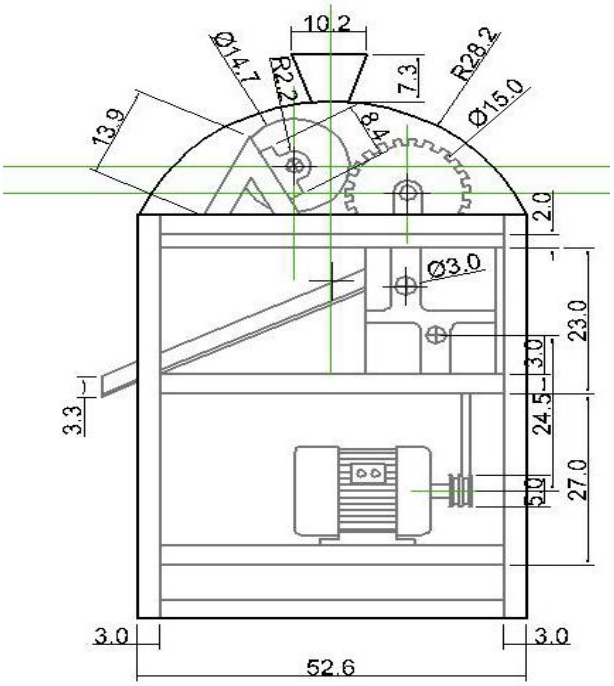

Figure 3: Side view of the machine (from 1st angle)

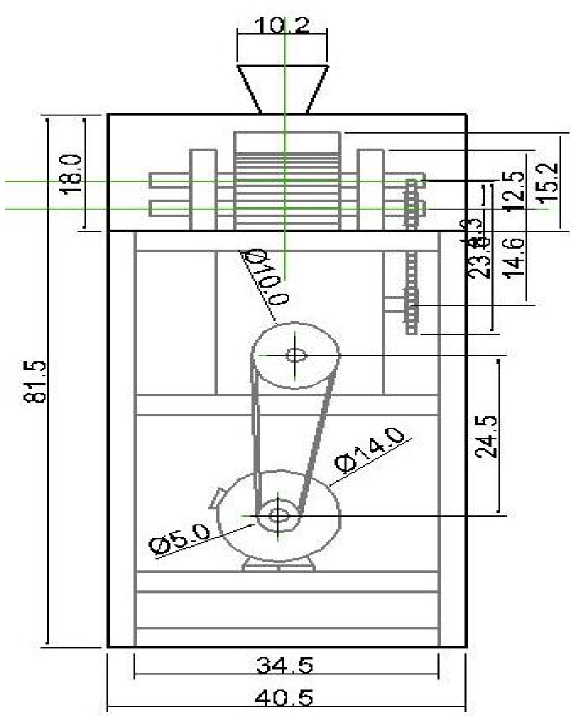

Figure 5: Side view of the machine (from 3rd angle)

2.3 *Design Analysis*

2.3.1 Shaft Design

Torque transmitted by the shaft (T) and the diameter (D) of the drive shaft were obtained using the equations (1) and (2) respectively as developed by Khurmi and Gupta (2018):

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$$T = \frac{60P}{2\pi N} \quad (1)$$

$$d^3 = \left(\frac{16T}{\pi\tau}\right) \quad (2)$$

The maximum permissible stress shear stress was taken as 42Mpa. The diameter of the shaft was obtained as 15mm and π = 3.142.

2.3.2 *Belt Design*

The length of the belt

$$L = \frac{\pi(D_1 + D_2)}{2} + 2x + \frac{(D_1 - D_2)^2}{4x} \quad (3)$$

D_1 is the diameter of the bigger pulley, given as 80mm, while D_2 is the diameter of the smaller pulley, given as 76mm. x is the center distance between the two pulleys (270mm). The length of the belt was obtained as 786mm.

The angle of contact of the belt and pulley was derived from the equation given by Khumni and Gupta (2006).

$$\theta = (180 - 2\alpha)\frac{\pi}{180}\text{ rad-} \quad (4)$$

Where, $Sin\alpha = \frac{r_1 - r_2}{x}$ (5)

The angle was obtained as 3.13 rad.

Tensions on the tight side (T_1) and slack side (T_2) of the belt T_1 were obtained by use of the equations below as established by Khurmi and Gupta (2018).

$$P = (T_1 - T_2)v \quad (6)$$

$$2.3\log\left(\frac{T_1}{T_2}\right) = \mu\theta \quad (7)$$

where, v = velocity of the belt

θ = Angle of wrap and

N = coefficient of friction between belt and pulley.

2.3.3 Chain Design

Speed of Rotation of the smaller sprocket, N_s

$$\frac{N_B}{N_S} = \frac{D_B}{D_S} = G.R. \quad (8)$$

N_b is the speed of the rotation of the smaller sprocket (1400 rpm) and the gear ratio taken as 3:1. The speed of rotation of the larger sprocket (N_s) was obtained as 491.3 rpm. The velocity ratio was obtained as 3. Computing the number of teeth on the larger sprocket was done using the equation below:

$$T_2 = T_1\left(\frac{N_b}{N_s}\right) = G.R. \quad (9)$$

The number of teeth (T_1) for a velocity ratio of 3 for a roller chain as specified by Khurmi and Gupta (2018) is 25. A value of 75 was obtained as the number of teeth of the larger sprocket. The design power (Pd) was obtained from the relation below as established by Khurmi and Gupta (2018).

$$P_d = RatedPower, P * ServiceFactor, Ks \quad (10)$$

The service factor was computed as the produce of various factors (k_1, K_2 and K_3). Where K_1 is the load factor, taken as 1.25, because the expected load was with mild shock; K_2 = lubrication factor, taken as 1, because of routine lubrication of the chain mechanism. K_3 = Rating factor, taken as 1, because the machine was assumed to be used for a maximum of eight hours per day.

$Ks = K_1 \times K_2 x K_3 = 1.25 \times 1 \times 1 = 1.25$

The design power was obtained as 1.87KW.

The choice of chain was made with reference to the standard table established by AMSE code for chain drives. The speed of the bigger sprocket (1400mm) was in constant with a No. 6 chain at 2.73KW (relatively higher than the design power given as 1.875KW). Thus a No.6 chain with strands was used to transmit the required power.

The pitch of the chain, P_1 was obtained as 9.525mm with reference to the standard table as specified by Khurmi and Gupta (2018). The roller diameter, d, was given as 6.35mm. The minimum width of the roller, w, was obtained as 5.72mm. The pitch diameter of the smaller sprocket, d, was obtained from the relationship below:

$$d_1 = pcosec\left(\frac{180}{T_1}\right) \quad (11)$$

$$d_2 = pcosec\left(\frac{180}{T_2}\right) \quad (12)$$

where T_1 and T_2 are number of teeth on the smaller and bigger sprocket respectively.

The pitch line velocity of the smaller sprocket, v1, was obtained from the expression below;

$$V = \frac{nD_1N_1}{60} \quad (13)$$

The value obtained was 5.87m/s

The load on the chain was obtained from the relationship below;

$$w = \frac{RatedPower}{Pitchlinevelocity} \quad (14)$$

The value was obtained as 226.58N.

The factor of safety was derived as below:

$$\boldsymbol{F_s} = \frac{W_b}{W} \quad (15)$$

The value obtained for the safety factor (39) was more than the value specified for a 1400rpm driven roller chain as given by Khurmi and Gupta (2018). The minimum center distance between the smaller and bigger sprockets was assumed to be 30 times of the pitch. The center distance between the sprockets was obtained as 285mm. in order to accommodate initial slag, the value of the center distance was reduced by 5mm. The number of chain links, according to Khurmi and Gupta (2018) was obtained from the relationship below:

$$K = \frac{(T_1 + T_2)}{2} + \frac{2x}{P} + \frac{(T_2 - T_1)^2}{2\pi} * \frac{p}{x} \qquad (16)$$

The value of K was obtained as 54.7.

The length of the chain was obtained from the expression below:

$$L = KP \qquad (17)$$

Where, k, is the chain linkage and p is the pitch diameter. It was obtained as 58.7mm.

2.4 ***Performance Evaluation***

Moisture Content (M.C.)

The moisture content (M.C.) of the seed was obtained using equation (18).

$$Moisture\ Content\ (M.C.) = \frac{(w_1 - w_2)}{w_2}\ (\%) \qquad (18)$$

W_1 is the initial weight of the seed and W_2 is the final weight of the seed after drying.

Feed Rate,

$$F_r = \frac{W_t}{T_c}\ (\frac{Kg}{hr}) \qquad (19)$$

W_t is the Weight of the seed that filled the hopper (kg) and
T_c is the time taken to empty the whole seed into the cracking chamber (hr)

Throughput capacity was computed as thus;

$$C_t = \frac{W_t}{T_d}\ (\frac{Kg}{hr}) \qquad (20)$$

T_d is the total time taken by the cracked mixture to level the discharge outlet (hr).

Efficiency of cracking was determined as below:

$$E_c = \left(\frac{W_t - W_n}{W_t}\right) * 100\% \qquad (21)$$

W_n is the weight of partially cracked and un-cracked Mucuna seeds (kg)

Percentage of seed breakage (P_{bk}) was computed as below:

$$P_{bk} = \left(\frac{C_d}{C_d + C_u}\right) * 100\% \qquad (22)$$

C_d is the weight of Cracked and damage seed (kg) and C_u weight of cracked and undamaged seed (kg)

3. Results and Discussion

3.1 ***Performance Testing***

The machine was tested at various moisture levels and the following results obtained: as shown in Table 1.

Table 1: Performance evaluation of the machine

S/N	Moisture content dry basis (%)	Feed rate (kg/hr)	Throughput capacity (kg/hr)	Efficiency of cracking (%)	Percentage of seed breakage (%)
1	5.31	8.01	12.02	56.60	60.34
2	9.14	7.52	11.29	60.19	63.33
3	11.52	7.26	10.89	61.80	64.20
4	14.53	7.01	10.51	62.76	66.82
5	16.31	6.67	10.00	64.1	67.4
6	18.38	6.59	9.88	66.1	69.60

From the results obtained, the feed rate of the machine decreased as moisture level (dry basis) of the seed increased. At the various moisture levels, a significant decrease of 17.31% was recorded as the feed rate of the machine decreased from 8.01 to 6.59kg/hr. The feed rate of the machine decreased as moisture content of the seed increased. This was responsible for easy flow of the seed when loaded on the hopper. A mathematical relationship linking the two variables was established in equation 23.

$$F_r = 8.561 - 0.11m \; (R^2 = 0.987) \tag{23}$$

The throughput capacity also decreased with increasing moisture level. At moisture level 5.31% (dry basis), the throughput capacity of the machine was obtained as 12.02kg/hr, while between 9.14 to 11.52% (% dry basis), it decreased by 3.5%. The throughput capacity decreased from 10.51 to 9.88Kg/hr as moisture content increased from 14.53 to 18.31% (dry basis). The efficiency of cracking of the seed increased with increasing moisture content. The values ranged from 56.6 to 66.1% as moisture level increased from 5.13 to 18.38%. The range of value was slightly less than what was obtained by Ojolo *et al.* (2009) for a cashew nut cracker and Hussian *et al*. (2018) for a walnut cracker. It was however higher than that obtained by Alonge *et al.* (2017) for a bambara groundnut sheller (7.5kg/hr). It was observed that the seeds tend to crack more efficiently when dried than wet owing to loss of moisture. Increased amount of moisture toughens the seed initially, though it gets softened after minimum of two days. A relationship between moisture content and throughput capacity was obtained as in Figure 5. The high coefficient of correlation obtained in equation 24, shows a strong relationship between moisture content and the throughput capacity.

$$C_{th} = -\,0.166m + 12.85 \; (R^2 = 0.988) \tag{24}$$

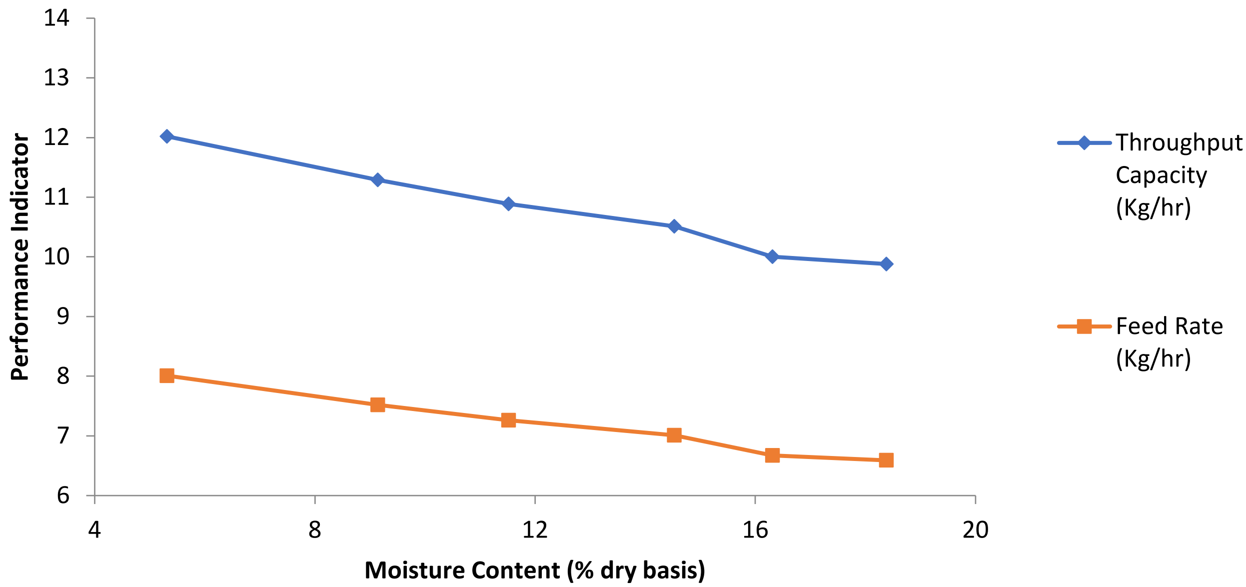

Figure 5: Relationship between moisture content and throughput capacity and feed rate

The percentage of seed breakage showed positive correlation with moisture level. This was evident in the high R^2 value obtained from a mathematical relationship established for the two factors as in equation 25. Some cracked samples of the seeds and pods are shown in Figure 6.

$$E_{sbr} = 0.680m + 56.75 \; (R^2 = 0.988) \qquad (25)$$

Figure 6: Cracked mucuna bean seeds with pods

The percentage of seed breakage decreased with moisture content. At the various moisture level tested, a variation of 13.3% was recorded. The efficiency of the machine to crack the seed increased as moisture level increased. The values ranged from 56.6 to 66.1% as captured in Figure 7. A mathematical relationship linking moisture level of the seed and cracking efficiency of the machine was established in equation 26.

$$E_c = 0.672m + 53.49 \; (R^2 = 0.976) \qquad (26)$$

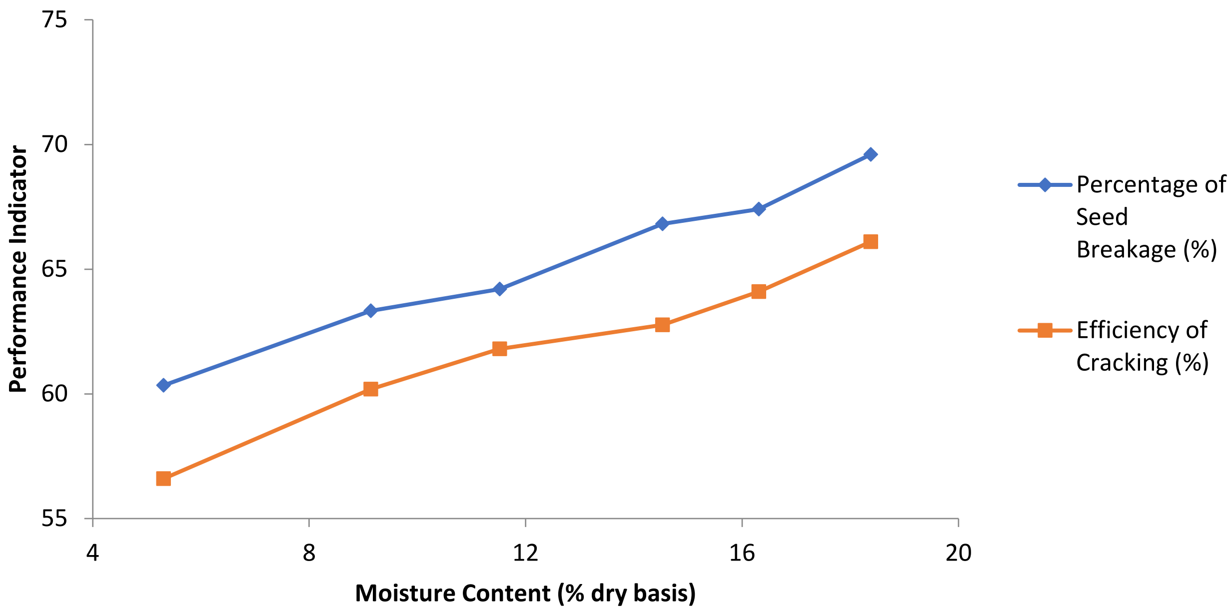

Figure 7: Relationship between moisture content and percentage of seed breakage and cracking efficiency

The range of values obtained was lower than what Ojolo and Ogunsina (2007) obtained for a cashew nut cracker, but higher than what Fadele and Aremu (2016) obtained for a moringa oleifera seed shelling machine. The seeds were observed to had cracked more efficiently when moisture was reduced (dry basis). An average of 500 seeds was cracked within an hour, as against a minimum of 48 hours that would have been spent if the seeds were to be soaked in water before manual cracking.

4.Conclusions and Recommendations

The economic potentials of Mucuna bean seed is enormous and the development of machine for its processing is of essence. As part of efforts to limit time taken to manually crack and process the seed, a cracking machine was developed. The machine was tested for efficiency at various moisture levels of the seed ranging from 5.31% to 18.38% (dry basis). The efficiency was highest (66.10%) at a moisture content of 18.38%, meaning the seed will crack more efficiently if it moisture content is increased (dry basis). The feed rate and throughput capacity of the machine decreased as moisture level of the seed increased. The percentage of seed breakage increased from 60.34 to 69.60% within the tested moisture levels. The cracker is recommended for low income farmers, who are in need of available technology to enable easy processing of the seed, against the conventional manual method of processing the seed, which involves soaking in water for days. Further development and optimization of the bean cracker should be considered to cover a range of speed (rpm) and other factors, to improve the capacity and efficiency of the machine.

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Declaration of Competing Interest

The authors wish to state that there is no competing interest associated with publication of the findings from the study.

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DECISION SUPPORT SYSTEMAPPROACH TO FARM MACHINERY MANAGEMENT IN NIGERIA

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Abstract
Power and machinery account for 60% of total investment in farm mechanisation. Despite huge investment of both Nigerian government and private sector in farm machinery acquisition, farm machinery are still underutilized and there is low level of mechanisation of agricultural production in the country. The traditional method of farm machinery management has been the intuitive and experience based approach commonly employed by farmers which often results in farm machinery not operating at optimum efficiency. In this paper, a scientific approach called Decision Support System (DSS) is proposed. This is a computer-based system that takes advantage of latest technologies in aiding the farmers to make proper decision in planning, selection and matching of farm machinery which results in increased profits and decreased costs of machinery operation and labour. Least Cost and Brixius Traction Models together with ASABE standard equations form the underlying logic for the DSS development. The DSS can be accessed synchronously on desktop computers, web browser and also as a mobile application. The proposed DSS approach is thought to be capable of increasing farm machinery usage efficiency and overall farm profits.

Keywords: Farm Machinery, Model, DSS, Computer, Mechanisation.

1. Introduction

Agricultural production at a massive rate can only be possible by the use of sophisticated farming machines and techniques which is totally lacking in the Nigerian farming system. Majority of the farmers in Nigeria still make use of crude farming tools such as hoe and matchet with only about 2 percent reported to engage in mechanized agricultural system (Sahel, 2017). The current mechanization rate in Nigeria is 0.27 hp/hectare and this is far below the FAO recommended rate of 1.5hp/hectare. Thailand which is the major supplier of rice to Nigeria has a rate of 0.7hp/hectare while highly industrialized countries like Japan has mechanization rate of 7hp/hectare (Buari, 2016). In USA, only about 3 percent of the entire population are farmers yet they are able to meet to a reasonable extent the food needs of the United States (Srivastava*et al.*, 2006; Mba, 2015). This is at variance to what is obtained in Nigeria where less than 2 percent of the agricultural production is mechanized (Faborode, 2001).

Tools, implements and power machinery are essential and major inputs to agriculture. Agricultural mechanization is generally used as an overall description of the application of these inputs to agriculture (Clarke, 2000); while the term agricultural machinery is generally referred to as the collection of machines for agricultural production (Yohanna, 2007). Power and machinery constitute the largest single item of expenditure in agricultural production systems, and a substantial investment is involved in the ownership of a tractor and associated equipment. They account for 60% of total investment on the farm (Sinha *et al*, 2016). Agricultural machinery management is the section of farm management that deals with the optimization of the equipment phases of agricultural production. It is concerned with the efficient selection, operation, repair and maintenance, and replacement of machinery. Selection of power units and agricultural machines for farming operations, can lead to profit or loss of all or part of the farm enterprise (Wenging*et al.*, 1999).

As stated by Ogunlowo (1997) and Onwualu*et al.*. (2006), the major factors militating against full mechanization in Nigerian agriculture are the high costs of owning and operating a tractor which are also the greatest factors in farm production costs. High cost of operating and maintaining tractor and other farm machinery always occurs as a result of ineffective machinery management (Faleye*et al.*, 2014). Transition from using hand–operated implements to power – operated machines in agricultural production has enabled the farmer to become a larger producer with a decrease in the effort and time necessary to obtain a unit of production.

The overall goal of farm machinery management is to reduce production costs to barest minimum and maximize farm enterprise profit. Optimum farm machinery management occurs when the economic performance of the total machine system has be maximized. Good machinery management therefore requires that the individual farm operations in a machine system be adjusted and combined in a manner so that their overall performance returns greatest profit to the farm business (Hunt, 2001). Farm machinery management components include the calculation of machinery ownership and operating costs such as labor and fuel costs, hiring cost, machinery size selection, tractor power selection, matching machinery to tractor size, replacement of equipment, and maintenance schedules (Kime, 2016). The optimum selection of farm machinery is in fact the most complex problem in machinery management. The complexity arises due to the wide range of machinery types, different sizes available, capital investment, competent technicians, labor requirements, timeliness, types of crops, unbalanced crop rotation and other related factors (Mohamed *et al.*, 2013). Modern farming systems require large capital investment, complex economic decisions and higher levels of technical management to minimize cost of production and maximize profit. This kind of enterprise is, however, accompanied by serious economic risks due to uncertainty of weather, timeliness, soil type and conditions, type of crops and crop rotation, management practices, labour availability and high cost of inputs relative to product value. Hence, selecting proper size farm power and equipment to permit economic production in a farm is of paramount importance (Dash and Sirohi, 2008).

In Nigeria and other developing countries, experience and intuitive based approach is usually employed in the selection of farm machinery while there is also no definite approach to evaluate the economic performance of the machinery. This has often resulted into low productivity, untimely and delayed field operations, low crop yield and frequent machinery breakdown. The solution is to use scientific approach which involves development of decision support tool for effective farm machinery management. In this paper, a cross platform computer-based decision support system for farm machinery management is therefore proposed.

2. Conceptual Issues and Previous Work

2.1 Challenges in Farm Machinery Management and Current Approach

Despite the efforts and progress made in mechanizing agriculture in Nigeria in the past few years, its effect in boosting food production is still low, yet the nation's population continues to increase. One way to overcome this problem is to produce crops with high yields by using less production inputs. To achieve sufficient food production, agricultural machinery usage in agriculture has to be increased, well planned and managed. Unplanned tractor and machinery selection and usage leads agricultural production away from meeting its target especially in big commercial farms where agricultural machinery and tractor selection is becoming more complex than ever before. Most commercial and government farms are characterized by a number of underutilized, damaged, and abandoned tractors and farm implements. This is largely due to ineffective management and improper maintenance of these equipment. Ineffective management such as incorrect tractor-implement matching do cause high loss of power during operation which consequently leads to rapid machinery breakdown, high cost of operation, low efficiency, and excessive soil compaction. Research shows that about 20% to 55% of the available tractor energy is wasted at the tractive device/soil interface. This energy wears the tires and compacts the soil to a degree that may be detrimental to crop production (Zoz and Grisso, 2003). For effective management, scientific approach is needed for selection and matching of farm machines and implement, their cost and performance evaluation, and scheduling of their operation and maintenance. This approach is in contrast with the intuitive and experience based approach commonly employed by farmers which can result in farm machinery not operating at optimum efficiency. The scientific approach is based on the knowledge of soil terrain properties, environmental factors, and farm machinery design and operational data. Based on scientific approach, there is need to develop decision support systems to assist in decision making process for the selection and management of farm machinery. Some studies have been conducted around the world to develop effective decision support system for farm machinery selection, optimum performance and cost management. These have been found to aid decision makers in selecting optimum farm machines for specific farm operations. They have also helped in predicting farm machinery performance and output. None of these DSSs is cross platform. This means that they cannot be synchronously accessed on the web, mobile device and desktop computers using the same database.

2.2 Decision Support Systems

A decision support system (DSS) has been defined as an interactive and adaptable computer-based information system that supports non-structured management problems (Turban and Aronson 2000). Sheng and Zhang (2009) also defined DSS as human-computer systems which collect, process and provide information based on computer systems. Through the use of DSS, decision-makers were able to find solutions to various problems. DSS is mostly used in business management such as portfolio management and optimization, capital budgeting, inventory scheduling and supply chain management. It is also applied in Industrial Engineering such as facility layout, queuing system, simulation and dynamic production (Hanna et al, 2004). The recent global increase in the number of computers, internet usage and mobile devices offer great potentials of applications of DSS to various number of decision making processes in agricultural production including tailored weather information, geo-referenced soil maps, natural disasters forecast, extension service advices, distance learning modules, plant diseases diagnosis, agri-products traceability, economic information, and agricultural machinery management (Sopegno*et al.*, 2016).

Decision support system (DSS) for farm machinery management involves the incorporation of regional or local variations in crops and cropping practices, farm characteristics, size of the farm equipment and cost of the resources and output (Singh and Chandraratne, 1995). An ideal DSS for farm machinery management is a tool for predicting the performance of tractor-machinery system, evaluation of costs of machinery usage, giving the optimum size of machinery and tractor power selection and predicting the available time for machinery operation.

In order to solve problems in farm machinery management, some studies have been conducted to develop computer-based decision support tools for various farm machinery management issues. Various optimization techniques and models were used for selecting optimal system of farm machinery, and these techniques or models form the underlying logic of most computer-based DSS. These techniques include linear programming (LP), integer programming, mixed integer linear programming, non-linear programming, dynamic programming, conditional optimization approach, traction model and least cost technique (Dash and Sirohi, 2008). The use of least cost technique was reported by Singh and Chandraratne (1995), Canakci*et al.* (2011) and Dash and Sirohi (2008). Bender *et al.* (1990), Mohamed *et al.* (2013) and Wang *et al.* (2014) reported the use of linear programming models in selection of farm machinery, evaluation and improvement of machinery management system and equipping of farm machines respectively. Camarena*et al.* (2003) also reported the use of mixed integer linear programming model to select agricultural machinery for multifarms system. Some researchers (Civelek and Say, 2016; Zarini*et al.*, 2013; Mohamed *et al.*, 2013; Ismail *et al.*, 2009; Grisso and Perumpral, 2006; Pelletier *et al.*, 2014) also based their DSS on traction models and ASABE equations (ASAE, 2000) for predicting tractor performance,matching tractor-implement system, economic evaluation and selection of farm machinery, and modelling fuel use for farm machinery and operations.

Most of these DSS are mostly desktop applications with few exceptions for mobile applications such as the one reported by Sopegno*et al.* (2016). There is a global increase in the use of mobile devices especially in Nigeria where it was reported that active mobile phone users has hit 146 millions as at 2018 (Business a.m., 2018). Therefore there is need for cross platform hybrid DSS which can be accessed synchronously on desktop computers, on web browser and also as a mobile application. This will enable farmers and managers to access the DSS application on mobile devices on the field in order to make on the spot decision and also get updates in the Desktop version in the office. Therefore a cross platform computer-based DSS approach for selection, matching and planning of farm machinery is presented in this paper.

3.0 Proposed Methodology

3.1 Design of the Computer Based DSS

The DSS consists of five modules as depicted in Fig. 1 and described as follow:

(i) Tractor Selection Module: Optimum tractor is selected based on the size and capacity of the implements available and other input factors

(ii) Implement Selection Module: If the tractor is available, optimum matching size of implement will determined by the DSS based on other input factors

(iii) Working Days Estimation Module: This module will calculate the number of hours or days needed for each field operation based on the field area, field efficiency and weather data obtained from weather station.

(iv) Field Operation Cost Module: This module calculates the cost of field operation based on the tractor and implement selected and other input factors.

(v) Machinery Performance Module: This module is not attached to a particular field operation. It can predict the performance of any farm machinery.

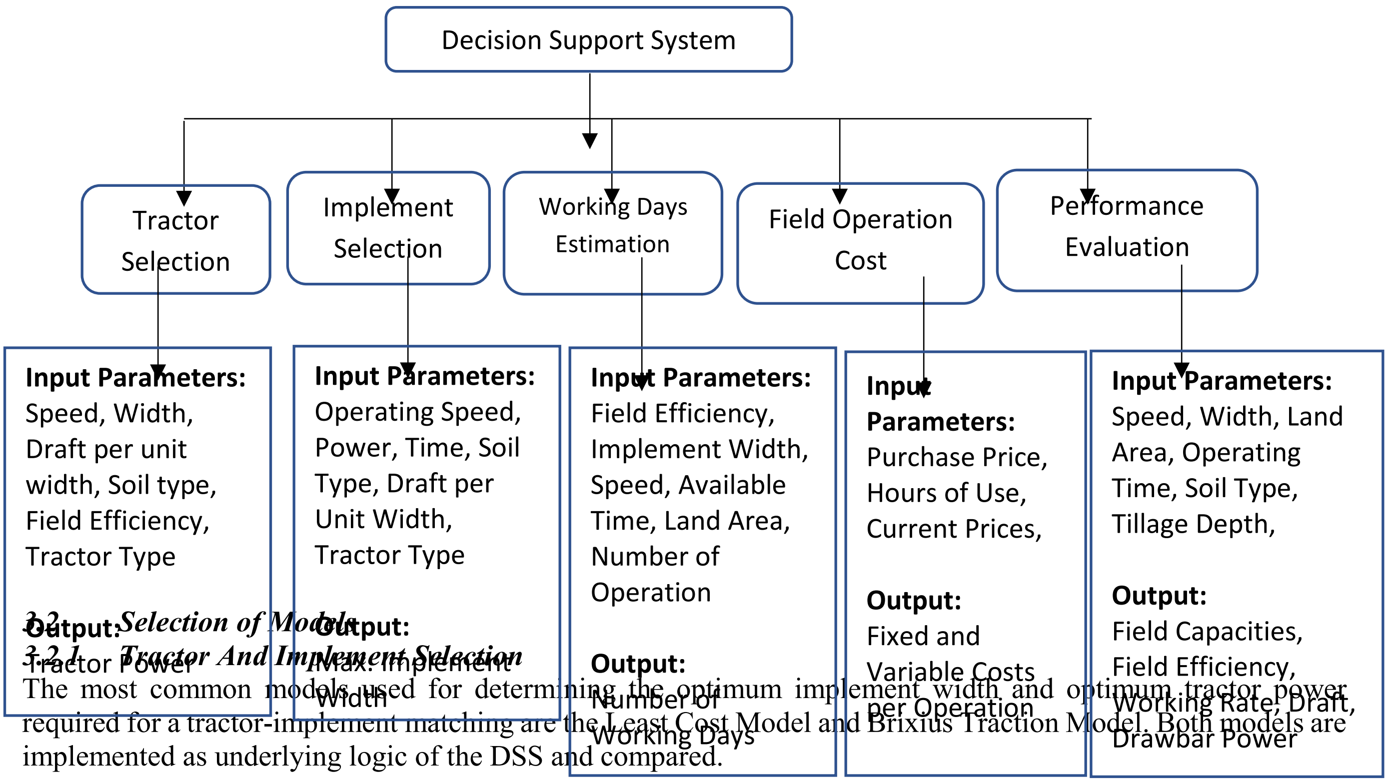


Fig. 1: Decision Support System Design

3.2 Selection of Models

3.2.1 Tractor And Implement Selection

The most common models used for determining the optimum implement width and optimum tractor power required for a tractor-implement matching are the Least Cost Model and Brixius Traction Model. Both models are implemented as underlying logic of the DSS and compared.

(a) The Least Cost Model developed by Hunt (1973) for determining the optimum machinery width (W) and optimum power requirement (P) are given as follow:

$$W_{opt} = \sqrt{\sum_{i=1}^{n} \frac{10.A_i}{FC.p.S_i.e_i}\left(L+T+TC\right)} \quad (1)$$

$$P_{PTO} = \sqrt{\sum_{i=1}^{n}\left[\frac{A_i E_i}{FC.T_p.r_1}.\left(L+TC\right)\right] + \sum_{i=1}^{n}\left[\frac{L}{FC.T_t}.\left(\frac{0.27.D_i.W_t}{r_2}\right)\right]} \quad (2)$$

$$TC = \frac{K.A_c.V.Y}{X.U.h} \quad (3)$$

Where W_{opt} = optimum machine width (m), A = annual use (ha), FC = annual fixed cost percentage (decimal), p = machine purchase price for unit width ($/m), S = forward speed (km/hr), e = field efficiency (decimal), L = labour cost (($/hr), T = total cost of tractor use by the machine ($/hr), TC = timeliness cost ($/hr), i= subscript denoting the operating type or crop type of all the crops (i = 1, 2, ….n), K = timeliness cost factor (1/day), A_c=

crop production area (ha), V = value of the crop (\$/kg), Y = potential crop yield (kg/ha), X = planning factor, U= ratio of workable days in planned operation period, h = daily work period (hr), P_{PTO} = total optimum PTO power, E = total energy requirement for unit production area (kWh/ha), T_p = tractor purchasing price for unit PTO power (\$/kW), D = transport distance, W_t = amount of transported material annually (tonnes/yr), r_1 and r_2 = tractor loading factors for field machinery and transportation operations respectively.

(b) The Brixius modelis based on tractive characteristics of bias-ply pneumatic tires which are given by the following relationships for mobility number (B_n), motion resistance (MRR), gross traction ratio (GTR), net traction ratio (NTR) and tractive efficiency (TE). The model equations are given as follow:

$$B_n = \frac{CI.b.d}{W}.\left[\frac{1+\frac{5\delta}{h}}{1+\frac{3b}{d}}\right] \tag{4}$$

$$MRR = \frac{M}{W} = \frac{1}{B_n} + \frac{0.5s}{\sqrt{B_n}} + 0.04 \tag{5}$$

$$GTR = \frac{T}{r.W} = 0.88\left(1-e^{-0.1B_n}\right)\left(1-e^{-0.75s}\right) + 0.04 \tag{6}$$

$$NTR = \frac{NT}{W} = GTR - MRR \tag{7}$$

$$TE = \frac{NTR}{GTR} = \frac{Drawbar\ Power}{Axle\ Power} \tag{8}$$

Where CI = cone index, b = unloaded tire section width, d = unloaded tyre diameter, W = dynamic load on the tractive devices, δ = tire deflection, h = tyre section height, T = axle torque, r = tyre rolling radius, M = motion resistance, s = wheel slip, NT = net traction or drawbar pull
In applying Brixius model, the goal is to determine the net traction or drawbar pull that the tractor can generate. This drawbar pull will be matched with the draft requirement of a particular implement of certain width.

3.2.2 Working Days Estimation

The real available working days for each farm operation are estimated using the equations given by Whitney (1988) as follows:

Total field days needed for each implement (days) = 10A / (Fe x W x S x T x N) (9)

Pwd = Sd + (0.5 x Cd) + 0.25 x (Pcd) + (0.125 x Rd)] (10)

Real available days for operation = Pwd x Available days for each working month (11)

where Fe = field efficiency of current implement (%), W = current implement width (m), S = implement speed (km/hr), T = available time per day (hr), N = number of operation by current implement, Pwd = possibility of working days for each month, Sd = sunny days in current month, Cd = cloudy days in current month, Pd = partly cloudy days in current month, Rd = rainy days in current month.

3.2.3 Machinery Cost And Performance Evaluation

The following ASABE standards equations (ASABE, 2006) are used for the estimation of field operation cost and machinery performance evaluation:

(i) Draft Requirement

$D = F_i\ [A + B\ (S) + C\ (S)\ ]\ W\ T$ (12)

Where D = implement draft (N), F = dimensionless soil adjustment paramenter, A, B and C are machine-specific parameters, S = field speed (km/hr), W = machine width (m), and T = tillage depth (cm)

(ii) Drawbar Power

$$DP = \frac{D \times W \times S}{3.6} \quad (13)$$

Where D = Draft (N), W = width of machine/implement (m); and S is the speed of operation (km/h).

(iii) Theoretical Field Capacity

$$TFC = \frac{W \times S}{10} \quad (14)$$

whereTFC is the theoretical field capacity (ha/h); W the width of machine/implement (m); and S is the speed of operation (km/h).

(iv) Effective Field Capacity

$$EFC = \frac{A}{T} \quad (15)$$

whereEFC is the effective field capacity (ha/h); A the area to be covered (ha); and T is the available working time (hr).

(v) Field Efficiency

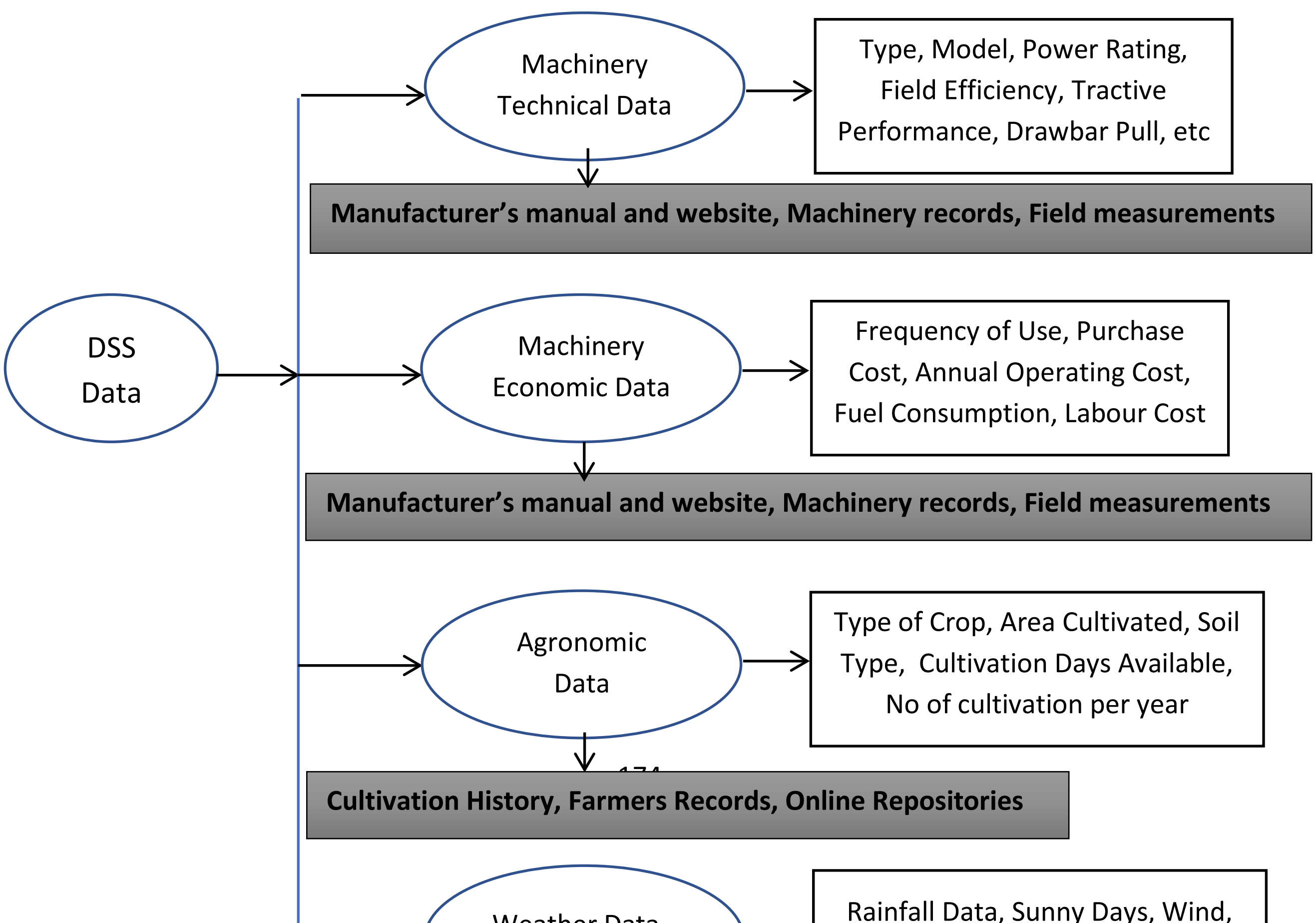
$$F_e = \frac{EFC}{TFC} \quad (16)$$

where $F_e$is the field efficiency (%)

3.3 DSS Development and Implementation

3.3.1 Data Collection

Both primary and secondary data are required for the development of the DSS. Such data include the machinery technical and economic data which is obtained secondarily from manufacturers website and manuals, and primarily from commercial farms through questionnaire and direct field measurements. Other data required are agronomic data of the crops cultivated in the targeted study area and weather data. The structure and type of data required is depicted in Fig. 2



3.3.2 Database Creation

Database is one of the major components of a DSS. The functionality of database is to store, retrieve and organise the raw data that will be used as information to make decisions. For the DSS to be developed, MongoDB which is an open source document database is used. It stores data in flexible, JSONlike documents. It is chosen not only because it uses JavaScript as its scripting and query language, but also ideal for spatial, unstructured and time-series data common in agriculture. It also provides high performance, high availability, and automatic scaling (MongoDBInc, 2016).

3.3.3 DSS development

The DSSis developed using NodeJS which is the runtime environment for programs developed with JavaScript programming language. JavaScript was chosen because it is fully integrated with HTML and CSS, simple to use and supported by all major browsers (Kantor, 2018). The DSSconsists of backend component for handling the database and the frontend component which the users interact with. The backend API is developed using ExpressJS which is a JavaScript framework for fetching data from the database. The frontend is developed using JavaScript frameworks and libraries such as Electron, Angular and Ionic for the desktop, web and mobile versions respectively. The DSS structure is shown in Fig. 3

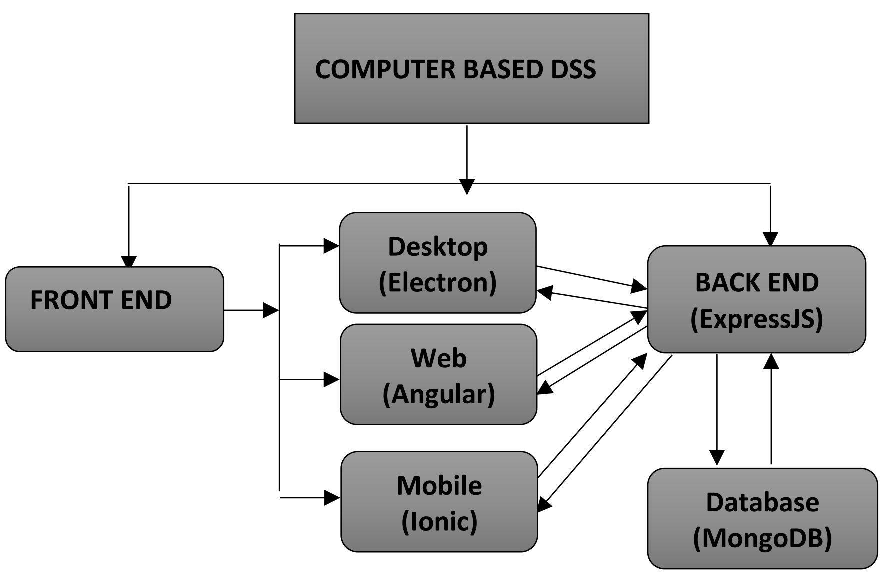


Fig. 3: DSS Development Framework

4. Conclusion

A computer based Farm Machinery Management DSS was proposed in this paper. The proposed DSS uses Least Cost, Brixius and ASABE Machinery models as its underlying logic. The development is implemented using JavaScript frameworks such as NodeJS, Angular, Electron and Ionic, and MongoDB database software. It was posited that the DSS will have cross-platform capability such that it can be synchronously accessed and used on desktop, mobile and web-enabled devices.

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PERFORMANCE EVALUATION OF A COMPRESSION IGNITION ENGINE USING SAND APPLE BIODIESEL

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Abstract

The objective of this study was to evaluate the performance of a compression ignition engine (CIE) fuelled with biodiesel produced from sand apple (ParinaripolyandraB.) oil using eggshell as catalyst. Sand apple fruits(non-edible) were harvested at National Centre for Agricultural Mechanization, Ilorin, Nigeria. The fruits were processed and oil extracted using solvent extraction method. Raw eggshells were calcined at 800 °C for 120 minutes in the muffle furnace. Transesterification of the Sand Apple Oil (SAO) with ethanol in the presence of the calcined eggshell (catalyst) to produce ethyl ester and glycerol was optimized using Central Composite Design under the Response Surface Methodology at different temperatures (55, 60 and 65 °C) and time (60, 90 and 120 minutes). The Sand Apple Ethyl Esters (SAEE) was blended with Automotive Gas Oil (AGO) at 5 – 25% mix with 5% increment of sand apple ethyl-ester to evaluate the performance of a 5 hp.(3.73 kW) diesel engine using the blends at five loading conditions (0, 25. 50, 75, 100%). Data obtained was analyzed using ANOVA at $P < 0.05$ significant level. Engine performance tests were carried out to determine the torque, speed, exhaust gas temperature and fuel consumption rate. Results obtained showed that the torque, speed, exhaust gas temperature and fuel consumption rate of the test engine ranged from 6.50 – 6.60 Nm, 2795 – 2950 rpm, 385 – 400 °C and 2.93 - 5.00 $kg/s^{*}10^{-6}$, respectively for all the blends, while the corresponding values for AGO were 7.20 - 10.10 Nm, 2990 - 3000 rpm, 405 - 815 °C and 2.82 - 3.15 $kg /s^{*} 10^{-6}$, respectively. This study established that the performance of a diesel engine using 5 – 25% SAEE-AGO blends was similar to AGO. SAEE could, therefore, be suitable biofuel for use in the compression ignition engine (CIE).

Keywords: Biodiesel, Sand Apple, Ethyl-Ester, Transesterification, Blend

1.0 Introduction

Biodiesel is a cleaner burning alternative fuel to petroleum-based diesel fuel (Huang, *et al.* 2010).The successful introduction of biodiesel in many countries around the world has been accompanied by the development of standards to ensure high product quality and user confidence. Some biodiesel standards were developed by ASTM D6751 (2018) and EN14214 (2018). The biodiesel is characterized by determining its physical and fuel properties which includes density, viscosity, iodine value, acid value, cloud point, pour point, gross heat of combustion and volatility.

The advantages of biodiesel as diesel fuel are its portability, availability, renewability, higher combustion efficiency, lower sulphur, aromatic contents, higher cetane number and higher biodegradability (Demirbas, 2009).

However, biodiesel is not with out some disadvantages. These include its higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxide emission, lower engine speed and power, injector coking, engine compatibility, high price and higher engine wear (Demirbas, 2008). Biodiesel offers safety benefits over diesel fuel because it is much less combustible, with a flash point greater than 423 K comparedto 350 K for petroleum-based diesel fuel (Demirbas and Balat, 2006). Biodiesel has a higher cetane number (48-60) than diesel fuel (Balat and Balat, 2008), no aromatics, no sulfur and contains 10–11% oxygen by weight (Chhetri *et al.,* 2008). The cetane number is a commonly used indicator for the determination of diesel fuel quality, especially the ignition quality. It measures the readiness of the fuel to auto-ignite when injected into the engine. Ignition quality is one of the properties ofbiodiesel that is determined by the structure of the fatty acid methyl ester (FAME) component. In general, biodiesel compares well to petroleum-based diesel. Viscosity is the most important property of biodiesel since it affects the operation of the fuel injection equipment, particularly at low temperatures when the increase in viscosity affects the fluidity of the fuel (Bamgboye and Hansen, 2008). Biodiesel has a high viscosity leads to poorer atomization of the fuel spray and less accurate operation of the fuel injectors (Balat, 2008). Due to the presence of electronegative element oxygen, biodiesel has heating value of biodiesel is lower when comparedslightly more polar than diesel fuel; as a result, viscosity of biodiesel is higher than that of diesel fuel. The lower heating value (LHV) is the most common value used for engine applications. It is used as an indicator of the energy content of the fuel (Kulkarni *et al.,* 2008).

This study, therefore, intends to evaluate the performance of a compression ignition engine (CIE) fuelled with biodiesel produced from sand apple (*Parinaripolyandra*B.) oil using eggshell as catalyst keeping in mind the properties that could affect the performance.

2.0 Materials and Methods

2.1 Experimental set-up

A single cylinder, 3.68 kW diesel engine made by Kipor Machinery Company was used for the performance evaluation. The test was carried out in the Automation Laboratory of Mechanical Engineering Department, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. The diesel engine was coupled to a Hydraulic Dynamometer made by AL – Tech BK. An overhead water tank supported by a standing table was placed above the level of the dynamometer for cooling. Water flow rate was controlled by a needle valve mounted on the engine bed. The water was passed into the dynamometer through an air vent and discharged into the drain tank through a tap. Attached to the drain tank was a water pump that pumped the drained water back to the overhead tank to maintain constant head water supply into the dynamometer.

The quantity of water in the dynamometer absorbed by the power from the engine depends on the settings of the needle valve and tap. The 3.68 kW diesel engine shaft drove the paddle in the valve casing, churning up the water in the dynamometer. This casing was restricted from rotating at the same speed with the paddle by a spring loaded nylon cord that passes round the casing. The tension of the two springs was always equal as the dynamometer casing rotates. A damper, which was connected to the casing, was filled with thick oil. The angular position taken up by the casing depends on the torque and stiffness of the two springs. The angular displacement of the casing was proportional to the torque which was measured by the calibration of the arm of the dynamometer by a rotary potentiometer that fed the output into the input of TDII4 torque meter.

2.2 Testing Procedure

The diesel used in the experiment was obtained from the Nigerian National Petroleum Corporation (NNPC) fuel station, Ogbomoso. The engine was first operated with automotive gas oil filled inside burette or tank. The 3.68 kW diesel engine is shown in Plate 1, while the engine specifications was presented in Table 1. The engine was operated with Wide Open Throttle (WOT) on no load condition for 5 min. For each of the fuel blends tested, the engine was allowed to run for 2 min at half throttle and then increased gradually until it reached WOT. The engine was operated at no load, 25%, 50%, 75%and 100% loading conditions at every 2 min interval. In a similar manner,

the engine was loaded using sand apple ethyl ester blended with AGO having B5, B10, B15, B20 and B25 as recommended by (Shresta*et al.,* 2005; Oniya and Bamgboye, 2013).This method was used to obtain values for torques, speed, fuel consumption rate and exhaust temperature at no load, 25, 50, 75 and 100 % loading as recommended by Oniya and Bamgboye (2014).
To determine the stable torque range of the engine, preliminary test was carried out, where water flow into the dynamometer was allowed for 2 min during which the inlet valve control knob was used to regulate the inflow of water into dynamometer until a stable, desired torque was attained.

Plate 1: Experimental Set-up of Engine Test; Automation Laboratory from Mechanical Engineering Department; (LAUTECH), Ogbomoso.

Table 1: Specification of the 3.68 kW diesels engine Test

Engine parameter	Engine Specification
Maker	Kipor Machinery Company
Model	KM 178 F (A)
Type	Air Cooled diesel Engine
Rated power	3.6 kW (3.3 hp)
Rated speed	3000 rpm
Maximum power	3.68 kW (5 hp)
Number of cylinder	1
Valve clearance	-0.10 – 0.15
Cooling system	Air cooled
Lubricating No	SAE 10W – 30
Net weight	40 kg

Fuel capacity	3.5 litres

Source:TQTD110-TD115 Small Engine manual for Test Bed and Instrumentation

2.2.1 Determination of fuel consumption rate

The time for the engine to consume fuel was determined using Equation 1 as adopted by Oniya and Bamgboye(2014).

$$M_f = \frac{8\rho \, X \, 10^{-4}}{t} \quad (1)$$

where:

M_f = Fuel consumption rate (kg/s)

ρ= Density of fuel (kg/m^3)

t = Time taken (s)

2.2.2 Determination of fuel equivalent power

The equivalent power of fuel was determined using Equation 2 as adopted by Oniya and Bamgboye(2014).

$$P_f = H_g \times M_f \quad (2)$$

where:

P_f = Fuel equivalent power (W)

M_f= Fuel consumption rate (kg/h)

H_g = Heating value (J/kg)

2.2.3 Determination of brake power

The output of brake power P_B was determined as stated by Oniya and Bamgboye (2014) using Equations 3 and 4.

$$P_B = \frac{2\pi NT}{60} \quad (3)$$

where:

N = Speed (rpm)

T = Torque (Nm)

ω = °C(4)

The $P_B = T\omega$

where:

ω = angular speed (rad/s).

2.2.4 Determination of brake specific fuel consumption (BSFC)

The brake specific consumption measures the efficiency of an engine using fuel supply to produce work. This is given in Equation 5(Oniya and Bamgboye, 2014).

$$BSFC = \frac{M_f}{P_B} \quad (5)$$

where:

BSFC = brake specific fuel consumption (kg/kwh)

M_f = fuel consumption rate (kg/s)

P_B = brake power (kW)

2.2.5 Determination of brake thermal efficiency

The brake thermal efficiency was also determined using Equation 6 by Oniya and Bamgboye(2014).

$$\eta bth = \frac{P_B}{M_f \times H_g} X \, 100 \quad (6)$$

where:

ηbth = brake thermal efficiency (%)

P_B = Brake power (kW)

M_f = Fuel consumption rate (kg/h)
H_g = Heating value (J/kg)

3.0 Results and Discussion

3.1 Engine Performance Test

Engine performance test on AGO was presented in Table 2, while its performance on SAEE-AGO blends on B5, B10, B15, B20 and B25 were presented in Tables 3 –7. The Analysis of Variance (ANOVA) of the SAEE-AGO blends using Duncan Multiple Range Test (DMRT) was shown in Table 8. These tables determine the engine performance test on engine torque, engine speed, engine fuel consumption rate, engine exhaust temperature, fuel equivalent power, brake specific fuel consumption, brake power and brake thermal efficiency.

3.1.1 Engine torque

Table 2 showed the performance test obtained for 3.68 kW compression ignition engine using AGO. It was observed that at no loading condition, a torque of 7.2 Nm was developed and it kept increasing to a peak value of 10.10 Nm for 100% full loading condition.The engine torque for SAEE-AGO blends (B5, B10, B15, B20 and B25) are shown in Tables 3 – 7, respectively. The torque developed increases with increase in loading conditions and ranged from 6.6 to 8.5, 6.0 to 7.9, 5.70 to 7.50, 5.10 to 7.2 and 4.75 to 6.5 Nm, respectively. At 100% loading condition, the peak values for B5 to B25 were 8.5, 7.90, 7.5, 7.2 and 6.5 Nm respectively. The bottom line is that as the blends increase, engine torque developed decreases. This trend is similar to the findings of Oniya and Bamgboye (2014) who reported that 8.47 Nm peak value was recorded for Loofah-AGO blends at all loading conditions. The DMRT Stats tables are not needed in the resusys discussion showed that SAEE–AGO blends have No table 10 in paper significant effect on engine torque at 5% level of significance.

3.1.2 Engine speed

From Table 2, the speed of the engine on AGO decreased with increase in engine loading condition. When AGO was used, the engine developed highest speed of 3000 rpm at no load condition and lowest speed value of 2990 rpm at 100% full load condition. Similarly, at B5 to B25 in Tables .3 to 7, the engine speed decreased with increased in blends from the peak value of 2950 to 2795rpm at 100% loading conditions.

Table 2: Performance test on 3.68 kW diesel engines using AGO

neters	**Unit**	**Load**				
		No load	**25 %**	**50 %**	**75 %**	**100 %**
Torque	Nm	7.20	7.85	8.65	9.47	10.10
Speed	Rpm	3000	3000	2995	2995	2990
Exhaust-gas temperature	ºC	405	501	610	713	815
Fuel-consumption rate	kg/s	2.825×10^{-6}	2.875×10^{-6}	2.992×10^{-6}	3.058×10^{-6}	3.15×10^{-6}
Brake power	Kw	2.26	2.47	2.71	2.97	3.16
Brake specific fuel consumption	g/kWh	4.50	4.19	3.97	3.71	3.59
Fuel-equivalent power	W	125.46	127.68	132.87	135.80	139.89
Brake-thermal efficiency	%	1.79	1.93	2.04	2.19	2.26

Table 3: Performance test on 3.68 kW diesel engines using B5

neters	Unit	Load				
		No load	25 %	50 %	75 %	100 %
Torque	Nm	6.60	6.95	7.60	8.10	8.50
Speed	Rpm	2950	2950	2950	2945	2945
Exhaust-gas temperature	ºC	385	401	475	550	660
Fuel-consumption rate	kg/s	2. 925 x 10^{-6}	2.998 x 10^{-6}	3.108 x 10^{-6}	3.258 x 10^{-6}	3.442 x 10^{-6}
Brake power	Kw	2.04	2.15	2.35	2.50	2.62
Brake specific fuel consumption	g/kWh	5.16	5.02	4.76	4.69	4.73
Fuel-equivalent power	W	2.65	2.72	2.82	2.95	3.12
Brake-thermal efficiency	%	76.98	79.04	83.33	84.74	83.97

Table 4: Performance test on 3.68 kW diesel engines using B10

neters	Unit	Load				
		No load	25 %	50 %	75 %	100 %
Torque	Nm	6.00	6.40	7.00	7.45	7.90
Speed	Rpm	2900	2900	2900	2895	2895
Exhaust-gas temperature	ºC	350	390	440	510	600
Fuel-consumption rate	kg/s	3.092 x 10^{-6}	3.158 x 10^{-6}	3.258 x 10^{-6}	3.425 x 10^{-6}	3.583 x 10^{-6}
Brake power	Kw	1.82	1.94	2.13	2.26	2.4
Brake specific fuel consumption	g/kWh	6.12	5.86	5.51	5.46	5.38
Fuel-equivalent power	W	2.82	2.88	2.97	3.12	3.26
Brake-thermal efficiency	%	64.54	67.36	71.72	72.43	73.62

Table 5: Performance test on 3.68 kW diesel engines using B15

neters	Unit	Load				
		No load	25 %	50 %	75 %	100 %
Torque	Nm	5.70	6.20	6.90	7.15	7.50
Speed	Rpm	2850	2850	2850	2845	2845
Exhaust-gas temperature	ºC	345	380	430	500	580
Fuel-consumption rate	kg/s	3.292 x 10^{-6}	3.425 x 10^{-6}	3.658 x 10^{-6}	3.758 x 10^{-6}	3.925 x 10^{-6}
Brake power	Kw	1.70	1.85	2.06	2.13	2.23
Brake specific fuel consumption	g/kWh	6.97	6.66	6.39	6.35	6.34

Fuel-equivalent power	W	2.99	3.11	3.32	3.42	3.57
Brake-thermal efficiency	%	56.86	59.48	62.05	62.28	62.46

Table 6: Performance test on 3.68 kW diesel engines using B20

neters	**Unit**	**Load**				
		No load	**25 %**	**50 %**	**75 %**	**100 %**
Torque	Nm	5.10	5.80	6.40	6.95	7.20
Speed	Rpm	2850	2850	2850	2845	2845
Exhaust-gas temperature	ºC	300	350	385	435	400
Fuel-consumption rate	kg/s	3.667×10^{-6}	3.767×10^{-6}	3.925×10^{-6}	4.0×10^{-6}	4.167×10^{-6}
Brake power	Kw	1.52	1.73	1.91	2.07	2.15
Brake specific fuel consumption	g/kWh	8.68	7.84	7.40	6.96	6.98
Fuel-equivalent power	W	3.33	3.43	3.57	3.64	3.79
Brake-thermal efficiency	%	45.64	50.44	53.50	56.87	56.73

Table 7: Performance test on 3.68 kW diesel engines using B25

neters	**Unit**	**Load**				
		No load	**25 %**	**50 %**	**75 %**	**100 %**
Torque	Nm	4.75	5.00	5.50	6.10	6.50
Speed	Rpm	2800	2800	2800	2800	20795
Exhaust-gas temperature	ºC	270	300	340	375	400
Fuel-consumption rate	kg/s	4.425×10^{-6}	4.5×10^{-6}	4.6×10^{-6}	4.767×10^{-6}	5.0×10^{-6}
Brake power	Kw	1.39	1.47	1.61	1.79	1.90
Brake specific fuel consumption	g/kWh	11.46	11.02	10.29	9.59	9.47
Fuel-equivalent power	W	3.99	4.06	4.15	4.30	4.51
Brake-thermal efficiency	%	34.84	36.21	38.79	41.63	42.13

3.1.3 Engine exhausts gas temperature

The exhaust gas temperature in the 3.68 kW diesel engine at various loading conditions for AGO is presented in Table 2. The exhaust gas temperature increased with increase in the blends. The result showed that it increased from 405 to 815 º Cfrom no load to 100% full load in AGO. The values of exhaust gas temperature for SAEE - AGO blends obtained are shown in Tables 3 – 7. The results revealed that as the load increases, the exhaust gas temperature also increases and ranged from 401 to 660 º C, 350 to 600 º C, 380 to 580 º C, 350 to 400 ºC and 300 to 400 °C for B5, B10, B15, B20 and B25, respectively. When comparing SAEE- AGO blends to AGO, it was observed that the exhaust gas temperatures increase as the blend increases. The DMRT revealed that SAEE – AGO blends has significant effect (P< 0.05) onengine exhaust gas temperature.

3.1.4 Engine Fuel consumption rate

Fuel consumption rate at different loading conditions when the engine was using AGO was also presented in Table 2. It was observed that the consumption rate increased as the loading rate increases. The maximum fuel consumption rates of 3.15x 10^{-6} kg/s was obtained at 100% full loading condition. For SAEE – AGO blends, the consumption rate for B5 to B25 increased from 2.95 x $10^{-6}$to 5.0 x 10^{-6}kg/s when the loading condition increases. It was generally observed that the same trend was followed when AGO was used. The increase in fuel consumption rate in loading condition could be as a result of increase in mechanical and pumping losses. This is similar to the report of Wail and Khaled (2012) who observed that the fuel consumption of a diesel engine fuelled with waste cooking oil biodiesel blends increased as the loading condition increases. The DMRT showed in Table 8 revealed that SAEE - AGO blends has significant effect on the rate ofengine fuel consumptionat 5% level of significance.

3.1.5 Engine brake specific fuel consumption

The results of the engine break specific fuel consumption (BSFC) rate were presented inTable 2 for AGO. The BSFC on the 3.68 kW diesel engines decreased from 4.50 to 3.59 g/kWh when the loading condition increased. Similar trends were observed on engine BSFC when SAEE – AGO blends were used. The decrease in BSFC was observed in Tables 3 – 7 for B5, B10, B15, B20 and B25, respectively which ranged from 5.16 to 4.73, 6.12 to 5.38, 6.97 to 6.34, 8.68 to 6.98 and 11.46 to 9.47 g/kWh, respectively. As the blends increased, the brake specific fuel consumption rate decreased at all loading conditions. Prasad *et al*. (2009) observed that diesel had a lower specific fuel consumption rate compared to castor oil – AGO blends. revealed that SAEE – AGO blends has significant effect (P< 0.05) on engine BSFC.

3.1.6 Engine brake power

The engine brake power with the reference fuel, AGO was presented in Table 2.When used on 3.68 kW diesel engines, it increased from 2.26 to 3.16 kW when the loading condition increased from no load to 100% full loading condition. The same trend was observed using SAEE – AGO blends from no load to 100% full load. At B5, B10, B15, B20 and B25, the engine brake power increases and ranged from 2.04 to 2.62, 1.82 to 2.40, 1.70 to 2.23, 1.52 to 2.15 and 1.39 to 1.90 kW, respectively. It was observed that as the blends increased from B5 to B25, the engine brake power decreased from 2.62 to 1.90 kW at 100% loading condition. The DMRT revealed that SAEE – AGO blends have significant effect on brake power at 5% significance.

3.1.7 Engine fuel equivalent power of fuel sample

The results of the engine fuel equivalent power using AGO were also presented in Table 2. It was observed that when the load increased, the engine fuel equivalent power also increased. The engine fuel equivalent power increased using SAEE – AGO blends as the loading condition increases at all blends. At B5, B10, B15, B20 and B25 blends the engine fuel equivalent power increased and ranged from 2.65 to 3.12, 2.85 to 3.26, 2.99 to 3.57, 3.33 to 3.79 and 3.99 to 4.51 W, respectively. The same trend was observed when compared with AGO. As the blends increased from B5 to B25, the engine fuel equivalent power increased at all loading conditions. This agrees with Oniya and Bamgboye (2014) on performance characteristics of loofah biodiesel – AGO blends in 2.46 kW diesel engines that the maximum fuel equivalent power increased from 4576 W to 628 W at different loading conditions. The DMRT revealed that SAEE – AGO blends has significant effect (P< 0.05) on engine fuel equivalent power of fuel sample.

3.1.8 Engine brake thermal efficiency

The engine brake thermal efficiency (EBTE) results for AGO, as reference oil were presented in Table 2. It was observed that the EBTE increased when the loading conditions increases. The EBTE increased at no load from1.79 to 2.26% at full load. Results obtained were presented in Tables 3 – 7. It was observed that the EBTE increased, similar to AGO, when the loading conditions increases from no load to 100% load. It was also observed that the EBTE decreased when the blending rate increased. At B5, B10, B15, B20 and B25, the EBTE decreased and

ranged from 76.98 to 83.97, 64.54 to 73.62, 56.86 to 62.46, 45.64 to 56.73 and 34.84 to 42.13%, respectively. Among the blends, B5 was found to have the maximum engine BTE of 83.97%. The DMRT revealed that SAEE – AGO blends has significant effect on engine brake thermal efficiency at 5% level of significance.
The DMRT revealed that SAEE – AGO blends engine speed has no significant effect ($P< 0.05$) on engine speed. This shows that the sand apple biodiesel can be used as an alternative in a compression ignition engine.

4.0 Conclusion

This study examined the performance of a 3.68 kW compression ignition engine (CIE) fuelled with biodiesel produced from sand apple (*Parinaripolyandra*B.) oil using eggshell as catalyst. Specifically, the engine performance test on engine torque, engine speed, engine fuel consumption rate, engine exhaust temperature, fuel equivalent power, brake specific fuel consumption, brake power and brake thermal efficiency were determined. The engine was operated at no load, 25%, 50%, 75% and 100% loading conditions at every 2 min interval. In a similar manner, the engine was loaded using sand apple ethyl ester blended with AGO having B5, B10,B15, B20 and B25. Results of the study revealed that SAEE – AGO blends has significant effect at 5% level of significance on all the performance parameters examined.

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DETERMINATION OF FUEL PROPERTIES OF BIODIESEL OBTAINED FROM SAND APPLE SEED OIL (*Parinari Polyandra*)

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Abstract

The objective of this study was to determine the fuel properties of sand apple ethyl ester (SAEE) and its blends with Automotive Gas Oil (AGO).using eggshell as catalyst. Sand apple seed oil (SASO) obtained was characterized based on America Society for Testing and Material (ASTM D6751) to determine acid value, saponification value, iodine value, density, kinematic viscosity, flash point, cloud point and pour point of the oil. The fruits were processed and oil extracted using solvent extraction method. Raw eggshells were calcined at 800°C for 120 min in the muffle furnace. The Blends of SAEE and AGO at 5-25% with 5% increase in Biodiesel mix with 5 % increment of sand apple ethyl-ester. AGO was used as control. Fuel properties of the extracted oil, or the fuel properties of SAEE were determined and this SAEE is the biofuel. Data obtained was analyzed using ANOVA at 5% significant level. Results obtained shows the specific gravity of sand apple oil was 0.836 at 40°C while kinematic viscosity of SASO determined were 4.2 and 6 mm^2/s which is much higher than that of refined diesel (3.13 mm^2/s). The cloud and pour points obtained for fuel are 4.68 and 3.09℃. Flash point was 103℃ which fell within ASTM D93 oil (99 – 169°C) approved range. The results showed that the SASO oil is safer in terms of handling and storage and less hazardous. The heating value was 42.61 MJ/kg, slightly lower than that of diesel oil of 44.8 MJ/kg indicating that AGO has ability to produce heat of combustion than SAEE. The iodine value of SASO was found to be 80.71 g I/100g while acid value was determined to be 2.62 mgKOH/g, which was higher than that of ASTM D6751 of 0.5 mgKOH/g. The sulphur contents for SAEE – AGO blends were 0.006, 0.009, 0.014, 0.016 and 0.004%, respectively. The low sulphur values was an indication that hazardous sulphur dioxide emission of SAEE has considerably reduced. This study established that all the properties of biodiesel obtained from SASO, except acid value, fall within the ASTM specification for standard biodiesels could suitably be compared with those of fossil diesel.

Keywords: Biodiesel, Sand Apple, Properties, Ethyl Esters, Blend

1.Introduction

Biodiesel is becoming increasingly important due to diminishing petroleum reserve and the environmental consequences of exhaust gases from petroleum fuelled engines. Biodiesel, which is made from renewable sources, consists of the simple alkyl esters of fatty acids. As a future prospective fuel, biodiesel has to compete economically with petroleum-based diesel fuels. One way of reducing the biodiesel production costs is to use less expensive feedstock containing fatty acids such as non-edible oils, animal fats, waste food oil and byproducts of the refining vegetables oils (Veljkovic *et al.,* 2006).

The demand for crude petroleum oil in the world constantly increase to about 75 million barrels per day. This translates to about 7% annual increase (OPEC, 2009). Similarly, continuous increase in price and consumption of petroleum products coupled with political and social instability in developing countries, particularly in Nigeria, have created the need to produce alternative fuels that are renewable and have positive environmental benefit (Barnwal and Sharma, 2005). The dependence on these fossil fuels has led to an increase in environmental pollution and global warming (Janske and Romijn, 2008). Fortunately, non-edible vegetable oils, mostly produced by seed-bearing trees and shrubs can provide an alternative fuel for diesel engine. Recent researches on bio-renewable fuels were mostly focused on producing biodiesel from vegetable oils (Demirbas, 2008). Several biodiesel production methods have been developed, among which trans-esterification using alkali catalyst that gives high level of conversion of triglycerides to their corresponding ethyl ester (Openshaw, 2000). More attention have to be paid on non-edible oil seeds such as Sand apple oil (*Parinari polyandra* B.) that are grown in tropical and subtropical regions across the underdeveloped countries (Oyelade *et al.,* 2017; Odetoye *et al.,* 2014; and Bamgboye and Oniya, 2012).

Sand apple belongs to the family of *rosaceae* that is found in tropical savannah region of West Africa extending from Mali to Sudan. It is found mostly in Middle belt region and some parts of Southern states of Nigeria. It is generally noted that the fruit has been grossly underutilized either because of its non-edibility or due to lack of extensive research on its fruit and seed. The seed oil, though considered not edible, has been reported as suitable for alkyd resin production with desirable properties (Odetoye *et al.,* 2012). These properties include acid value, saponification value, iodine value, density, kinematic viscosity, flash point, cloud point and pour point of the oil. However, combustion of biofuels results in deposits formation which include carbon monoxides, surphur dioxide, volatile organic compound, and heavy metal that are harmful to human health and the environment (Gerpen, 2005). The properties also have serious effect to the engine by causing engine delay, deposit and particulate matter that led to poor engine performance. There is therefore a need to explore and investigate these properties in order to determine the suitability of the oil for use in Internal Combustion engines, hence the objective of this study.

2.Materials and Methods

2.1 Materials

Sand apple seed oil (SASO) extracted from sand apple seeds (SASs) in the Mechanical Engineering Laboratory of Ladoke Akintola University of Technology, Ogbomoso via solvent extraction method using petroleum ether as solvent was used in determining the properties outlined. Other materials are 50ml beakers, 5 ml conical flasks, pipette, Cannon Fensky capillary viscometer, stop watch, electric weighing balance, pyrometer, thermometer, cooling bath, Gallen Kamp Ballistic bomb calorimeter, 25 ml of diethyl ester and 25 ml of ethanol, potassium hydroxide.

2.2 Methods

2.2.1 Characterization of sand apple seed oil (SASO)

The sand apple oil obtained was characterized based on America Society for Testing and Material (ASTM D6751) to determine acid value, saponification value, iodine value, density, kinematic viscosity, flash point, cloud point and pour point of the oil as recommended by Oniya (2010), Abdul Rohman *et al.,* (2015) and various ASTM standards.

2.2.2 Determination of acid value of SASO

A 25 ml of diethyl ester and 25 ml of ethanol were mixed in a beaker. The mixture was added to 5 g of biodiesel in a conical flask and a drop of phenolphthalein as indicator was added to the mixture and shaking vigorously. Volume of 0.5M NaOH added was noted. Acid value was calculated as the percentage of acid present by stating the result in terms of oleic acid. Acid value was determined from Equation 1 (Oniya, 2010).

$$A_v = 14.1 \times \frac{V_o}{W_O} \quad (1)$$

where:

$A_v = Acid\ value$
V_O= Volume of 0.5M NaOH (ml)
W_O = sample weight, (g)

2.2.3 Determination of saponification value of SASO

The saponification value was determined by completely saponifying the oil. One gram (1g) of the oil sample was transferred into a flask and adds 10 cm^3 of 0.5M KOH (potassium hydroxide) and 5 m^3 of ethanol. Another flask was added with 20 cm^3 of 0.5M KOH without oil and used for blank determination. The two flasks were fitted with air condenser and reflux the contents on a water bath for 1 hr. The contents was cooled slightly, disconnected the condenser and rinse with distilled water. 10 to 13 drops of phenolphthalein were added to the contents of the two flasks and titrated with standard solution of 0.5M hydrochloride HCl. The saponification value was determined from Equation 2 (Oniya, 2010 and Abdul Rohman *et al.,* 2015).

$$S_v = \frac{(B-A)}{W} \times 28 \quad (2)$$

where:

S_v = Saponification value

B = volume of 0.5 M HCl used for blank, (ml)

A = volume of 0.5M of KOH used for sample, (ml)

W = weight of oil sample, (g)

2.2.4 Determination of iodine value of SASO

The iodine value was determined according to ISO 3761 (2005). One gram (1 g) of the biodiesel was poured into a conical flask and 10 ml of carbon tetrachloride was added to it. A 25 ml of Dam reagent was then added to the content in the flask using safety pipette in the fume chamber and mixed vigorously. The flask was placed in the dark for 2 h 30 min. At the end of this period, a 20 ml of 10% aqueous Potassium Iodide and 125 ml of water was added to the mixture with measuring cylinder. The whole content was treated with 0.1M sodium-thiosulphate solution until the yellow colour almost disappeared. A drop of 1% of starch indicator was added to the content in the flask and titrations continue with sodium-thiosulphate, until color of the content turns blue. The same procedure was used for blank test without biodiesel. The iodine value biodiesel was determined by the expression in Equation 3 (Oniya, 2010 and Abdul Rohman *et al.,* 2015).

$$I_v = \frac{12.69\ \times C\ (V_1) - (V_2)}{M} \qquad (3)$$

where:

I_v = Iodine value
C = concentration of sodium thiosulphate used (g/ml)
V_1 = Volume of sodium thiosulphate used for blank (ml)
V_2 = volume of sodium thiosulphate used for determination (ml)
M = mass of the sample (g)

2.2.5 Determination of kinematic viscosity of SASO

Kinematic viscosity of fuel sample was determined using Cannon Fensky capillary viscometer tube calibrated series obtained from Central Research and Diagnostic Laboratory, Tanke, Ilorin according to ASTM D445/446, (2017). The process was conducted by measuring the time required for a volume of fuel sample to flow by gravity through capillary of the viscometer. The fuel sample was poured into viscometer which was held vertically at room temperature of 28 °C and allowed to move to the upper meniscus. A stop watch was preset to know the time taken from upper meniscus to lower meniscus. The same process was repeated at temperature of 40°C three times and average value was obtained. The value obtained was then multiplied by the factor or path length of the viscometer. The viscosity V in m²/s was calculated from Equation 5, (Oniya, 2010).

$$V_k = kt \qquad (5)$$

where:

V_k = Viscosity (m^2/s)
k = the constant calibration of the viscosity (m^2/s^2)
t = time (s)

2.2.6 Determination of specific gravity of SASO

The specific gravity of the fuel sample was determined according to ASTM D1298, (2005) method using empty pyrometer weighed with electric weighing balance and denoted as W_1. A required fuel sample at 15 °C was poured into pyrometer and weighed as W_2. An equal volume of distilled water was weighed and denoted Ww. The specific gravity (SG) of fuel sample was calculated as in equation 4, (Oniya, 2010).

$$S.G = \frac{W_2 - W_1}{W_w - W_1} \quad (4)$$

where:

W_1 = weight of empty pycometer (g)
W_2 = weight of pycometer fuel sample (g)
W_w = weight of equal volume of distilled water (g)

2.2.7 Determination of flash point of SASO

The flash point was determined at the minimum temperature in which the vapour evaporated by the fuel samples when a test flame was held above the surface without the fuel catching the fire. Refusina Penky Martem flash point closed cup apparatus was obtained at Lubcon Oil Company, Ilorin, Nigeria. The test was conducted according to ASTM D93, (2018) method where a brass test cup fitted with cover was filled with sample. The sample was heated and stirred in a container. An ignition source was directed into the cup at regular increment of 2°C with simultaneous interruption of stirring until a flash that spread throughout the inside of the cup is seen; the corresponding temperature at this point is known as flash point.

2.2.8 Determination of sulphur content

Sulphur content of the sand apple oil produced was determined by the ASTM standard. Oil sample was poured into a high temperature combustion tube where sulphur is oxidized to sulphur dioxide (SO_2) in an oxygen rich atmosphere. Oil combustion gases were then exposed to ultraviolet rays. The SO_2 was then excited from which fluorescence was emitted as it returns to its stable state. The fluorescence detected by a photomultiplier tube and the signal was a measure of the amount of sulphur contained in this oil (ASTM, D6751, 2002).

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2.2.9 Determination of carbon content

Carbon content of the sand apple oil was determined by ASTM method using Conrad son residue that was specified by heating the product in a standard crucible with a burner, in such a way that the vapours which are freed were burned up within a specified time (ASTM D5291, 2018).

2.2.10 Determination of heating value of SASO

The heating value of fuel samples was determined according to ASTM D40, (2005). Gallen Kamp Ballistic bomb calorimeter was used to determine the heating or calorific value of the fuel. A required amount of fuel sample was burnt in a bomb calorimeter. Air in the system was replaced by pure oxygen. A maximum deflection of the galvanometer on the control box was recorded after using the samples. The effective heat capacity of the system was also determined using the same procedure but with pure and dry benzoic acid as the test fuel. The heating value was calculated using Equation 6 (Oniya, 2010).

$$H.V = \frac{Y(a_3 - a_1)}{Z} \quad (6)$$

Where;

$H.\ V$ = Heating Value
a_1 = Galvanometer deflection without sample
a_3 = Galvanometer deflection with sample
Y = Calibration constant
Z = mass of fuel sample (g)

The calibration constant (Y) is given by Equation 7:

$$Y = \frac{6.32w_1}{a_2 - a_1} \quad (7)$$

where;

Y = Constant
a_1 = Galvanometer deflection without sample
a_2 = Galvanometer deflection with benzoic sample
w_1 = mass of benzoic acid (g)

2.2.11 Determination of cloud point of SASO

Cloud point of SASO was determined according to ASTM D2500, (2015). The fuel sample was firstly poured into a test jar to a level approximately half full. A cork carrying the test thermometer was used as closed jar. The thermometer bulb was positioned to rest at the bottom of the jar. The whole test then placed in a constant temperature cooling bath on top of a gasket to prevent excessive cooling. At every 1°C, the sample was taken out and inspected for cloud then quickly replaced until crystal appears as cloud, using visual inspection in the clear fuel sample as cloud point (Oniya, 2010).

2.2.12 Determination of pour point of SASO

Pour point of the sample is the temperature below which the liquid loses its flowing characteristics. It was determined according to (ASTM D97, 2005) method where the fuel was cooled inside a cooling bath to allow the formation of crystal. At about 9°C above expected point, the test jar was removed and tilted for 5 sec. to check for surface movements. Fuel sample was observed at 3℃ intervals to flow. The lowest temperature at which the sample moves was noted as the pour point.

3 Results and Discussion

The properties of sand apple seed oil (SASO) were determined according to various recommendation stated. Inferences were also made with that of ASTM standards. Results of the study were presented in Tables 1.

Table 1: Physiochemical properties of sand apple and ASTM/EN oil

Properties	Sand apple oil	ASTM/EN
Iodine value (gI/100g oil)	80.71	120
Acid value (mgKOH/g)	2.62	0.5
Specific gravity	0.83	0. 98
Viscosity @ 40 ºC (mm^2/s)	4.2	1.9 – 6.0
Flash point (ºC)	103	93
Cloud point (ºC)	4.68	4.00
Pour point (ºC)	3.09	8.00
Heating value (MJ/kg)	42.61	39. 62

Are the values obtained once or is it replicated? Minimum of the replication should have been better and average reported stating the standard error

From the results obtained, iodine value of SASO was found to be 80.71 gI/100g compared to EN14214, (ISO 3761, 2005) standard oil which was 120 g I/100g. It was observed that iodine value of 120 gl /100 g (ASTM D6751, (2018) standard was higher than that of sand apple oil of 80 gl/100 g which indicated that it has higher unsaturated fat than SASO. The acid value of SASO was determined to be 2.62 mgKOH/g, which was higher than that of ASTM D6751, (2018) of 0.5 mgKOH/g. this result indicates the mass of potassium hydroxide, in milligrams, that is required to neutralize one gram of the fuel substance and is useful in determining the number of carboxylic acid functional groups on a molecule. Acid value is measured by dissolving a known amount of fuel in an organic solvent and titrating it with a solution of known concentration of KOH with phenolphthalein indicator.

The higher acid value of SASO indicated that SASO could be more corrosive to engine parts than that of ASTM D 6751, (2018) oil. However, ASTM standard has more suitability for lubrication under operating condition of engine than SASO oil but SASO can equally be subjected to some treatment to reduce the acidic value to make it suitable for engine operation.

The specific gravity of sand apple oil was 0.836 as presented in Table 1. This value is lower than that of loofah oil (0.88) as reported by Bamgboye and Oniya (2012). The specific gravity of soybean and rapeseed are 0.91 and 0.92 as reported by Ramsesh *et al.* (2008) and Rahmah *et al.* (2010), respectively. The specific gravity of SASO (0.83) and loofah oil (0.88) are not the same, which shows that their fluids characteristic are comparable and fell within the ASTM D792, (2015) standard. Results from similar studies showed that the specific gravity values of sunflower ethyl ester, soybeans ethyl ester and *jatropha* methyl ester as reported by Rao *et al*. (2008), Ramesh *et al*. (2002) and Rahman *et al*. (2010) were given as 0.86, 0.92 and 0.88, respectively. The soybeans ethyl ester value seems closer to the specific gravity of sand apple ethyl ester

At 40º C reference temperature, sand apple oil viscosity as shown in Table 1 was 4.2 mm^2/s, this value was slightly lower than that of loofah (6.2 mm^2/s) but higher than groundnut oil of 3.9 mm^2/s (Bamgboye and Onyia 2012).

The kinematic viscosity of SASO determined and ASTM D6751, (2018) oil were 4.2 and 6 mm^2/s which is much higher than that of refined diesel (3.13 mm^2/s). The higher kinematic viscosity of SASO could be because sand apple oil has higher molecular weight of triglyceride molecules. The pre-heating and transesterification process would significantly reduce the viscosity as reported by Oniya and Bamgboye (2014). The lower kinematic viscosity of SASO means that it exhibits a lower tendency of internal resistance to free motion and therefore less restricting tendency to flow.

While making inferences with results of other studies conducted earlier, it was observed that the kinematic viscosity for AGO was 2.95 mm^2/s is much lower than that of SASO. However the mean viscosity of SASO fell within the ASTM D6751, (2002) standard of 1.9 – 6.0 mm^2/s. The value obtained was lower than that of peanut ethyl ester, soybean ethyl ester; palm oil ethyl ester and sunflower ethyl ester were 4.9, 4.5, 5.7 and 4.6 mm^2/s respectively as earlier determined by Ramadhas *et al.,* (2004). This results mean SASO a lower tendency of internal resistance to free motion than these fuels and thus becoming a better fuel that in in winter and other colder environments.

The cloud and pour points obtained for sand apple oil are 4.68 and 3.09℃ , respectively. This is the temperature at which a fuel begins to form wax crystals. These values were lower than that of *jatropha curcas* of 4.00 and 8.00℃ as reported by Rao *et al.* (2008). The two seeds oil values indicated that the cold flow behaviour were fair when compared with 6.00^{o} C for diesel fuel (Bamgboye and Oniya, 2012). The lower the cloud point of SASO obtained indicates that the fuel is suitable in temperate environment because weather could be colder before crystals start to form. These crystals very easily clog up filters. Cloud point is directly attributed to the saturated methyl ester content because saturated fats solidify faster than unsaturated fats. Similarly, the lower the pour point indicates better the fuel for the same reasons seen in the cloud point. The results shows that the SASO would require as low as 3.09 ℃ before it could starts losing its ability to flow. The results also means the lower cloud and pour points of SASO may not require some treatment before use in the diesel engine during the cold weather as reported by Onyia (2010).

The flash point of SASO was 103 ℃ which fell within ASTM D93, (2018) oil (99 – 169^{o} C). According to Abdul Rohman *et al.,* (2015), flash point of a volatile liquid is the lowest temperature where the fluid evaporates to form a combustible concentration of gas. This result, therefore, indicates how easy SASO may burn. SASO thus gives off sufficient vapours which can be mixed with air and will ignite momentarily Fuel with higher flash points are less flammable or hazardous, making the fuel safer to handle and transport. The results obtained, therefore, showed that the SASO oil is safer in terms of handling and storage and less hazardous.

The heating value for SASO was 42.61 MJ/kg, slightly lower than that of diesel oil of 44.8 MJ/kg. Lower heat of combustion from fuel obtained from SASO means that less energy is released for combustion. It is, thus, a less efficient fuel source than that of diesel oil that exhibits relatively a higher heat of combustion. This indicates that AGO has ability to produce heat of combustion than sand apple seed oil. Similarly, the lower value of heating value of SASO showed that the carbon contents of SASO have considerably reduced during the transesterification reaction.

4 Conclusion

Fuel properties of sand apple seed oil (SASO) and its blends with Automotive Gas Oil (AGO).using eggshell as catalyst was characterized based on America Society for Testing and Material (ASTM D6751) to determine acid value, saponification value, iodine value, density, kinematic viscosity, flash point, cloud point and pour point of the oil. The present study shows that sand apple seed oil (SASO) from non-edible oil may serve as an alternative feedstock for the production of biodiesel with its blends to run compression ignition engine. The results of characterization of calcined eggshell from the study has established that 64% calcium oxide after calcination served as highly active and low-cost heterogeneous catalyst derived from the eggshell conversion of sand apple seed oil to biodiesel. Results of the study shows the specific gravity of sand apple oil was 0.836 at 40°C reference temperature, kinematic viscosity of 4.2 and 6 mm^2/s which is much higher than that of refined diesel, cloud and pour points of 4.68 and 3.09℃ and flash point of 103℃ which fell within ASTM D93 oil (99 – 169°C) approved range. The results showed that the SASO oil is safer in terms of handling and storage and less hazardous. Sand apple ethyl ester – AGO blends was thus observed to have significant effect on nearly all the fuel properties except pour point. The study, therefore, established that the biodiesel obtained from SASO could suitably be used in the compression ignition engine.

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CHARACTERIZATION OF EGGSHELL – A HETEROGENEOUS CATALYST IN THE TRANSESTERIFICATION OF SAND APPLE (*Parinari polyandra*) SEED OIL

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Abstract
The objective of this study was to characterize a low cost heterogeneous catalyst from the transesterification of sand apple (parinari polyandra B.) biodiesel using eggshell catalyst. Sand apple fruits were processed and oil was extracted using solvent extraction method. Raw eggshells were calcined at 800°C for 120 min in the muffle furnace. Surface properties (absorption wave number and calcium oxide composition) of the raw and calcined eggshell were characterized using Fourier Transformed Infrared Radiation (FTIR) and X-Ray Fluorescence (XRF). Transesterification of the Sand Apple Oil (SASO) with ethanol in the presence of the calcined eggshell (catalyst) to produce ethyl ester and glycerol and was optimized using Central Composite Design under the Response Surface Methodology at different temperature (55, 60 and 65° C) and time (60, 90 and 120 min). The reactants for the transesterification process were the raw SASO, anhydrous ethanol. 7g of catalyst derived from calcined eggshell was vigorously stirred with 55 ml of ethanol on magnetic stirrer to form ethoxide. The ethoxide was swiftly introduced into heated SASO and stirred on a reactor at a temperature of 65°C to produce biodiesel and glycerol as byproduct. The reaction time used was enough to allow perfect contact between the reagents and the oil during transesterification as the reaction mixture was continuously stirred at a constant rate. The transesterification reaction involved the use of 12 moles of alcohol to 1 mole of oil. Catalyst concentration used was 6% by weight of the SASO. The study shows that an oil yield of 53.13 % was obtained from sand apple kernels. Absorption wave number and calcium oxide composition of the catalyst were 2712.29 cm^{-3} and 64.31%, respectively. Ethyl ester yield of 90% was obtained from SASO. The values of Kinematic Viscosity (KV) at 40°C, Specific Gravity (SG), Flash Point (FP), Heating Value (HV), Cloud Point (CP) and Pour Point (PP) obtained for SASO were 4.20 mm^2/s, 0.93, 183°C, 42.60 MJ/kg, 4.63°C and 3.09°C, respectively. The corresponding values obtained for SAEE were 3.94 m^2/s, 0.91, 163°C, 20.50 MJ/kg, 4.85°C and 1.01°C, respectively. Similarly, at 40 ℃, KV, SG, FP, HV, CP and PP for blends of SAEE with AGO ranged from 3.50 - 3.90 mm^2/s, 0.90 – 0.91, 63 – 90°C, 0.90 – 0.91 MJ/kg, -3 to - 4°C and -7.50 to -15°C, respectively. This study established that SAEE blended with diesel in different proportion have significant effect on all the fuel properties observed except PP which has no significant effect at 5% level of significance.

Keywords: Biodiesel, Ethyl-Ester, Transesterification, Blend, Oil yield

1.Introduction

There are several methods of biodiesel production. These include dilution, pyrolysis and emulsification. However, these methods were noted with negative effects of high carbon deposit, incomplete combustion, increased lubrication from higher viscosity (Daniyan *et al.,* 2013). Biodiesel is commonly produced by the transesterification of vegetable oil or animal fat feedstock (Oniya and Bamgboye, 2014). The transesterification process can be classified into batch process, supercritical processes, ultrasonic and microwave methods. Chemically, transesterified biodiesel comprises a mix of mono-alkyl esters of long chain fatty acids. The most common form uses methanol (converted to sodium Methoxide) to produce methyl esters referred to as Fatty Acid Methyl Ester (FAME) as it is the cheapest alcohol available. Though ethanol can be used to produce an ethyl ester commonly referred to as Fatty Acid Ethyl Ester (FAEE), higher alcohols such as isopropanol and Butanol have also been used. Using alcohols of higher molecular weights improves the cold flow properties of the resulting ester, at the cost of a less efficient trans-esterification reaction (Bamgboye and Oniya, 2012).
A lipid trans-esterification production process is used to convert the base oil to the desired esters. Any free fatty acids (FFAs) in the base oil is either converted to soap or removed from the process, or they are esterified (yielding more biodiesel) using an acidic catalyst. After this process, unlike straight vegetable oil, biodiesel has combustion properties very similar to those of petroleum diesel that could replace it in most current uses. A by-product of the trans-esterification process is the glycerol (Wei *et al.,* 2004). Usually, crude glycerol has to be purified, typically by performing vacuum distillation. The refined glycerol (98% + purity) can then be utilized directly or converted into other products (Kusdiana *et al.,* 2007).

A catalyst is a substance that increases the rate of chemical reaction (catalytic force) without itself undergoing any permanent chemical change (Shruti *et al.,* 2012). The catalyst is capable of accelerating the reaction rate or to change the selectivity of the reaction, toward different product with respect to the situation when the reaction occurs in the absence of the catalyst. The role of catalyst is therefore to reduce the activation energy by providing another pathway for the reaction to occur so that the catalytic agent makes the reaction proceed faster and at lower temperature than non-catalyzed reaction. However, it should be noted that high yield of products can be obtained in the presence of the catalyst only when the reaction is run under kinetic control (Ayhan, 2005).

Catalysts are distinguished into homogeneous and heterogeneous catalysts (Shruti, *et al.* 2012). Where the reaction occurs in the same phase (homogeneous catalyst) but if it is in different phases (heterogeneous catalyst). Most of the processes using homogeneous catalysts occur in liquid form, while heterogeneous catalyst is always in solid form. Heterogeneous catalyst has a major advantage over the homogenous catalyst because at the end of reaction; the catalyst can be separated by simple filtration and re-utilized for the next reaction (Vyas, *et al.* 2009). Heterogeneous catalyst has good thermal stability, environmentally friendly, reusability, simple and cheaper compared to homogeneous catalyst that is difficult to recover from the reaction. The thrust of this this study was, therefore, to characterize heterogeneous catalyst (eggshell) from the transesterification of sand apple (*parinari polyandra B.*) biodiesel

2. Materials and Methods

2.1 *Materials*

Materials used in this study include Sand apple fruits, Eggshell, Muffle furnace, anhydrous ethanol, magnetic stirrer, reagents, mortar and pestle and 2mm sieve, and Spectrophotometer.

2.2 Preparation of Catalyst from Eggshell

Broken eggshells were collected from Uncle Willy bakery in Ilorin, Kwara State, Nigeria. The eggshells were washed and sun-dried on a platform for 1h. They were then grounded using mortar and pestle and sieved with 2 mm size. 180g of dried ground egg shell was measured into crucibles and put in a muffles furnace and subjected to high temperature above 800 ℃ for 2h to transform the calcium in the shell into calcium oxide (CaO); Niju *et al.* (2014). A sample in crucible was removed from muffles furnace after 24 h of cooling and placed in an air tight container to prevent oxidation. The characterization of the raw and calcined eggshell was determine using Fourier

Transformed Infrared Radiation (FTIR) and X-Ray Fluorescence (XRF) analyses in order to determined their surface characteristics and oxide composition, respectively as recommended by Feunte *et al.* (2003).

2.3 Fourier transformed infrared radiation (FTIR) analysis

Buck scientific model, M530 Quick Scan Dispersive Infrared Spectrophotometer was used for FTIR analysis. The raw and calcined eggshell samples were crushed with potassium bromide (KBr). The product was introduced into the equipment with sample holder; the spectra was displayed on the screen and printed out (Feunte *et al.,* 2003).

2.4 X- Ray fluorescence

Thermo Scientific XRF (Niton XL3t model) was used for this process. Sample of powdery eggshell was poured into the vial and closed with foil leather. The vial was then placed on the sample holder stand. An analyzer was set to Cu/Zn method which reads material as sample. The analyzer ray point was placed tightly on the sample vial and the reading button was pressed for 30 sec., then reading was taken. The analyzer automatically produced both the result and spectra and noted them on the computer attached.

2.5 Production of Biodiesel from Sand Apple Seed Oil

Biodiesel was produced from sand apple seed oil (SASO) by transesterification reaction. The reactants for the transesterification process were the raw SASO, anhydrous ethanol and calcined eggshell which was used as catalyst. The variables taken into consideration for the transesterification reactions were reaction temperature and reaction time. Seven grams (7g) of catalyst derived from calcined eggshell was vigorously stirred with 55 ml of ethanol on magnetic stirrer to form ethoxide. The ethoxide was swiftly introduced into heated SASO and stirred on a reactor at a temperature of 65 ^{o}C to produce biodiesel and glycerol as byproduct.

The experiments were conducted with temperatures ranged from 55 – 65 ^{o}C which are below the boiling point of ethanol. A maximum temperature of 65 °C was adopted for the reaction temperature as recommended by Alamu *et al.* (2007). Reaction time used ranged from 60 to 120 min, which were enough to allow perfect contact between the reagents and the oil during transesterification as the reaction mixture was continuously stirred at a constant rate. The transesterification reaction involved the use of 12 moles of alcohol to 1 mole of oil and this is more than the standard 3:1 alcohol to oil stoichiometric requirement. The reason for this is that the reaction was desired to proceed in the forward direction by shifting the equilibrium to the right as recommended by Gerpen *et al.* (2004). Catalyst concentration used was 6% by weight of the SASO. All these reaction conditions were based on the conditions of seed oil transesterification using heterogeneous catalysts derived from eggshells as suggested by Wei *et al.* (2004).

A constant volume of 70 ml of SASO was pre-heated and measured into the reactor (Roger *et al.,* 2005). 7 g of catalyst was mixed with 55 ml of ethanol and stirred vigorously. Thereafter, the formed product was swiftly introduced into the oil on the reactor and stirred vigorously for 2 h. 15 min. to the end of the reaction, 14 ml of distilled water (20% of initial volume of oil) was added to the mixture and stirred continued for next 15 min to aid formulation and easy separation of biodiesel as recommended by Oniya and Bamgboye (2014). The mixture was thereafter poured inside a separating funnel and allowed to stand for 24 h, glycerol which is a heavier liquid settled at the bottom and ethyl ester, which is lighter, was at the top (Figure 1). The glycerol was decanted in a container and biodiesel was stored in a sample bottle.

Figure 1: Separation of ethyl ester and glycerol obtained from transesterification process

Biodiesel product was washed with distilled water at 30% of the ester volume. The mixture was stirred vigorously with mechanical stirrer. Stirring was stopped after 10 min and poured into separating funnel for the next 48 h, the unreacted ethanol and glycerol that are present were decanted. It was washed three times to obtain a pure ethyl ester sample. Biodiesel produced was heated to 105 ^{o}C for 20 min to remove any water present and then stored for further analysis. The percentage of ester yield from sand apple was determined using Equation 1 as recommended by Oniya (2010).

$$Y = \frac{V_e}{V_r} \times 100\% \qquad (1)$$

where:

Y = yield of ethyl ester (%)
V_e = volume of ethyl ester produced (m^3)
V_r = volume of raw oil used (m^3)

2.6 Experimental Design

Central Composite Design (CCD) under Response Surface Methodology (RSM) in the design expert software 6.0.8 was used to evaluate yield of SASO produced. The dependent variable that was considered for this study was biodiesel yield while the independent variables considered were the temperature and time. The factors considered were; Temperature (A) and Time (B) while the response was Biodiesel yield (Y1). Data obtained from transesterification experiments of the SASO using calcined eggshell as catalyst were analyzed statistically. Analysis of Variance (ANOVA) was used to evaluate whether there is significant difference between the means of the values of reaction parameters at 5% probability level on biodiesel yield.

Thirteen (13) experimental runs were generated at random from the experimental design. The central composite design layout for biodiesel production is shown in Table 1 while Table 2 shows factors level selected for the transesterification experiment. Maximum yield was used to determine the optimum condition for the transesterification factors at a particular contact time, agitation rate and concentration. One -factor-at- a- time method was used to study the effect of factors after obtaining the optimum condition. The effect of the reaction temperature from 55 – 65℃ on the yield of the SASO was investigated with the optimum value of obtained at interval of 5^{o} C. Effect of the reaction time from 60-120 min on the yield of SASO was also investigated with the optimum value obtained at interval of 30 min.

Table 1: Central Composite Design Layout for Biodiesel Production

Run	Factor Temperature (℃)	Factor B time (min)	Response biodiesel yield %
1	55.00	60	
2	55.00	60	
3	55.00	60	
4	60.00	90	
5	60.00	90	
6	60.00	90	
7	60.00	90	
8	55.00	60	
9	65.00	120	
10	65.00	90	
11	60.00	60	
12	60.00	90	
13	60.00	90	

Table 2: Factors Level Selected for Tranesterification

Factors	Units	Level	
		Low	High
Temperature	ºC	55	65
Time	Min	60	120

2.7 Development of Blends of Sand Apple Biodiesel with AGO

Petroleum diesel fuel otherwise known as Automotive Gas Oil (AGO) used in the blends was obtained from NNPC fuel station, Ogbomoso. Biodiesel blends were produced from SASO blended with petroleum diesel fuel in volume basis. The blending ratios are:

i) Biofuel at 5% of SAEE and 95% AGO by volume, (B5)
ii) Biofuel at 10% of SAEE and 90% AGO by volume, (B10)
iii) Biofuel at 15% of SAEE and 85% AGO by volume, (B15)
iv) Biofuel at 20% of SAEE and 80% AGO by volume, (B20)
v) Biofuel at 25% of SAEE and 75% AGO by volume, (B25)

3 Results and Discussion

3.2 Characterization of Eggshell using FTIR and XRF

The results of FTIR and XRF analyses of the prepared catalyst (calcined eggshell) are discussed in 3.1.1 and 3.1.2, respectively.

3.2.1 FTIR analysis of raw and calcined eggshell

The FTIR analysis of the raw eggshell and calcined eggshell are shown in Figures 2 and 3, respectively. Prominent peaks identified on the spectra of the raw and calcined eggshell are presented respectively in Tables 2 and 3. The peaks observed in the raw eggshell ranges from 638.5 - 3891.0 cm^{-1} and percentage transmittance ranged between 5 and 20 (% T), while the peaks observed in the calcined eggshell ranges from 646.4 - 3871.0 cm^{-1} and their percentage transmittance ranges between 20 and 60 (% T). Also the wave number ranges from 1000 cm^{-1} – 4000 cm^{-1}. Different types of bonds such as O–H stretching vibration, C-H stretching vibration C=C vibration and C-C vibration, C≡C vibration were observed to occur between the bands. The C=O stretching is of lactone, ketones and carboxylic anhydrides. The infrared of the raw eggshell peak at 3616 cm^{-1} was unstable with O-H stretching vibration due to the presence of carboxylic compound and high amount of protein. Reverse was the case for calcined egg shell (Figure 3), which has a stable condition with strong intensity of OH up to the state of 3342 cm^{-1} that has weaker intensity and less broad band than O-H and amine. At 3,000 – 2,850 cm^{-1}, the calcined eggshell has carbon which is hybridized with convenient dividing line between C-H stretching vibration bond and preceding type but in raw eggshell, the C-H bond was medium. Raw eggshell was more stable with hydrogen bond form at 2,724 cm^{-1} with a dipolar group having large amount of protein but in calcined eggshell, the protein had been vapourized and weak. From 1,645.7-1,608.6 cm^{-1} the spectra shows the presence of strong intensity in both raw sample and calcined eggshell with presence of carbon to carbon double bond noted. At 1,614, 1,506 and 1,465 cm^{-1} carbon to carbon vibration in the aromatic ring with C-H bending and C-H loop at 638 cm^{-1}. The disappearance of O-H stretching in the calcined sample indicated the water molecules in the sample had been removed to the minimum. This results was similar to the observations of Rafique and Nasir (2013) in an earlier study.

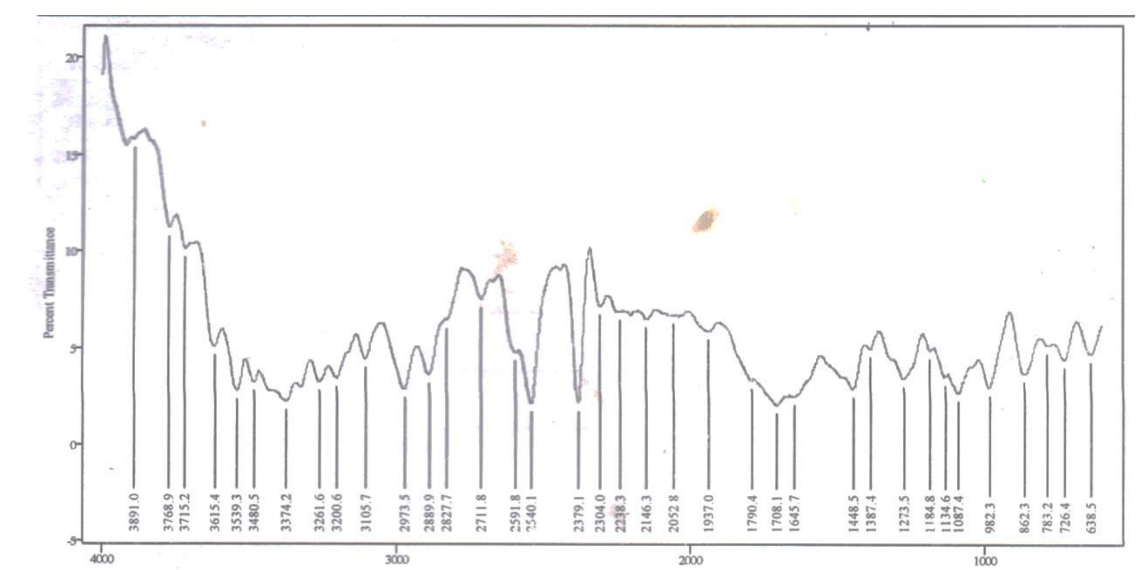

Figure 2: Raw eggshell spectra

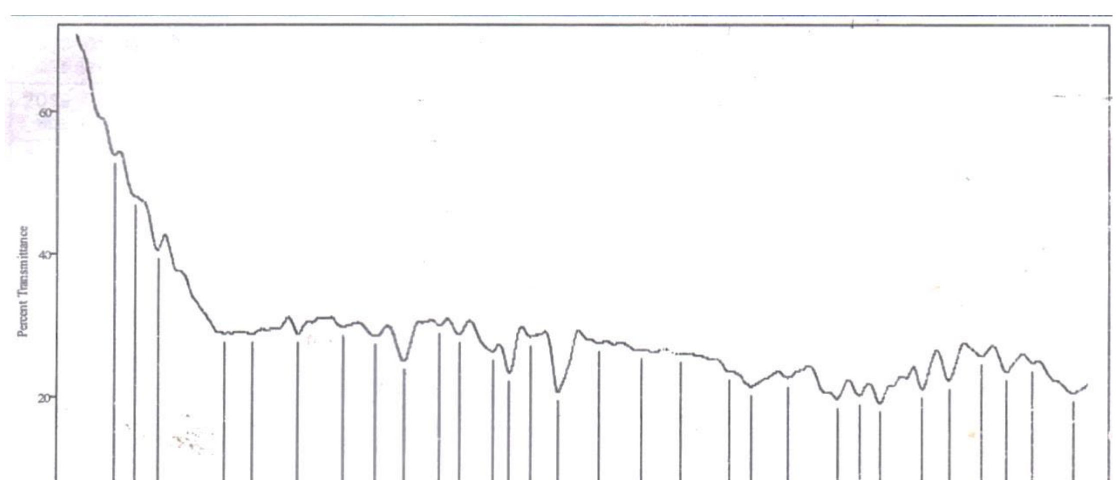

Figure 3: Calcined eggshell spectra

Table 2: Classification of wavenumber for egg shell using FTIR analysis

Raw eggshell wavenumber (cm^{-1})	Calcined eggshell wavenumber (cm^{-1})
3339.3 – 3374.2	3407.3 – 3355.1
2973.5	2995.1
2827.7 – 2591.8	2899.2 – 2712.9
1790.4 -1645.7	1802.5 – 1608.6
982.3 - 862.3	1066.2 – 871.9

Table 3: Result of absorption wavelength capacity for eggshell using FTIR

S/N	Raw egg shell Wave number (cm^{-1})	Calcined egg shell wave number (cm^{-1})	Residual	Band assignment and remark	Shift in peak
1	3339.3	3407.3	+68	O -- H stretching vibration	Upward
2	3374.2	3355.1	- 19.1	O -- H stretching vibration	downward
3	2973,5	2995.1	+21.6	C -- H stretching vibration	Upward
4	2827.7	2899.2	+71.5	C -- H stretching vibration	Upward
5	2591.8	2712.9	+120.1	C -- O stretching vibration	Upward
6	1790.4	1802.5	+12.1	C = O vibration	Upward
7	1645.7	1608.6	- 37.1	C = C vibration	Downward
8	982.3	1066.2	+83	C = C vibration	Upward
9	862.3	871.9	+9.6	C ≡ C vibration	Upward

3.3 X- Ray Fluorescence (XRF) analysis of raw and calcined eggshell

X- Ray Fluorescence results showing the chemical and oxide composition of raw and calcined eggshell produced are presented in Tables 4 and 5, respectively. The composition of elements recorded in the tables shows that the calcium oxide ratio of raw eggshell which was initially 53.265 increased to 64.305 in the catalyst (calcined eggshell) produced. The increased in ratio of calcium oxide is attributed to decomposition of eggshell above 800 ℃. This agreed with earlier observations of Viayan *et al.* (2010). It was observed that at 700 ℃ for 2 h, eggshell contains $CaCO_3$ as major phase and CaO as minor phase.

Table 4: Result of eggshell Chemical Composition using XRF

Elemental composition	Raw eggshell	calcined eggshell
Al	0.313	0.421
L.O.I	57.502	52.109
Si	0.602	0.493
P	1.254	0.117
S	1.867	0.591
Cl	0.117	0.081
K	0.173	0.101
Ca	38.046	45.932
V	0.01	0.011
Fe	0.029	0.026
Sr	0.064	0.07
Ba	0.022	0.037

Note: L.O.I - Loss on Ignition

Table 5: Oxide composition of the raw and calcined eggshell

Oxide composition	Raw eggshell	Calcined eggshell
Fe_2O_3	0.041	0.037
MnO	NP	0.014
CaO	53.265	64.305
Al_2O_3	0.591	0.795

SiO_2	1.289	1.056

Note: NP - Not Present

It was observed that water and organic materials were removed below 600 ℃ but carbon dioxide was lost between 700 - 800 ℃ . The Loss on Ignition (L.O.I.) of the raw eggshell was 57.5% and decreased by 5.4% in the catalyst. The decrease in L. O. I. after calcination could be attributed to dehydroxylation of the catalyst during production process as observed by Viayan *et al.* (2010).

3.4 Biodiesel Yield from SASO

The results of transesterification are presented in Table 6. The maximum biodiesel yield of 90% was obtained at reaction temperature of 65 °C and time of 120 min, while the minimum yield of 70% was obtained at temperature of 55 °C and time of 60 min. The percentages of biodiesel yield obtained from sand apple oil transesterification in this study showed that sand apple is promising oil for biodiesel production as compared with other vegetable oil crop such as soybean (20%), *jatropha* (99%), sunflower (43%) and canola (40%). These findings were similar to what Viayan *et al.* (2010) obtained. The variation in biodiesel yield values presented in Tables 6 indicates the temperature and time of reaction considerably affected the sand apple biodiesel yield. The Analysis of Variance (ANOVA) of biodiesel yield from SASO transesterification using calcined eggshell as catalyst is shown in Table 7. The model F-value of 12.53 implies the model was significant and there is only a 0.15% chance that a model "F-value" of this magnitude could be due to noise. Values of "prob>F less than 0.05 indicate the model terms are significant and values greater than 0.10 indicate the model term are not significant.

Table 6: Results of experimental design for transesterification of SASO

Run	Factor A Temperature (℃)	Factor B Time (min)	Response Biodiesel yield (%)	Predicted Value (%)
1	55.00	90	70	80.58
2	55.00	90	76	74.99
3	55.00	120	78	78.49
4	65.00	60	72	73.13
5	60.00	90	75	77.78
6	60.00	120	80	79.1
7	60.00	90	72	73
8	55.00	60	72	73
9	65.00	120	90	89.36
10	60.00	90	78	77.1
11	60.00	90	77	77.78
12	60.00	60	70	69.1
13	60.00	90	78	77.78

Table 7: ANOVA for response surface model on biodiesel yield

Source	Sum of square	DF	Mean square	F value	Prob>F	Comments
Model	256.82	3	85.61	12.53	0.0015	*Significant*
A	38.97	1	38.97	5.70	0.0407	*Significant*
B	181.85	1	181.85	26.62	0.0006	*Significant*
AB	36.00	1	36.00	5.27	0.0473	*Significant*
Residual	61.48	9	6.83			*Significant*
Lack of fit	35.48	5	7.10	1.09	0.4795	*Not significant*
Pure error	26.00	4	6.50			
Cor total	318.31	12				

In this case A, B and AB are the significant model terms. The "lack of fit F- value of 1.09 implies that the lack of fit is not significant relative to the pure error. There is a 47.95% chance that a "Lack of fit F-value" this large would occur due to noise. Standard deviation of 2.61, mean of 76.77; C.V of 3.40; R^2 of 0.8068; Adjusted R^2 of

0.7425; predicted R^2 of 0.5122, and adequate precision of 11.531 were obtained. "Adequate precision" measure the signal to noise ratio and value greater than 4 is desirable. The ratio of 11.531 obtained in this study indicated an adequate signal and this model can be used to navigate the design space. The final empirical model equation in terms of coded factor for the yield is given in Equation 2:

$$BD_y = 76.77 - 2.21 + 4.77B - 3.00AB \qquad (2)$$

where:

BD_y = Biodiesel Yield
A = Temperature
B = Time

From the coded factor, it can be seen that A (temperature) has negative coefficient which implies that increase in temperature would lead to decrease in value of the yield, while B (time) has positive coefficient implying that increase in time would lead to increase in value of the yield. Figure 4 shows the 3-D response surface plot representing the effect of temperature and time while keeping the mole ratio constant. The curvature nature of the surface plot indicates effect of mutual interaction between time and temperature. The 3-D plot of yield indicated mutual interaction effect of temperature and time on biodiesel yield also showed that an increase in time will lead to increase in biodiesel yield. The results of the diagnostic case studies for biodiesel yield were shown in Table 8 and Figure 6. The actual values on the table represent the amount of biodiesel yield from SASO while the predicted values represent the values from the model equation.

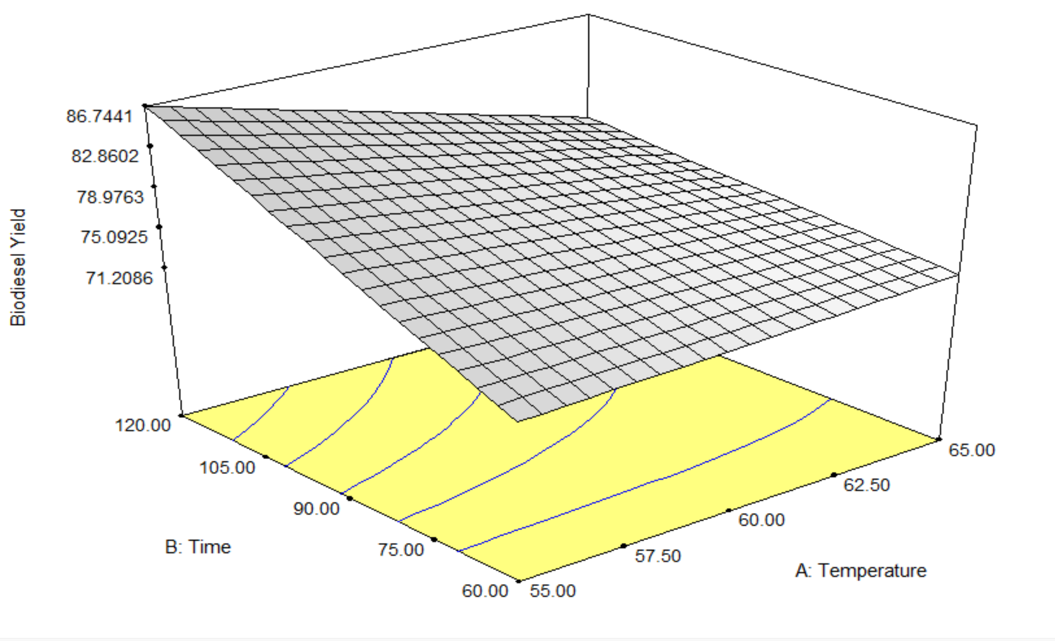

Figure 4: 3-D plot of yield with respect to temperature and time

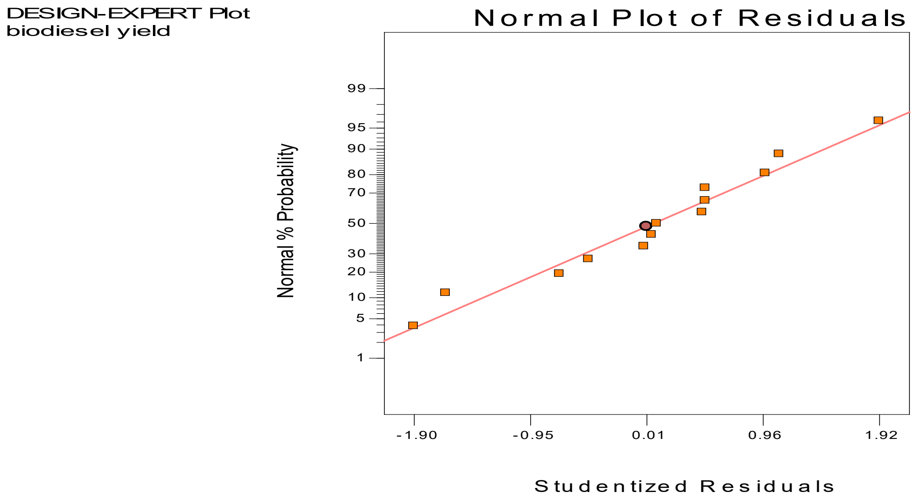

Figure 5: Biodiesel yield plot of residual

Table 7: Diagnostic case studies for yield (%)

Standard order	Actual value	Predicted value	Residual
1	72.00	71.21	0.79
2	72.00	72.79	-0.79
3	90.00	86.74	3.26
4	78.00	76.33	1.67
5	80.00	79.89	0.11
6	76.00	73.65	2.35
7	70.00	70.03	-0.027
8	80.00	83.51	-3.51
9	75.00	76.77	-1.77
10	78.00	76.77	1.23
11	77.00	76.77	0.23
12	78.00	76.77	1.23
13	72.00	76.77	-4.77

The residual showed the deviation of the actual from the predicted values. The negative value of the residual indicates that the predicted value is greater than the actual value while the positive value implies that the actual value is greater than the predicted value as observed by Viayan *et al.* (2010).

3.5 Effect of reaction temperature on biodiesel yield from SASO

Table 6 above presents the reaction temperature and time. The rate of reaction temperature is indispensible and need to be controlled in the transesterification process. Generally, the rate of reaction temperature used was below the alcohol boiling point (78ºC) so as to prevent its evaporation during transesterification reaction. Figure 6 shows that when the reaction temperature increased, the yield of ethyl ester of sand apple oil also increased. At low reaction temperature of 55ºC, the free fatty acid conversion of 60% was achieved until it reaches optimum temperature of 65 ℃ when 90% of biodiesel yield was obtained. The conversion did not improve much with further increase in temperature which means that the reaction temperature attained the equilibrium position at 65℃ . Figure 6 can testify the suitable reaction temperature for conversion of free fatty acid was 65℃.

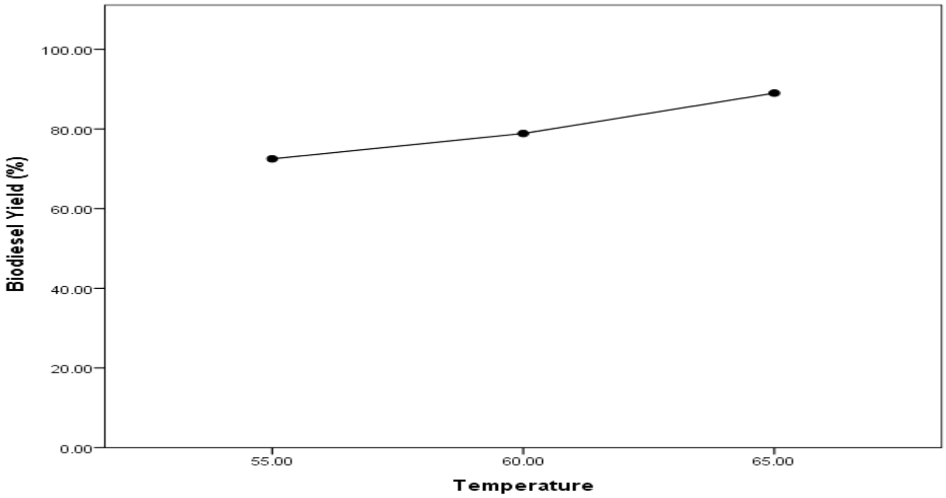

Figure 6: Effect of reaction temperature on biodiesel yield

3.6 Effect of reaction time on biodiesel yield

The influence of reaction time is presented in Figure 7. The influence of reaction time is very important in the transesterification of free fatty acid. The minimum of 70% yield of biodiesel was obtained when the time expended was 60 min. It was observed that the yield of conversion of free fatty acid of was 90% when reaction time increased to 120 min and SAEE keep increasing when the time increased. The yield of 80% was observed when reaction time increased to an interval of 30 min. The equilibrium conversion of FFA obtained for any further increase in reaction time to 120 min was 90%. Any further increase in time did not improve but rather decreased the yield.

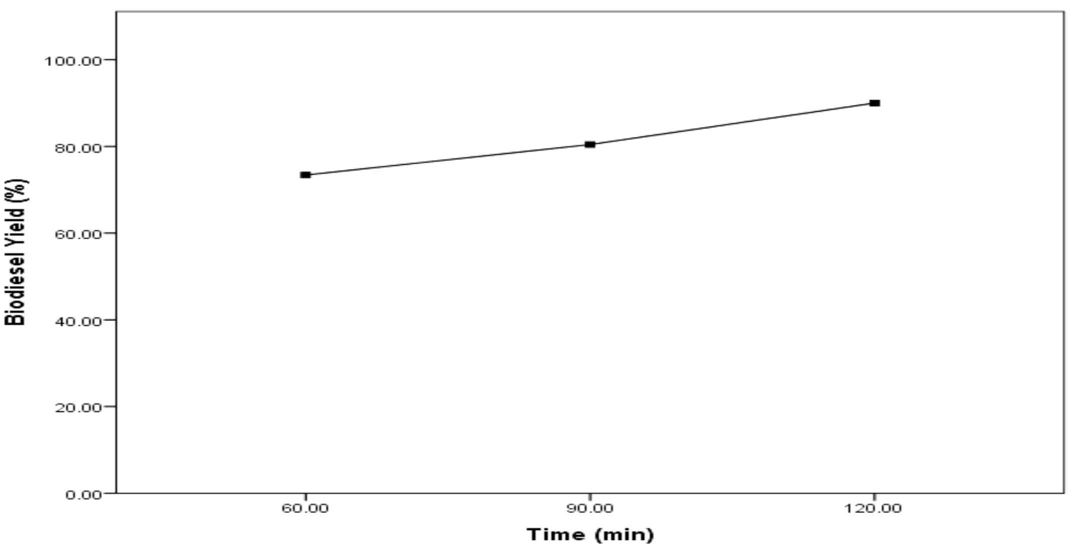

Figure 7: Effect of reaction time on biodiesel yield

4.0 Conclusion

This study characterized heterogeneous catalyst (using eggshell) from the transesterification of sand apple (*parinari polyandra B.*) biodiesel using solvent extraction method. The surface properties (absorption wave number and calcium oxide composition) of the raw and calcined eggshell were characterized using Fourier Transformed Infrared Radiation (FTIR) and X-Ray Fluorescence (XRF) under the Response Surface Methodology at different temperature (55, 60 and 65^{o} C) and time (60, 90 and 120 min). The study shows that an oil yield of 53.13 % was obtained from sand apple kernels. Biodiesel produced from SASO was blended with petroleum diesel fuel various proportions by volume. The values of Kinematic Viscosity at 40^{o}C, Specific Gravity, Flash Point, Heating Value, Cloud Point and Pour Point obtained for SASO were 4.20 mm^2/s, 0.93, 183°C, 42.60 MJ/kg, 4.63°C and 3.09°C, respectively. This study established that SAEE blended with diesel in different proportion have significant effect on all the fuel properties observed except PP which has no significant effect at 5% level of significance.

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INSTRUMENTATION SYSTEM FOR DRAUGHT MEASUREMENT AND STAKE COUNTING OF A CASSAVA PLANTER

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Abstract
Accurate measurement of draught is important for determining power requirement of a cassava planter and selecting appropriate tractor as well as choosing the forward speed to operate the planter. It is also necessary to know the number of stakes cassava planter plants per time. Therefore, an instrumentation system was assembled for simultaneous measurement of draught and the number of stakes planted per time. The system consists of a 5-ton load cell, a load cell amplifier, opto-coupler module, micro-controller, LCD display, SD-card shield and the connection cable. The system is installed between the tractor and the cassava planter with the aid of a bracket which serves as a linkage between the planter and the draw-bar of the tractor. An experiment was carried out on a tilled (flat) sandy clay loam soil to determine the effect of tractor forward speed on draught and number of stakes planted per time. In the experiment, five forward speeds of 1.5, 1.8, 2.1, 2.3 and 2.6 km/h were used at soil depth of 100 mm. The results showed an exponential relationship between forward speed and draught in which draught ranging between 24.91 and 744.44 N increased with an increase in forward speed. Planting rate varying between 30 and 42 stakes per minute were recorded at forward speed ranging between 1.5 and 2.6 km/h. Conclusively, the instrumentation system was tested and found suitable for the measurement and recording tasks it was developed for with good correlation between forward speed and draught as well as the number of stakes planted per time.

Keywords: Instrumentation, measurement, draught, planting rate, cassava planting.

1. Introduction

Accuracy in measuring parameters is key in research and development of farm machinery. It is required in order to provide reliable data for farm machinery industries to mass produce efficient machines for agricultural production. This can be achieved through instrumentation which involves the use of computerized instruments and electronic system. Instrumentation was defined by Haslam *et al.*(1993) as the application of instruments for monitoring, sensing and measurement. Its purpose may be product testing and quality control; monitoring in the interest of health safety or costing; part of a control system or research and development. Various types of instrumentation systems especially the mechanical ones have been in use but there is an increasing usage of computer and electronic equipment (Haslam *et al.*, 1993). The major components of the electronic instrumentation system are load cells, strain gauges, sensors and transducers (Usher and Keating, 1996; Haslam *et al.*, 1993; Suwanee *et al.*, 1999). The use of instrumentation systems varies from one area of life to the other, but in agriculture, instrumentation system is applicable almost in all aspects of agriculture starting from farm surveying to processing and storage in terms of monitoring and control, even in laboratory experiment.

Owende and Ward (1997) developed a towed ring which was a low-cost data acquisition system for tillage tool to measure draught, vertical force reaction, moment about the vertical axis, depth and speed. The main components of the towed ring include a data logger with a portable computer, tensile load cell, chain-driven tacho generator and speedometer units for recording and monitoring speed respectively, a linear potentiometer for sensing depth and a two-component octagonal ring transducer for measuring moment and vertical force reaction in the shank of the mounted tool.

John *et al.* (2007) used a pressure transducer to assess the soil post load response to 1,338 kg boige striking the post at 33km/hr. Cone penetrometer that consists of a load cell had been widely used in tillage and off-road mobility researches as an indicator of soil strength and density characteristics (Nader –Boldaji*et al*., 2008; Manuwa and Ale, 2011). In a soil – tool interaction study reported by Mardani*et al.* (2010), the instrumentation system used for data acquisition system was made up of some sensor outputs interfaced to a computer system. It was reported by Mamman *et al.* (2002) that the draught of model chisel plough in a laboratory soil bin by the use of bonded electric resistance wire strain gauges to measure the horizontal component of working resistance in the direction of motion. An extended octagonal Rig Transducer (EORT) was used to measure the horizontal and vertical reaction forces generated from soil tool interaction on the field (Pitla *et al.*, 2009). The EORT consisted of a machine block made of AISI 1045 alloy steel. An instrumentation system was also developed by Ale *et al.* (2013) to measure the values of draught of a mouldboard plough at varying speed forward speeds and compaction characteristics. The system consists of a 10-ton load cell that was interfaced with a computer system and sensor outputs, strain gauge amplifier and a data logger.

In the area of precision for seed planting, there are devices that can monitor the quantity and quality of planting in terms of the number of seeds planted per hectare per time. The monitoring of metering quality could be technically done by photoelectric effect, piezoelectric effect and high-speed photography (Hu and Li, 2005; Soyoye, 2018). In the single chip micro computer technology, infra-red photoelectric sensors are installed near the furrow openers to monitor the performance of the planter (Gong, 2008). Kocher *et al.* (1998) and Soyoye (2018) used optoelectronics technology to detect the uniformity of row spacing and automatic counting of seeds planted. An automatic monitoring system for direct seeding was designed by Zhang and Zhao (2008). With the development of electronics and sensors, the following methods are applicable for quality and quantity measurement. The electromagnetic induction method that is based on Faraday's law of electromagnetic induction; magnetic resistance effect method which utilizes the changing characteristics of materials resistance under magnetic field; hall effect method that is achieved by measuring the electromotive force; the magnetic resistance imaging which is by absorption or radiation of a certain frequency of electromagnetic wave in the magnetic field and the magnetic optical method which utilizes magneto optical and magneto-structure effects. This method is unique because of its adaptability to harsh environment (Soyoye, (2018). Accurate measurement of draught is important for determining power requirement of a cassava planter and selecting appropriate tractor as well as choosing the forward speed to operate the planter. It is also necessary to know the number of stakes cassava planter plants per time. Therefore, this study is on the assembly and performance evaluation of an instrumentation system cassava planter for draught measurement and counting of planted stakes.

2. Materials and Methods

2.1 Instrumentation System

The Instrumentation system for the automatic measurement of draught and the electronic counting consists of a load cell and the data acquisition components which include load cell amplifier, opto coupler module, Micro-Controller, LCD display, SD-card shield and Cable.

2.1.1 Load Cell

A 5 tons load cell (Figure 1) of no. 091209770 and output 2.005mV/V- (TM AUTO INSTRUCO, LTD) was used for the soil draught measurement.

2.1.2 Data Acquisition System

The data acquisition system (Figure 2) consists of the load cell amplifier that performs the function of amplification of electronic signal from the load cells; opto-coupler module for light emitting; micro-controller for precise motion control; LCD display for electronic digital display of values as measured by the system; SD-card shield for data storage and cable for wire connection between the system and the tractor. The system was designed to be powered by the battery of the tractor.

2.1.3 Installation of the load cell and Circuitry Works of Instrumentation System

The load cell was installed on the frame of the cassava planter by the use of brackets as presented in Figure 3. The components of the system were circuited at the Instrumentation Laboratory of the Department of Physics, Federal University of Technology, Akure. The circuit diagram of the system is presented in Figure 4.

2.1.4 Calibration of the Instrumentation System

To ensure the accuracy of the measurements, the instrumentation system was calibrated in advance of being used for force measurement using the dead weight method (Figure 5).

2.2 Field Performance Evaluation of the Cassava Planter

The performance evaluation of the cassava planter was carried on the teaching and research farm of Federal University of Technology, Akure, Nigeria. The performance evaluation to determine the effect of the draught and the power requirement of the planter. In the experiment, tractor forward speeds of 1.5, 1.8, 2.1, 2.3 and 2.6 km/h were used at the constant furrow depth of 100 mm. At each of the forward speed, the soil draught was electronically measured using the on-the-go soil draught measuring instrumentation system developed for this research purpose. Details of the soil preparation, soil measurements and analysis, method of data analysis and the evaluation procedure are presented below.

2.3 Soil Bulk Density and Moisture Content

Soil samples were collected from the depth of 0-5, 5-10 and 10-15 cm by the use of a core sampler of 5.8 cm diameter and 5 cm height. The core sampler was driven into each depth of the soil and the collected soil was kept in an air tight polythene bag to avoid moisture loss. The sample was oven dried and weighted. The oven dried soil was allowed to cool for one hour. The bulk density was determined using the standard Equation 1. The moisture content of the soil was taken using a soil moisturemeter at the soil depth of 5, 10 and 10 cm.

$$\text{Bulk Density} = \frac{Mass(g)}{Volume(cm^3)} \qquad (1)$$

3. Results and Discussion

3.1 Result of the Calibration Test of the Instrumentation System

The calibration test on the load cell showed excellent linearity with the coefficient of determination r^2 of 0.9997. The calibration curve is presented in Figure 6. This is in conformity with a study by Mardani *et al.* (2010) and Ale *et al*. (2017) for similar studies of soil-tool interaction on outdoor soil bin. The results have shown that the system has the potential to be used for the on the go and automatic measurement of soil forces in soil machine interaction studies.

The electronic stake counting system was also tested suitable for automatic counting of the number of cassava stakes planted per time (planting rate). The real-time curve of the test is presented in Figure 7. Average planting rate of 30, 36 and 42 stakes per minute were recorded as measured by the instrumentation system in the test at the forward speed ranging between 1.5 and 2.6 km/h.

3.2 Effect of Tractor Forward Speed on the Draught Requirement of the Planter

The performance evaluation of the cassava planter showed that there was an increase in the average value of draught from 24.91 N to 744.44 N as forward speed increased from 1.5 to 2.6 km/h at a soil dept of 100 mm and average soil moisture content of 14 %. This is in conformity with the study by Veerangouda and Shridhar (2009) in which the effect of planter forward speed and depth of operation on ground wheel speed was carried out. The result was also similar to Abdalla and Mohamed (2017). But it was contrary to Ale *et al.* (2017) that reported that the values of draught increased with an increase in operating speed and later decreased with further increase in speed in the study on the performance evaluation of an instrumentation system for soil draught measurement in which high tractor forward speeds and a mouldboard plough as the tillage tool were used. The power regression model that described the relationship as presented in Figure 8 is with coefficient of determination r^2 of 0.9377. But this is contrary to Al-Janobi and Al-Suhabami, 1998 that reported that draught-speed regression varied from linear to quadratic.

4. Conclusions

The following conclusions can be drawn from this study:

i. Electronic instruments were developed and installed on the cassava planter for automatic measurement of draught and counting of planted stakes per time.
ii. The instrumentation was found suitable for automatic measurement of the draught of the planter as well as counting of stakes planted per area per time.
iii. The forward speed had a strong correlation with the draught requirement of the planter.

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Figure 1: Load Cell ***Figure 2: Data Acquisition System***

Figure 3: Load Cell and Bracket as Installed on the Planter

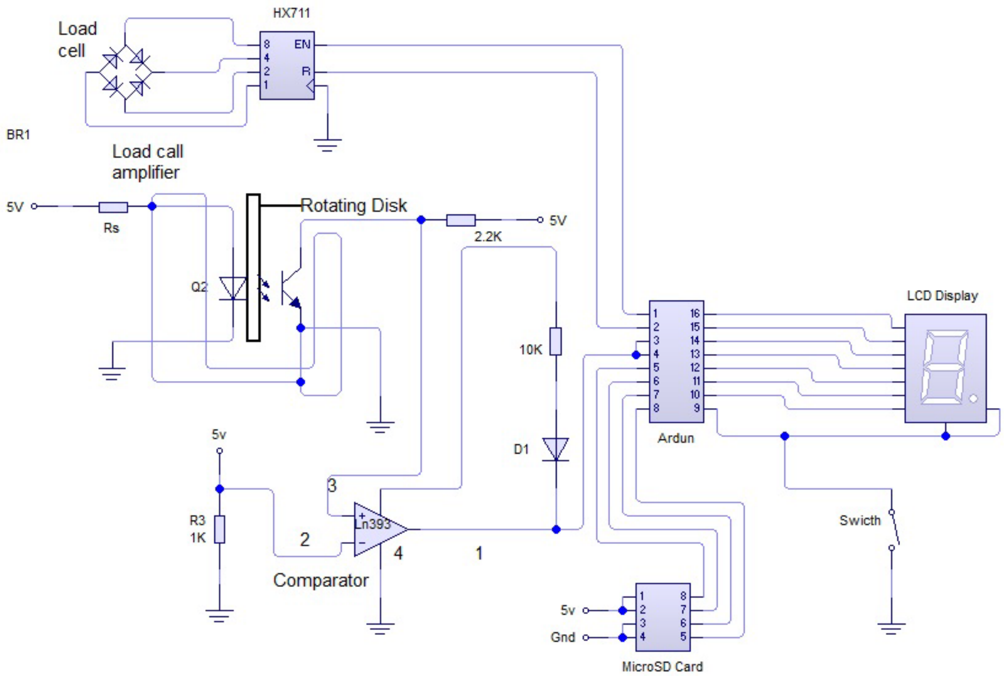

Figure 4: Circuit Diagram for the Instrumentation System

Figure 5: Dead Weight on the Load Cell Interfaced with the data Acquisition System and Computer System During the Load Cell Calibration

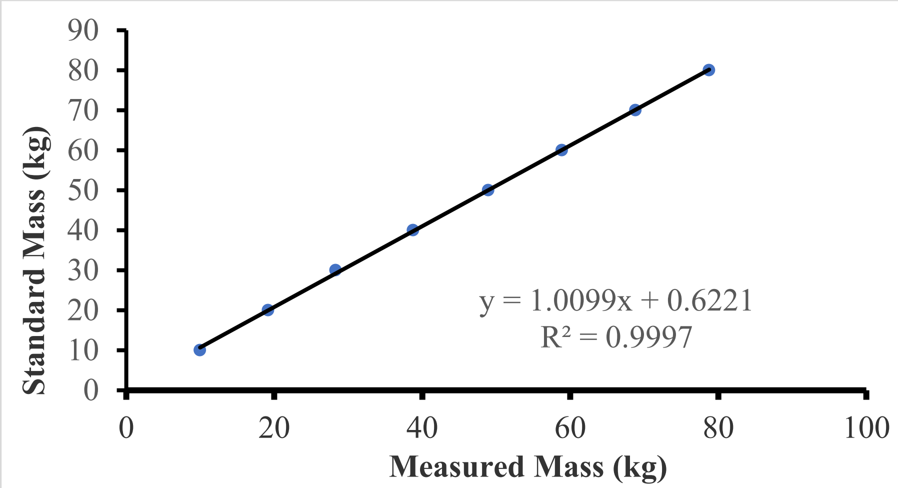

Figure 6: Calibration Curve of the Load Cell

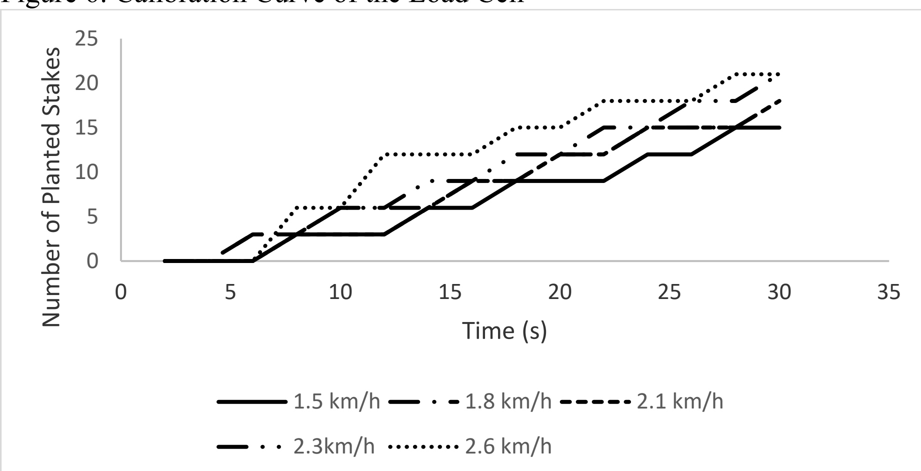

Figure 7: Real-Time Curve of the Automatic Counting System of Stakes

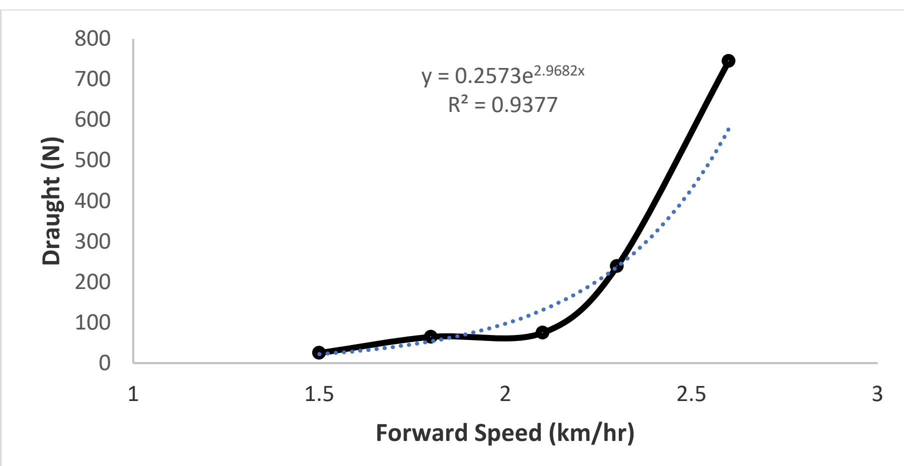

Figure 8: Effect of Tractor Forward Speed on draught Requirement of the Planter

DESIGN, DEVELOPMENT AND EVALUATION OF A SCREW PRESS BIOMASS BRIQUETTING MACHINE USING SUGARCANE BAGASSE

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Abstract

The aim of this study was to design, fabricate and evaluate a low cost briquetting machine that would convert biomass material into briquettes for domestic use. This study was birthed as a result of the potentials of the sugarcane bagasse in large quantities that has not been tapped in Zaria and its environs thereby offering numerous benefits such as waste management, source of energy, employment and entrepreneurship, pollution control and preservation of forest resources. Vital components of the briquetting machine include the hopper, frame, screw shaft, bearings, compression chamber and pressing cylinder or die. A 3 hp. electric motor was used to drive the machine. It was evaluated using sugarcane bagasse mixed with cassava starch as binder at different biomass-binder ratio of 7:2.5, 7:3 and 7:4 by volume. The sugarcane bagasse was sun dried and crushed with the aid of a hammer mill to particle sizes of 4 – 6 mm. It was kept at a constant moisture content (dry basis) of 8.2 %. Results obtained shows that the mean output capacity of the machine was 4.1 kg/h, 3.5 kg/h and 3.67 kg/h with the three biomass-binder ratios respectively. The physical characteristics of the briquettes produced were also evaluated according to the proportion of the starch binder used. Briquette at binder ratio 7:2.5 was observed to crumble more easily than the others binder ratios. Flame test also shows that the rate of burning decreases as the binder content increases. The briquettes produced burnt without sparks, smokeless and does not produce irritating smell. They also ignite easily and took relatively long before they were extinguished. The study found sugarcane bagasse briquette as suitable replacement for wood fuel.

Keywords: Briquette, binder, biomass, sugarcane bagasse

1. Introduction

Traditionally, wood in the form of fuel wood, twigs and charcoal had been the major sources of renewable energy in Nigeria, accounting for about 51% of the total annual energy consumption (Akinbami, 2001). The demand for fuel wood has been on steady increase due to increase in population and urbanization (Bello, 2010). However, fuel wood extraction is one of the causes of climate change and thus becomes one of the primary causes for deforestation in developing countries (Ayuba and Dami, 2011). Deforestation is major contributing causes of erosion, flooding, loss of soil nutrients, poor agricultural produce, global warming, climate variability, climate change and desertification (Audu, 2012).

Many of the developing countries produce huge quantities of agro-residues that are used inefficiently causing extensive pollution to the environment. Major residues are rice husk, jute sticks, bagasse, groundnut shells, sawdust and cotton stalks (Grover and Mishra, 1996). Agricultural wastes are non-product outputs of production and processing of agricultural products that may contain material beneficial to human but whose economic values are less its cost of collection, transportation, and processing. Estimates of agricultural waste arising are rare, but they are generally thought of as contributing a significant proportion of the total waste matter. (Obi, *et al* 2016). These residues have limited use in developing countries becomes difficult to manage giving rise to serious cases of environmental pollution. If utilized, such waste could ease the strain on forest trees, provide a better means of disposing refuse and cheaper source of fuel for cooking and heating (Agamuthu, 2009).
The decreasing availability of fuel wood, coupled with the ever rising prices of kerosene and cooking gas in Nigeria, there is need to explore alternative sources of energy for domestic and cottage level industrial use in the country (Olorunnisola, 2007). For this reason, a transition to a suitable energy system is urgently required in the country. This study, therefore, intends using sugarcane bagasse in order to replace the wood fuel as an alternative fuel as well as protect forest reserves from the deforestation process and environmental pollution.

Briquetting, as an alternative energy source, improves the handling characteristics of biomass materials and enhance its calorific value, reduce transportation cost, and produces clean, uniform and stable fuel, (Bamigboye and Bolufawi, 2008). Briquetting of biomass materials requires high pressure as additional force needed/required to overcome the springiness of the materials. This gives briquettes greater advantages over fuel wood in terms of heat intensity, cleanliness, convenience in use and relatives small store space requirement.

2.Materials and Methods

2.1 Design Concept

The briquetting machine designed was a screw press type (conical screw type). Its main parts are the electric motor, pulleys and belts, screw, compression chamber, frame and briquette die. Power is transmitted through pulleys and belts from the 3hp motor to the screw. After starting the motor, raw material was fed into screw that compress and extrude it through the die. Design considerations were based on forces required to drive the shaft, diameter of the screw shaft, the dynamic load on the bearing transmitted by the screw shaft, power required to compact pulverized feedstock as well as extrude the resultant briquette from the die. Other considerations include determination of dimensions and shapes of components for smooth operation.

2.2 Materials selection

The following materials were selected based on their mechanical strength as regards the type of forces acting on the machine members, its operational environment, cost the material and its availability locally.

Table 1: Machine parts and material requirement

S/No	Machine part	Materials	Specifications
1	Hopper	Mild steel sheets	2mm
2	Frame	Angle iron	2½’’ x 2½ ’’
3	Pressing cylinder	Mild steel circular pipe	100mm diameter x 500mm length
4	Briquette Die	High carbide steel	150mm x 125mm Ø

			100mm
5	Power screw shaft	Mild steel round rod	50mm x 700mm
6	Motor	-	Single phase electric motor; 3hp, 1420 rpm
7	V-Pulley		150mm Ø

2.3 Evaluation of briquette making machine

Sugarcane bagasse was the material selected for the production of the briquettes due to the availability of sugarcane in large quantity the northern parts of the country Jemima *et al*., (2011). Similarly, chewable sugarcane is consumed in large quantity as a snack in most places in northern Nigeria. Therefore its bagasse could be collected in large quantity at relatively no cost and could thus be used instead of allowing it to litter the environment.

Other materials used for production and characterization of the briquettes were: Hammer mill; Gallenhamp Oven for drying residue materials; Digital weighing machine for measuring the mass of samples; Vernier calliper for measuring diameters and height of briquettes; Stop watch for measuring time during briquetting process; Desiccator is a device used to prevent heated sample from absorbing moisture; Electric heater for boiling water to prepare the binder; Measuring cylinder to measure the quantity of water for preparing binder; and Infrared thermometer for measuring the temperature of briquettes.

2.4 Design Calculations

2.4.1 Size of briquettes

Briquette size required is important in determining the machines die dimensions. For the circular hollow briquette, an outer diameter of 150mm, inner diameter of 125mm and length of 100mm was chosen so as to enable the briquetted burn effectively in the conventional domestic charcoal stoves (commonly called coal pot). The diameter of the briquettes is usually kept between 100 and 150 mm as suggested by Edwards and Smith (2004).

2.4.2 Weight and volume of the Briquettes

Diameter and pitch of last flight of compression zone

$$V_f = \frac{\pi}{4}\{(90)^2 - (50)^2\} \times 46 = 202{,}318.6\, mm^3$$

To calculate pitch of compression zone assume diameter of last flight of compression zone was 65 mm, and assumed that the compression ratio was 10. So,

$$V_c = \frac{\pi}{4}\{(65)^2 - (50)^2\} \times P = 1354Pmm^3$$

$$10 = \frac{V_f}{V_c} = \frac{202{,}318.6}{1354P}.\ P = 149.4\, mm^3$$

The density of feeding material (i.e. sugarcane bagasse) is 120.1 kg/m3, so the mass of material conveyed in one complete revolution of feeding zone was determined from equation (1); (Singh and Singh, 1982):

$$\rho = \frac{Mass\ of Material}{Volume\ of\ Material} \qquad (1)$$

$m=120.1\ kg/m^3 \times 2.02 \times 10^{-4}\ m^3 = 0.024\ kg$

Assume the efficiency of the screw conveyor is 50%, then mass of material conveyed in one full flight of feeding zone in one revolution was:

$m=0.024 \times 0.5 = 0.0121\ kg$

Now, the density of compacted briquette was assumed, 1000 kg/m3

ρ_b =1000 kg/m3

Volume of briquette was,
$V_b = \pi/4 \{(60)^2\} \times 100 = 282{,}743.3\ mm^3 = 2.82 \times 10^{-4}\ m^3$

Mass of briquettes:
$m_b = 1000\ kg/m^3 \times 2.82 \times 10^{-4}\ m^3 = 0.282\ kg$

Number of revolutions required to make one briquette,
N= 0.282/0.024 = 11.75 revolutions

Capacity of machine was assumed to be 200 kg/h.
Number of briquettes made in 200 kg,
Number of briquettes= 200/0.282 = 709.2 briquettes
709 briquettes were made in one hour (3600 sec) so,

Time required for one briquette = 3600/709 = 5.1 seconds
We know that revolution required for one briquette was 118 so,
Time required for one revolution= 11.75/5.1 = 2.30 seconds

Revolutions per minutes = 2.30 x 60 = 138 rpm 140rpm

2.4 Procedures for evaluating the machine

The biomass material (sugarcane bagasse) was collected from a sugarcane juice vendor beside Usman Danfodio Hostel, Ahmadu Bello University, Samaru campus. It was collected in sacks and transported to the workshop and spread on the bare flow to dry naturally for a week. After drying, it was crushed using hammer mill powered by a diesel engine to particle sizes of 4-6mm. The sample of the crushed sugarcane bagasse was then taken to the laboratory to determine its moisture content.
The binder selected was cassava starch which was bought from Samaru market. 2000cm^3 of water and 300gm of semi-solid starch were measured. 200cm^3 out of the measured water was used to dissolve the semi-solid cassava starch. The remaining water was put to boil and poured into the already dissolved starch solution immediately and stirred to form the cassava starch paste. The crushed biomass was then mixed with binders (cassava starch) prepared as stated above in the biomass-binder ratios of 7:2.5, 7:3 and 7:4 by volume. The mixed feedstock was used to evaluate the performance of the machine.

2.5 Moisture content determination of biomass material

The moisture content of the sugarcane bagasse was determined after crushing using the oven dry method. The samples was oven-dried at temperature of 103ºC for 24hours. The weight of the samples was measured and recorded before as (M_1) and after oven-drying (M_2). The moisture content (dry basis) was calculated as ratio of the weight of moisture to the final weight of sample, expressed in percentage as given in the equation (2):

$$Mc_{(db)} = \frac{Mw}{Mf} \times 100 \quad \text{.......} (2)$$

Where $Mc_{(db)}$= moisture content (dry basis) (%)
M_i = Initial weight of the sample (g)
M_f = Final weight of dried sample (g)
M_w = Mass of moisture i.e M_i- M_f

2.6 Determination of machine output capacity

The machine output capacity according to Obi *et al*. (2016) is the ratio of the mass of briquettes produced to the average time used in producing the briquette. The machine production time components include: biomass loading time (s), biomass compaction time (s), briquette residence time (s), and briquette ejection time (s). That is;

$$\text{Machine output capacity (kg/s)} = \frac{\text{mass of briquettes(kg)}}{\text{briquettes' production time (s)}} \quad \text{.......} (3)$$

2.7 Burning rate

This determines the rate at which a specified amount of the briquette is combusted in the air. Samples of briquettes of known weight are placed on wire gauze and ignited. This process, as recommended by Ndirika, (2002), was closely monitored until the briquette if burnt and constant weight is attained.

$$B_r = \frac{Q_r - Q_2}{T} \quad (4)$$

where:

$$B_r = Burning\ rate, \frac{g}{min}$$
$$Q_1 = Initial\ weight\ of\ the\ brequtte, g$$
$$Q_2 = Final\ weight\ of\ the\ brequtte, g$$
$$T = Total\ Time, min$$

3. Results and Discussion

Having procured all required materials and parts, the designed screw extruder biomass briquetting machine was successfully fabricated (Figure 1 and Appendix 1). Its evaluation was then carried out.

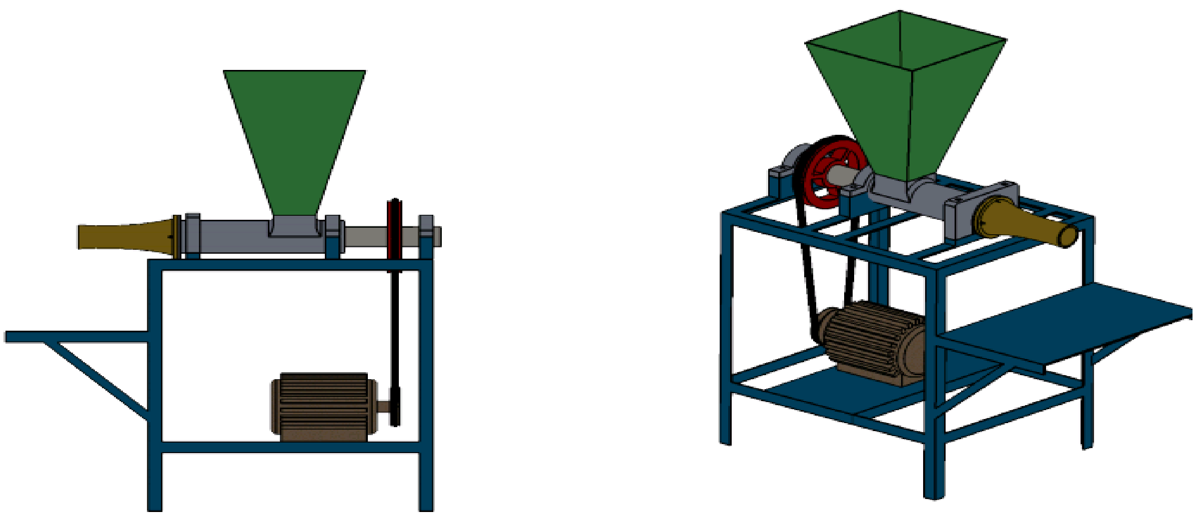

Figure 1: Pictorial View of the Designed Machine

3.1 Machine evaluation analysis

The machine evaluation was carried out using sugarcane bagasse crushed to particle sizes of 4-6mm with cassava starch as binder at ratios 7:3, 7:4 and 7:2.5. The parameters determined for each binder ratios are: time taken to produce a briquette, weight of briquette produced, sample inlet temperature, and sample outlet temperature. The machine was observed to exhibit a very high temperature of the die in the beginning of the operation; however the temperature appears to drop with time (Table 2). The briquettes produced using the developed briquetting machine is presented in Figures 2.

Table 2: Results of machine evaluation

S/N	Biomass-binder ratio	Time (s)	Weight of briquette produced (g)	Temp in (°C)	Temp out (°C)
1.	7:3	56	55	25	92.5
2.	7:4	140	143.4	24.8	75
3.	7:2.5	128	145.3	21.1	41

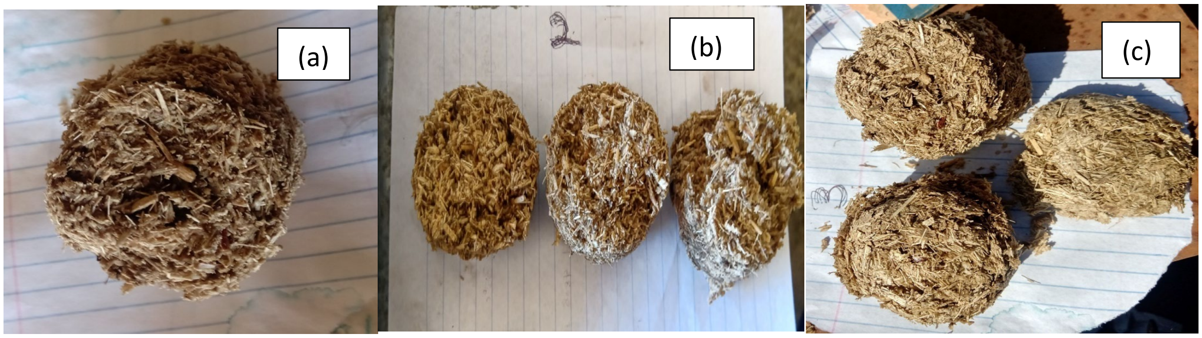

Figure 2: Briquettes produced from sugarcane bagasse with (a) 7:3 (b) 7:4 and (c) 7:2.5 binder ratios

Results of the study shows that the physical characteristics of the produced sugarcane bagasse briquette differs according to the binder ratios. With increasing biomass binder ratio, the briquette were more firmly bound as the briquette at binder ratio 7:2.5 was observed to crumble more easily than the other ratios. Similarly, lighting the dried briquettes at the same time, it was found that the rate of burning decreases as the binder content increases. The diameters of the briquettes produced from the binder ratios considered were relatively the same (about 100mm), perhaps because the same outlet diameter was used. However, their respective lengths extruded were observed to differ significantly ranging from 100 – 200mm.

3.2 Machine output capacity

Results obtained shows that the machine capacity of the briquettes produced differ for different binder ratios. It was observed that the capacity of the machine was at its peak when 7:2.5 biomass-binder ratio was used (Table 3). An average of 4.1 kg/h was obtained at this ratio while the maximum machine output capacity was 3.5kg/h

Table 3: Machine output capacity

S/N	Binder ratio	Weight (g)	Time (s)	Capacity (g/s)	Capacity(kg/h)
1.	7:3	55	56	0.98	3.5
2.	7:4	143.4	140	1.02	3.67
3.	7:2.5	145.3	128	1.14	4.1

4. Conclusion

A low cost screw press biomass briquetting machine capable of making circular briquettes to replace charcoal and firewood for domestic cooking and general heating application was designed and fabricated in the main workshop of the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Zaria. It was evaluated using sugarcane bagasse and cassava starch (binder ratio) of 7:3, 7:4 and 7:2.5. The machine was found to have a peak capacity of 4.1kg/h and the physical characteristics of the briquettes produced varied with varying binder ratio i.e. the higher the binder, the lesser the briquette crumble and vice versa. From the evaluation, the machine is suitable for production of solid fuels (briquettes) from plant wastes for a small family of five.

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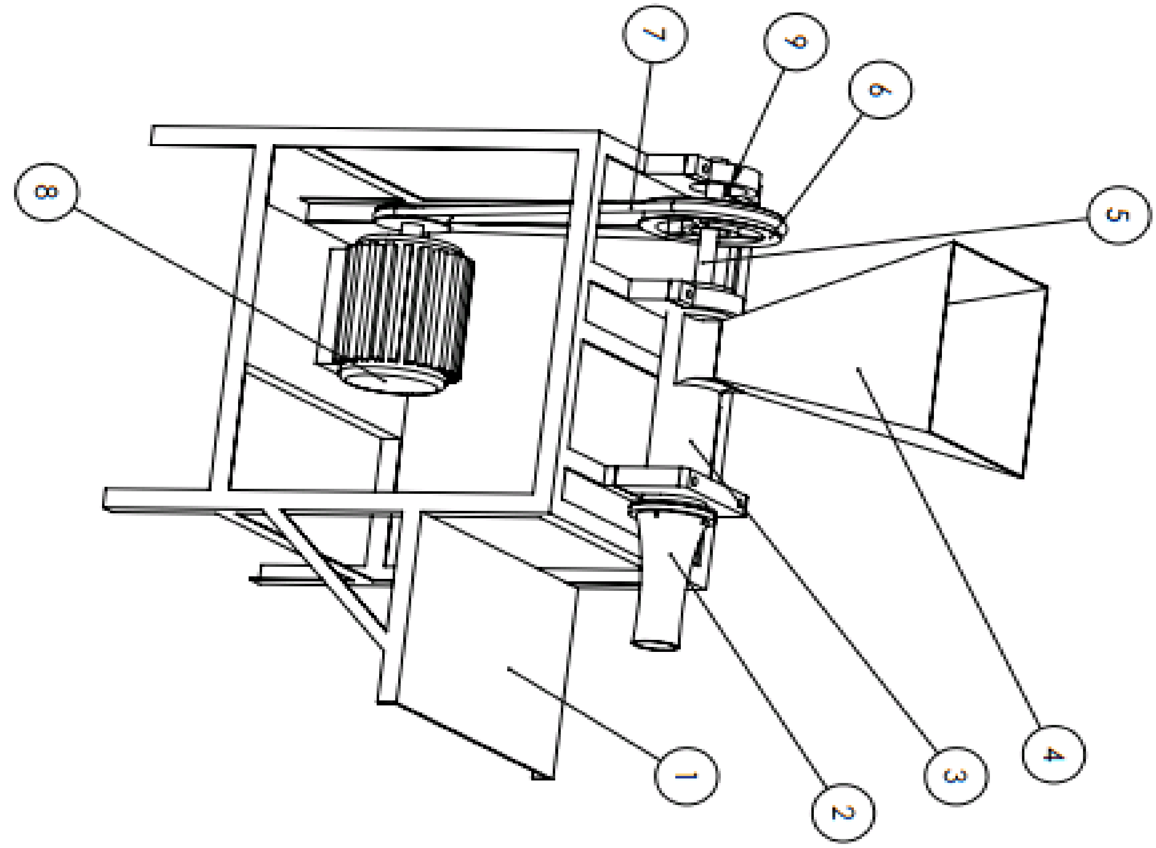
APPENDIX 1



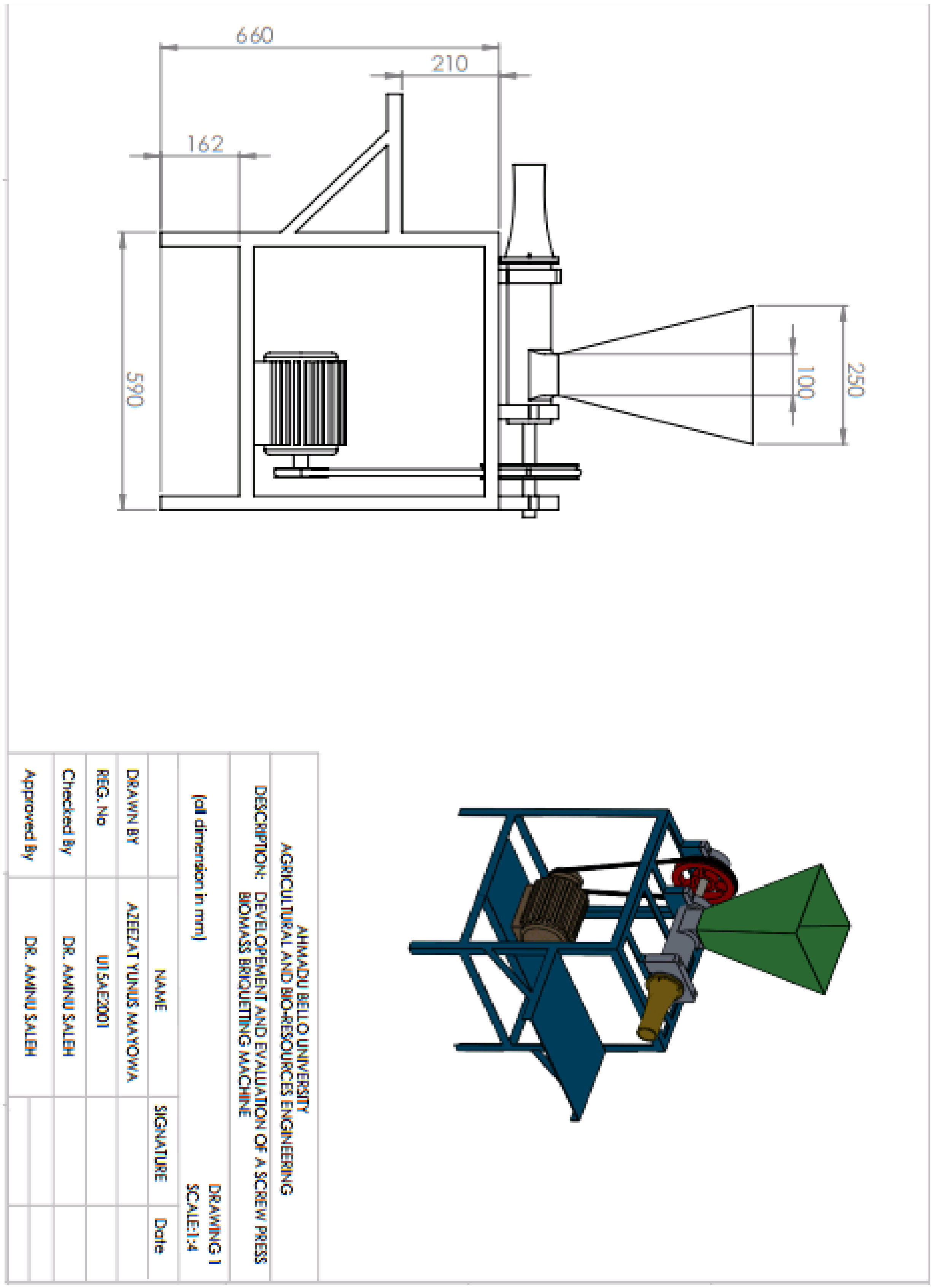
S/N	COMPONENT	MATERIAL	UNIT	REMARK
10				
9	BEARING	STEEL	2	STANDARD
8	MOTOR	-	1	STANDARD
7	BELT	FIBRE	1	STANDARD
6	PULLEY	-	1	STANDARD
5	POWER SCREW	MILD STEEL	1	FABRICATED
4	HOPPER	MILD STEEL	1	FABRICATED
3	COMPRESSION CHAMBER	MILD STEEL	1	FABRICATED
2	PRESSING CYLINDER	MILD STEEL	1	FABRICATED
1	FRAME	MILD STEEL	1	FABRICATED

AHMADU BELLO UNIVERSITY
AGRICULTURAL AND BIO-RESOURCES ENGINEERING

DESCRIPTION: DEVELOPEMENT AND EVALUATION OF A SCREW PRESS BIOMASS BRIQUETTING MACHINE

(all dimension in mm) DRAWING 1 SCALE1:4

	NAME	SIGNATURE	Date
DRAWN BY	AZEEZAT YUNUS MAYOWA		
REG. No	U15AE2001		
Checked By	DR. AMINU SALEH		
Approved By	DR. AMINU SALEH		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AHMADU BELLO UNIVERSITY
AGRICULTURAL AND BIO-RESOURCES ENGINEERING
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(all dimension in mm)
DRAWING 1
SCALE:1:4
NAME
SIGNATURE
Date
DRAWN BY
AZEEZAT YUNUS MAYOWA
REG. No
U15AE2001
Checked By
DR. AMINU SALEH
Approved By
DR. AMINU SALEH

LEVEL OF AGRICULTURAL MECHANIZATION IN ENUGU STATE, NIGERIA

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Abstract

This study determined the mechanization index and agricultural productivity of selected farms in Adani and Omor of Enugu state, Nigeria. Factors which resulted in the profitability of farm activities and whole farms were deduced. Structured questionnaires, interviews and on-the-spot assessments were used to establish the socio–economic characteristics, educational level, and technical know-how of the farmers as well as the information about the tractors being used in the farm. At the end of the survey, the mechanization index, agricultural productivity and gross margin analysis of the farms in Adani and Omor were determined. Results showed that the highest mechanization index value was recorded at 50.81% for farm 6 at Omor. This is basically because of the under-utilization of tractors of high power rating and the lowest mechanization index was recorded at 9.26% for farm 19 at Adani. The highest productivity recorded is at 0.3078 ha/kWhr in farm 8 in Adani which is about 4 ha and the lowest productivity is at 0.0392 ha/kWhr in farm 19 in Omor which is about 2ha. The estimate of crop yield ranges from 2 to 3 tons / ha for rice being cultivated in Adani and 2 tons / ha for cassava if conditions are favourable. The estimate of crop yield for rice at Omor is about 2 tons which indicates relatively high productivity. The gross margin analysis showed that for the same rate of agronomic inputs, the total cost of production inputs was estimated at 116,200 Naira per hectare for rice and 39,500 Naira for cassava in Adani and 135,600 Naira for rice at Omor on selectively mechanized and non-mechanized operations from tillage up to harvesting and processing. The profit and loss situations in both farm settlements with farmers at Omor earning the profit of 76,900 Naira and farmers in Adani earning of 83,800 Naira per hectare of land per planting season while majority of the cassava farmers run at a loss.

Keywords: Agricultural mechanization, Mechanization index, Agricultural productivity, Gross margin, Farm tractors, Farm settlements

1. Introduction

Agriculture is one of the most important primary economic activities of man and it is the basis of food supply of the entire population of the world (Smith, 2009). It encompasses the production of food, feed, fibre, fuel and other goods through the systematic raising of plants and animals (Diao, Hazell and Thurlow, 2010). Although the activity is defined variously in different parts of the world, it mostly includes raising of crops and animals (Hubbard and Gorton, 2011). The word mechanization in many minds connotes tractors and similar power machinery. A broader definition of the term is, however, that which encompasses the use of hand and animal operated tools and implements, as well as motorized equipment to reduce human effort, improve the timeliness and quality of various farm operations, thereby increasing yields, quality of product, and overall efficiency. The common definition of mechanization involves all issues related to machines and their management in crop production in agriculture (Almasi et al. 2008). Mechanization is benefiting from technology, which is site-specific and dynamic (Singh, 2006). Agricultural mechanization is the application of agricultural engineering principles and technologies to agriculture, using mechanical systems, in food, fibre, fuel and fur processing, and also, in the production, processing, handling and storage of agricultural product (Asoegwu 1998). It is the "application of mechanical implements or as a whole, the application of the state-of-the-art technologies in agriculture to increase productivity and to reach sustainable agriculture". Agricultural mechanization is the application of mechanical technology and increased power to agriculture, largely as a means to enhance the productivity of human labour and often to achieve results well beyond the capacity of human labour (http://businessdayonline.com, 2014). This includes the use of tractors of various types as well as animal-powered and human-powered implements and tools, and internal combustion engines, electric motors, solar power and other methods of energy conversion.

According to the Food Agriculture Organisation (FAO), in the last 50 years, few economies have been able to overcome the challenges of development and become truly competitive. In those few cases, there are concrete indications that industrial development, including agro-industrial development, has played a key role. Agricultural mechanization is part of agro-industrial development, and it has either stagnated or retrogressed in many countries of sub-Saharan Africa (SSA). Agriculture is by far one of the most important sectors of Nigeria's economy, engaging about 70 per cent of the labour force. However, holdings have been generally small and scattered; and farming is often of the subsistence variety, characterized by simple tools and shifting cultivation. Productivity has been hampered by the use of crude tools and implements, lack of finance or credit facilities, poor transportation, inadequate land due to land tenure system, as well as inadequate agricultural education and extension services. In overall terms, humans are the principal sources of power for cultivating about 65% of total land area under cultivation while draught animals cultivate 25% of the total land area and tractors take 10%. This situation is however quite different when compared to other parts of Africa like the North and East Africa that 25% of the land is cultivated by hand tools, 25% of land by animal power and 50% of land is cultivated by tractors (FAO, 2005). Most developing countries and, indeed, African countries have an economy strongly dominated by the agriculture sector. Agriculture generates up to 50 percent of gross domestic product (GDP), contributing more than 80 percent of trade in value and more than 50 percent of raw materials to industries. It provides employment for the majority of Africa's people. Despite this domination and the fact that agriculture is backed with good policy documents and statements, investment in the sector is still grossly underdeveloped in most African countries. Furthermore, 30 to 40 percent of agricultural produce is lost owing to poor post-harvest handling, storage and processing methods (FAO, 2001)

Thus, this research is aimed at measuring the level of mechanization of two farm settlements located in the eastern regions of Nigeria namely Adani and Omor. In course of this research, it was noted that Adani and Omor does not have readily available and accessible records/information showing their levels of mechanization. The absence of this relevant data in the literature or database makes it difficult for people who do not know much about Adani and Omor to engage in crop cultivation and other related activities. The aim of this study is to determine the level of mechanization in the selected areas in Adani and Omor based on the mechanization index, agricultural productivity and gross margin. The names of the farms are Ada rice plantation in Adani and Lower Anambra irrigation project at Omor.

2. Materials and Methods

2.1 Study areas

Adani is a place that is situated in Uzo-Uwani, Enugu, Nigeria; its geographical coordinates are 6° 44' 0" North, 7° 1' 0" East and 7°0'36" east of the Greenwich Prime Meridian. Adani has a population of approximately 6,161 people and its original name (with diacritics) is Adani. Agricultural activity in Adani town is predominantly subsistence, except the flood plain agriculture which is based on comparatively large - scale cultivation of Rice, Yam and also Fish farming. There have been increases in the number of migrants from the densely settled slow growing and land hungry rural areas of Awka, Orlu, Okigwe, Eastern Onitsha, Ikot Ekpene and Uyo areas, who have moved into the plains to join in exploiting the vast agricultural potentialities of the flood plains which are beyond the capability of the local people (Ani, 2010).

Figure 1: Map of Adani

Omor in Ayamelum local government area of Anambra state in Nigeria, is on the shores of the Omambala River and lies between Latitude 06º30'17.54" N and Longitude 06º58'09.53" E at an altitude of 213 meters above sea. It is thought to be geographically the largest town in Anambra closely followed by Agulu. It also has a large population and is made up of the villages of Akanator, Aturia, Amikwe and Orenja. There have been communal clashes between Omor and Igbakwu locals over land on the border of both towns. It has good vegetation, fertile lands for production of food crops such as rice, maize, yam, cassava and assorted fruits.

The Nigerian Federal Government started the rehabilitation of the Lower Anambra River Irrigation Rice Farm project at Omor, which has resuscitated the growing of rice in that part of the State. 40 hectares of Fadama land have been cultivated with rice in Omor under the collaborative arrangement between the state government and farmers under the auspices of the state Rice Farmers Co-operative Union Limited. In addition, a newly installed rice mill complex with units for parboiling, milling, de-stoning, and bagging capacity sufficient to produce over

10,000 metric tons of high quality rice annually is enhancing production of the staple food for local consumption and export.

Figure 2: Map of Omor

2.2. Data collection and analysis techniques

The socio – economic characteristics, educational level, and technical know-how of the farmers as well as the information about the tractors being used in the farm were established using structured questionnaires, interviews and on-the-spot assessments. At the end of the survey, the mechanization index, agricultural productivity and gross margin analysis of the farms in Adani and Omor were determined.

2.2.1. Interviews and on-the-spot assessments

An interview is a series of questions a researcher addressed personally to the respondents, while on-the-spot-assessment is a technique used by the interviewer or researcher where he or she stands and observed all the activities going in the farm at that particular time and makes personal assessments of the farms at that point. Both structured (clearly defined questions) and unstructured, questioning led by the responses of the interviewee were used. Interviews were advantageous in discovering how individual farmers thought and felt about impacts of mechanization on the current trends of agricultural performance and why farmers had such opinions. The researcher also found interviews to be ideal when dealing with sensitive issues which people would feel uncomfortable discussing in focus groups. This provided deeper understanding and a more detailed explanation on statistical data.

2.2.2. Questionnaires

A questionnaire with a series of written questions was supplied to respondents, requesting theirresponses. The way the data were to be analyzed influenced the layout of the questionnaire. The questionnaire made use of closed questions which provided boxes for the respondents to tick (hence provided easily coded information). The study

avoided open questions as these would require respondents to write answers, though giving more freedom of information; they had a
drawback of being more difficult when coding. In the course of this research, we observed that some of the respondents did not have true knowledge of the tractors that were used in their farms. As a result of that, some of the questions about the tractor model and power rating were not properly answered in the questionnaire. Due to this problem, data about the models and power rating of tractors needed for the analysis were gotten from a website (www.tractordata.com).

2.3 Analytical tools

Qualitative and quantitative criteria by which the impact of mechanization on productivity was used to identify the significance of draft power sources and machinery on productivity and production efficiencies of rice and cassava. Gross Margin Analysis was used to investigate the economic significance/ viability of mechanization in relation to crop productivity per given unit of land. The stated indices of mechanization will be determined through survey using on-the-spot assessment, structured questionnaire and documentation. Data collected will be used to determine the following parameters:

2.3.1 Degree of agricultural mechanization/mechanization index

The degree of agricultural mechanization with respect to the average energy input of work wholly provided by human power (labour) per hectare was determined according to Nowacki (1974) using eqn. (1):

$$L_H = 0.1. N_H. \frac{T_H}{\mathrm{A}} \quad (1)$$

Where L_H denotes the average energy input or work per hectare by human labour (kWhr/ha); $N_H$is the average number of labour employed; T_H depicts the average rated working time devoted to manual operation; 0.1is the theoretical average power of an average man working optimally; A represents the area of land cultivated (ha), which was calculated as the product of the area of cultivated land and the total number of farmers participated while T_H was determined as a function of rate of energy consumption and resting period for different manual operations. The resting period T_R was determined according to Caruthers and Rodriguez (1992) using on eqn. (2):

$$T_R = 60\left(1 - \frac{250}{\mathrm{P}}\right) \quad (2)$$

where: T_R = required resting time for 8 hours effective working hours per day (minute per hour); P is rate of power consumption for various farming activities (watts).
The degree of mechanization based on motorized machinery co-existing with a high participation of operators was also estimated according to Nowacki (1974) using eqn. (3):

$$L_M = 0.2. N_M . \frac{T_M}{\mathrm{A}} \quad (3)$$

Where L_M is the average energy input or work per hectare by motorized machines for tillage operations; 0.2 is the corrector co- efficient of the tractor-powered machine; $N_M$depicts the rated working power of the tractor (kW); $T_M = \frac{1}{C}$ represents the rated working time of the motorized energy source, (hr/ha); and A is the area cultivated by the motorized machines (hectares). C is the effective field capacity which is given estimated using eqn. (4):

$$C = \frac{SWE_f}{10} \quad (4)$$

where: C is effective field capacity (ha/hr); W is width of cut of implements (m); E_F = field efficiency (%); S is Operating speed, (m/s).

Mechanization index was thus determined according to Nowacki (1974) as the percentage work of the tractors in the total work outlays by human and machinery.

$$\mathrm{W_{ME}} = \frac{\mathrm{L_M}}{\mathrm{L_T}} . 100\% \quad (5)$$

where: W_{ME} represents the mechanization Index (%); $L_M = L_M + L_H$ is the average sum of all mechanical operation work of the machine, (kWhr/ha); $L_T$depicts the sum of all average work outlays by human and tractor powered machines, (kWhr/ha).

2.3.2. Productivity of machine and human labour

The productivity of machine and human labour (i.e., the measure of the engineering efficiency of the production) was determined according to Ortiz-Canavate and Salvador (1980) based on the principle of the production schedule.

$$A_M = \frac{1}{L_M} \quad (6)$$

$$A_H = \frac{1}{L_H} \quad (7)$$

$$A_T = \frac{1}{L_H} + \frac{1}{L_M} \quad (8)$$

Where; A_M depicts the productivity of machines; A_H is the productivity of labour; and A_T represents the total productivity.

2.3.3. Production gross margin analysis of the main arable crops in the surveyed area

The gross margin analysis for production of the main arable crops (rice & Cassava) in the surveyed areas was obtained according to Jhingan (1997) using eqn. (9):

$$G_M = T_R - T_C \quad (9)$$

Where; G_M is the gross margin/gross profit value; T_R is the total revenue (P x Y); P depicts the price; Y is the yield (tons/ha or kg/ha); TC denotes the total cost (TC=FC+VC); FC =is the fixed cost; VC represents the cost of the variable inputs. Meanwhile, the prevailing agricultural wages per day and market prices were used for variable inputs and outputs which were estimated on the probable rates of returns based on the conditions at the time of the study.

3. Results and Discussion

3.1. Educational level of farmers

Most of the farmers interviewed in these areas were mid-aged ranging between 30 to 50 years. A good number of farmers below 30 years were also interviewed and are fully involved in farming while very few of the farmers above 50 years are present in these areas. Both farm settlements in Adani and Omor had a percentage of 53.8 and 75.7 of farmers above 35 years. This also indicates the lack of involvement or interest of much of the youths in both settlements. About 68.96% of the farmers have their educational training in tertiary institutions, both universities and polytechnics (Table 1). This influences their level of awareness in adopting new innovations and ideas on new methods of farming and use of machines to perform various jobs thereby enhancing the productivity in their farms.

Table 1: Distribution of educational levels in the research study areas: Adani and Omor

	Educational Levels

NAME OF FARM SETTLEMENTS	No of farmers interviewed	NIL	Primary school	JSCE	SSCE	Tertiary
ADANI	37	1	11	0	2	23
OMOR	21	1	0	1	2	17
TOTAL	58	2	11	1	4	40
Percentage (%)		3.45%	11.97%	1.72%	6.89%	68.96%

3.2. Mechanization index

Both farm settlements practice selective mechanization which indicates that machines and implements namely tractors, ploughs, harrows and ridgers are used for pre-planting or tillage operations such ploughing, harrowing, and also in the case of rice puddling of the land which is also a type of rotavating. While all other operations from weeding by herbicides, planting, fertilizer application, manual weeding, spraying of pesticides and herbicides, harvesting, packing, winnowing, loading and unloading are done manually. Also, threshing and parboiling are semi manual, though the main work is done by the machine. The farm settlements are lacking very important mechanization inputs such as developed planters and harvesters which help to increase efficiency and productivity. Owing to the absence of these inputs, the farm schemes have not realized their full potential in rice and cassava cultivation. This is an indication that the programs did not witness visible application of modern techniques. The study revealed low production efficiency and drudgery, most especially, during planting and post-planting operations which were manually done. The results of the study also unveiled under-utilization of mechanical power which involves the use of tractors with high power ratings for only tillage operations which contributed to the level of mechanization of the farms. The work outlay (LM: machines, LH: Human labour) were determined for various farm settlements. L_H which indicates the degree of mechanization for human labour was determined using equation 1, taking into consideration the number of workers per hectare of land, time devoted to manual labour and area of land cultivated in ha. L_M which indicates the degree of mechanization for tractor power was obtained using equation 2 taking into consideration the rated working power of the tractor, rated working time of the tractor and area of land cultivated.

The index of mechanization for each farm was determined using Equation 5, and the result is presented in Tables 2 and 3. From these tables, it can be observed that as index of mechanization increased, the energy input per land area in hectare by human work is greater than the energy input of machine. This is because great work capacity and more time of utilization of the human work are needed for the same area (Olaoye and Rotimi, 2010). A major defect in quantifying a mechanization indicator based on the ratio of mechanical tractive farm power to total farm power is that it does not bring to light the actual use scenario. The results also showed higher mechanization index value of 50.81% for farm 6 at Omor. This is basically because of the under-utilization of tractors of high power rating; however, the lower mechanization index was recorded at 9.26% for farm 19 at Adani. According to Olaoye and Rotimi (2010), measurement of agricultural mechanization index and analysis of agricultural productivity of some farm settlements in South West, Nigeria, it was deduced that the mechanization of a farm is low if the value of the mechanization index is below 50%, however, if the value ranges between 50% to 70%, the mechanization level is moderate and for values above 70%, the mechanization level is high. Table 2 and 3 also show the statistical analysis of the farms that were carried out. The tables also present the total, mean or average, standard deviation and variance of the various parameters or indices.

In Table 2, the values of standard deviation for cultivated area of land per hectare, total human power, total tractor power, total power and mechanization index are not closer to zero, instead all have a high standard deviation value. The high standard deviation of mechanization index indicates that the data points are spread out over a wider range of values and the values of the mechanization index all deviated or dispersed from the mean values. This also applies to their variance. Variance measures how far a set of numbers is spread out. A variance of zero indicates that all the values are identical. The high variance of cultivated area of mechanization index indicates that the data points spread out around the mean and from each other.

In Table 3, though the means are larger than that of the Table 2, its standard deviation and variance have smaller values. However, the same principle applies to both the standard deviation and variance of the data points of the mechanization index. They do not tend towards zero which indicates that the data points are far away from the mean and spread out from each other.

Table 2: Summary of the level of mechanization in relation to total output power, human productivity, machine productivity and total productivity per unit areas of cultivated land for Adani

Farms	Area of land cultivated for arable crop (ha)	Total human power (Kw/ha)	Total Actual Tractor Power (Kw/ha)	Total Actual Power (Kw/ha)	Level of Mechani-zation (%)	Productivity of human power (ha/Kwhr)	Productivity of tractor power (ha/Kwhr)	Total productivity (ha/kwhr)
Farm 1(4)	1	19.3	13.43	32.73	41.03	0.0518	0.0745	0.1263
Farm 2(15	1	21.9	20.14	42.04	47.91	0.0457	0.0497	0.0954
Farm3(36	1	38.3	20.14	58.44	34.46	0.0261	0.0497	0.0758
Farm 4(5)	2	21.1	11.19	32.29	34.65	0.0474	0.0894	0.1368
Farm 5(6)	2	19.3	16.41	35.71	45.95	0.0518	0.0609	0.1127
Farm 6(3)	2	21.9	13.43	35.33	38.01	0.0457	0.0745	0.1202
Farm 7(14)	2	32.3	8.95	41.25	21.70	0.0309	0.1117	0.1426
Farm 8(17)	2	25.5	0	25.50	0	0.0392	0	0.0392
Farm 9(31)	2	27.1	11.64	38.74	30.05	0.0369	0.0859	0.1228
Farm 10(32)	2	19.3	11.94	31.24	38.22	0.0518	0.0838	0.1356
Farm 11(33)	2	21.9	12.31	34.21	35.98	0.0452	0.0812	0.1264
Farm 12(37)	2	30.3	11.19	41.49	26.97	0.0330	0.0894	0.1224
Farm13(27)	2	16.2	13.43	29.63	45.33	0.0617	0.0745	0.1362
Farm14(39)	2	29.4	16.41	45.81	35.82	0.0340	0.0609	0.0949
Dr Obalum	2	33.3	13.43	46.73	28.73	0.0300	0.0745	0.1045

Farm 16(9)	3	19.3	14.09	33.39	42.19	0.0518	0.0709	0.1227
Farm 17(16)	3	27.1	7.38	34.48	21.40	0.0369	0.1355	0.1724
Farm18(34)	3	19.3	11.94	31.24	38.22	0.0518	0.0838	0.1356
Farm 19(35)	4	35.08	3.85	38.93	9.26	0.0285	0.2793	0.3078
Farm 20(8)	4	16.6	12.31	28.91	42.58	0.0602	0.0812	0.1414
Farm 21(38)	5	31.9	19.34	51.24	37.70	0.0313	0.0517	0.0830
Farm 22(12)	6	32.3	11.19	43.49	25.73	0.0309	0.0894	0.1203
Farm 23(10)	10	19.3	11.19	30.49	36.70	0.0518	0.0894	0.1412
Farm 24(26)	10	21.9	13.43	35.33	38.01	0.0457	0.0745	0.1202
Farm 25(30)	10	14.1	8.95	23.05	38.82	0.0709	0.1117	0.1826
Farm 26(28)	10	18.3	8.65	26.95	32.09	0.0546	0.1156	0.1702
Farm27(22)	15	14.1	13.43	27.53	48.78	0.0709	0.0745	0.1454
Farm28(23)	15	32.3	13.43	45.73	29.37	0.0309	0.0745	0.1054
Farm29(24)	20	21.9	11.19	33.09	33.82	0.0457	0.0894	0.1351
Farm30(25)	20	24.5	14.92	39.42	37.85	0.0408	0.0670	0.1078
Farm 31(1)	20	30.6	22.38	52.98	42.24	0.0327	0.0442	0.0769
Farm 32(11)	22	33.3	13.43	46.73	28.74	0.0300	0.0745	0.1045
Farm33(29)	30	18.3	7.38	25.68	29.97	0.0546	0.1355	0.1901
Farm34(21)	30	19.3	13.43	32.73	41.03	0.0513	0.0745	0.1263
Farm 35(19)	40	27.9	14.92	42.82	34.84	0.0358	0.0670	0.1028
Farm 36(20)	40	24.5	13.43	37.93	35.41	0.0408	0.0745	0.1153
Farm 37(13)	40	21.9	14.92	36.82	40.52	0.0457	0.0670	0.1127
Total	387	900.88	469.22	1370.1	1227.84	1.6248	3.0862	4.7115
Mean	10.45946	24.34811	12.6816	37.0297	34.10667	0.043914	0.083411	0.127338
Standard Deviation	12.08441	6.412927	4.25829	8.15918	9.87124	0.011645	0.041223	0.042508
Variance	146.033	41.12563	18.1330	66.5723	97.44138	0.000136	0.001699	0.001807

Table 3: Summary of the level of mechanization in relation to total output power, human productivity, machine productivity and total productivity per unit areas of cultivated land for Omor

Farms	Area of land cultivated for crop (ha)	Total human power (Kw/ha)	Total Actual Tractor Power (Kw/ha)	Total Actual power (Kw/ha)	Level of Mechani-zation(%)	Productivity of human power (ha/Kwhr)	Productivity of tractor power (ha/Kwhr)	Total productivity (ha/Kwhr)
Farm 1(10)	1	20.8	20.14	40.94	49.19	0.0481	0.0497	0.0978
Farm 2(16)	1.5	24.2	11.77	35.97	32.72	0.0413	0.0849	0.1262
Farm 3(36)	1.5	20.8	8.95	29.75	30.08	0.0481	0.1117	0.1539
Farm 4(1)	2	20.8	6.71	27.51	34.39	0.0481	0.1490	0.1971
Farm 5(17)	2	15.7	11.77	27.47	42.85	0.0637	0.0849	0.1486
Farm 6(4)	2	19.5	20.14	39.64	50.81	0.0513	0.0497	0.1010
Farm 7(5)	2	15.8	11.19	26.99	41.46	0.0633	0.0894	0.1527
Farm 8(6)	2	17.4	14.90	32.30	44.13	0.0575	0.0671	0.1246
Farm 9(8)	2	20.8	11.77	32.57	36.14	0.0481	0.0849	0.1330
Farm 10(9)	2	25.2	11.19	36.39	30.75	0.0397	0.0894	0.1291
Farm 11(13)	2	15.7	11.19	26.89	41.60	0.0637	0.0894	0.1531
Farm 12(14)	2	20.8	11.64	32.44	35.88	0.0481	0.0859	0.1340
Farm 13(12)	3	15.7	11.19	26.89	41.60	0.0637	0.0894	0.1531
Farm 14(2)	3	19	11.94	30.94	38.59	0.0526	0.0838	0.1364
Farm 15(7)	3	17.4	11.77	29.17	40.35	0.0575	0.0849	0.1424
Farm 16(30)	3	17.4	13.43	30.83	43.56	0.0575	0.0745	0.1320
Farm 17(15)	3	14.0	11.77	25.77	45.67	0.0714	0.0849	0.1563
Farm 18(33)	3	25.2	20.14	45.34	44.42	0.0397	0.0497	0.0894
Farm 19(37)	4	24.2	11.19	35.39	35.39	0.0413	0.0894	0.1307
Farm 20(29)	4	17.4	10.74	28.14	38.17	0.0575	0.0931	0.1506
Farm 21(3)	4	15.7	11.94	27.64	43.20	0.0637	0.0838	0.1475

Total	52	403.5	265.47	668.97	840.95	1.1259	1.7695	2.8895
Mean	2.47619	19.21429	12.64143	31.85571	40.04524	0.053614	0.084262	0.137595
Standard Deviation	0.858432	3.431368	3.486758	5.334963	5.636152	0.009291	0.021369	0.02346
Variance	0.736905	11.77429	12.15748	28.46183	31.76621	0.112786	0.000457	0.00055

3.3. Agricultural Productivity

Productivity of the human labour and machines (i.e., tractors) were determined using Equations 6 to 8. The variability between productivity was compared to the areas of cultivated land and index of mechanization for each farm to identify the contribution and efficiency of the variable input power source in terms of returns to the factor of production. According to Olaoye and Rotimi (2010) that carried out the measurement of agricultural mechanization index and analysis of agricultural productivity of some farm settlements in South West, Nigeria, the level of productivity of a farm is said to be high if the sum of the values of the inverse of the productivity of the machine and human labour is between the range of 0.7-0.99; it is medium if the productivity value ranges between 0.41-0.69, and low if the value is below 0.4. Data on the productivity of land or crop yields is a function of the size of the mechanization inputs. The estimate of crop yield ranges from 2 tons / ha for rice being cultivated in Adani and 2 tons / ha for cassava if conditions are favourable. The estimate of crop yield for rice at Omor is about 2.5 tons which indicates relatively high productivity (Tables 2 and 3). The highest productivity recorded is at 0.3078 ha/kWhr in farm 8 in Adani which is about 4 tons/ha and the lowest productivity is at 0.0392 ha/kWhr in farm 19 in Omor which is about 2tons/haha. The value of the productivity bng relatively high is as a result of the mechanization inputs that were put into only tillage operations. All tillage operations in both settlements were all done using tractors but the rest operations were done manually.

In Tables 2 and 3, the standard deviation for human, tractor and total productivity are all tending towards zero. This is an indication that the data points of the parameters are closer to the mean and do not spread out over a wide range but are all closer together. This also applies to their variances. Variance measures how far a set of numbers is spread out. A variance of zero indicates that all the values are identical. Human, machine and total productivity have a small variance which indicates that the data points tend to be very close to the mean and hence to each other.

Figures 1 and 2 are bar charts showing the level of productivity per hectare of land for the various farms. The unit is ha/Kwhr indicating how much power and time is put into cultivating one hectare of land. Each of the bars represents the level of productivity of human power employed per hectare of land, tractors and the total productivity which is the addition of the human and tractor power. In figure 1, the highest total productivity was at farm 4 while the lowest was at farm 18 for farms at Omor. In Figure 2, the highest total productivity was at farm 19 and the lowest at 8. The values of productivity of the two farms were the highest because the farms utilized the highest tractor power while also the human labour was employed effectively while farm 8 and 18 have the least due to utilization of the least tractor power.

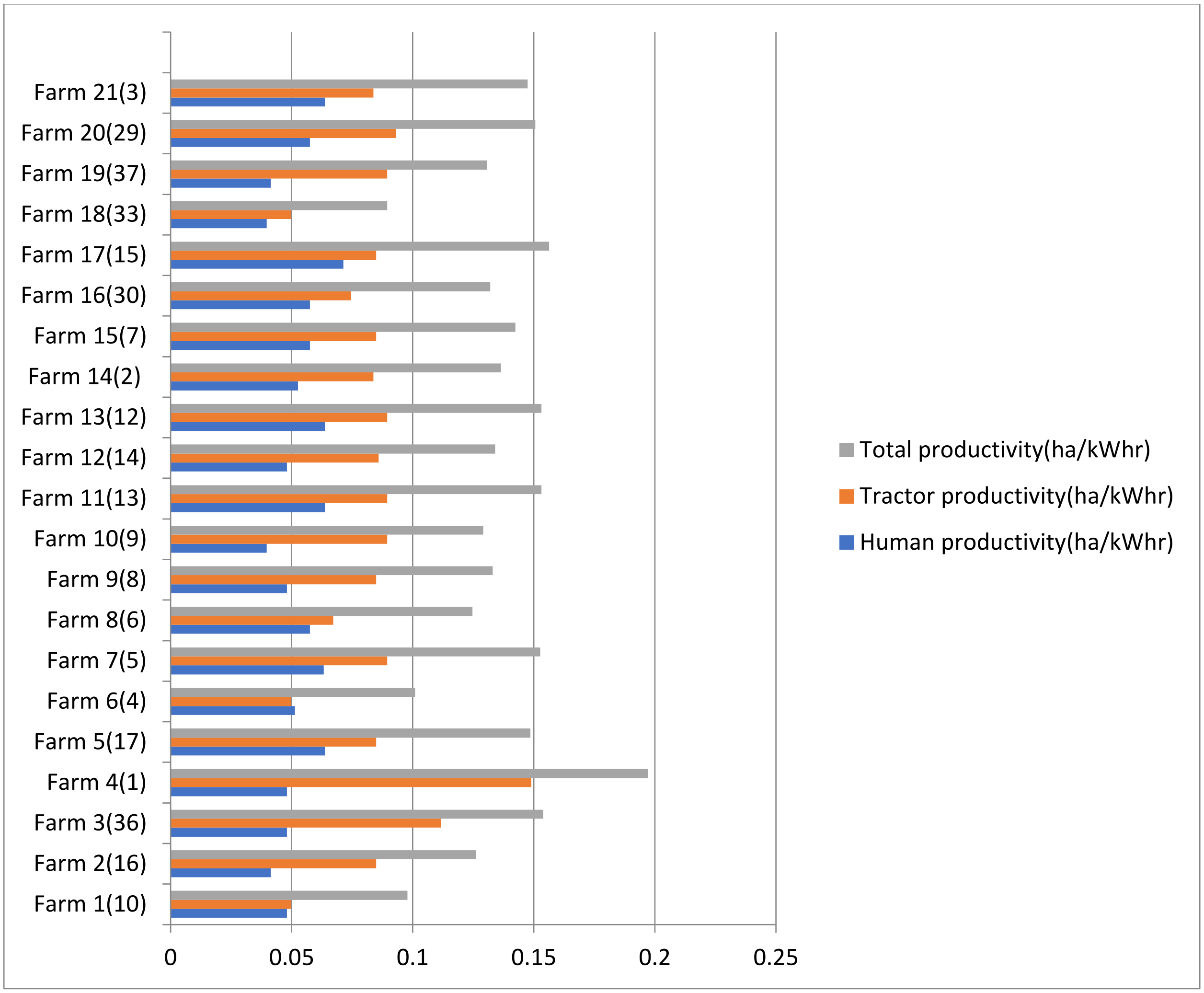

Figure 1: Bar-chart of productivity in Omor

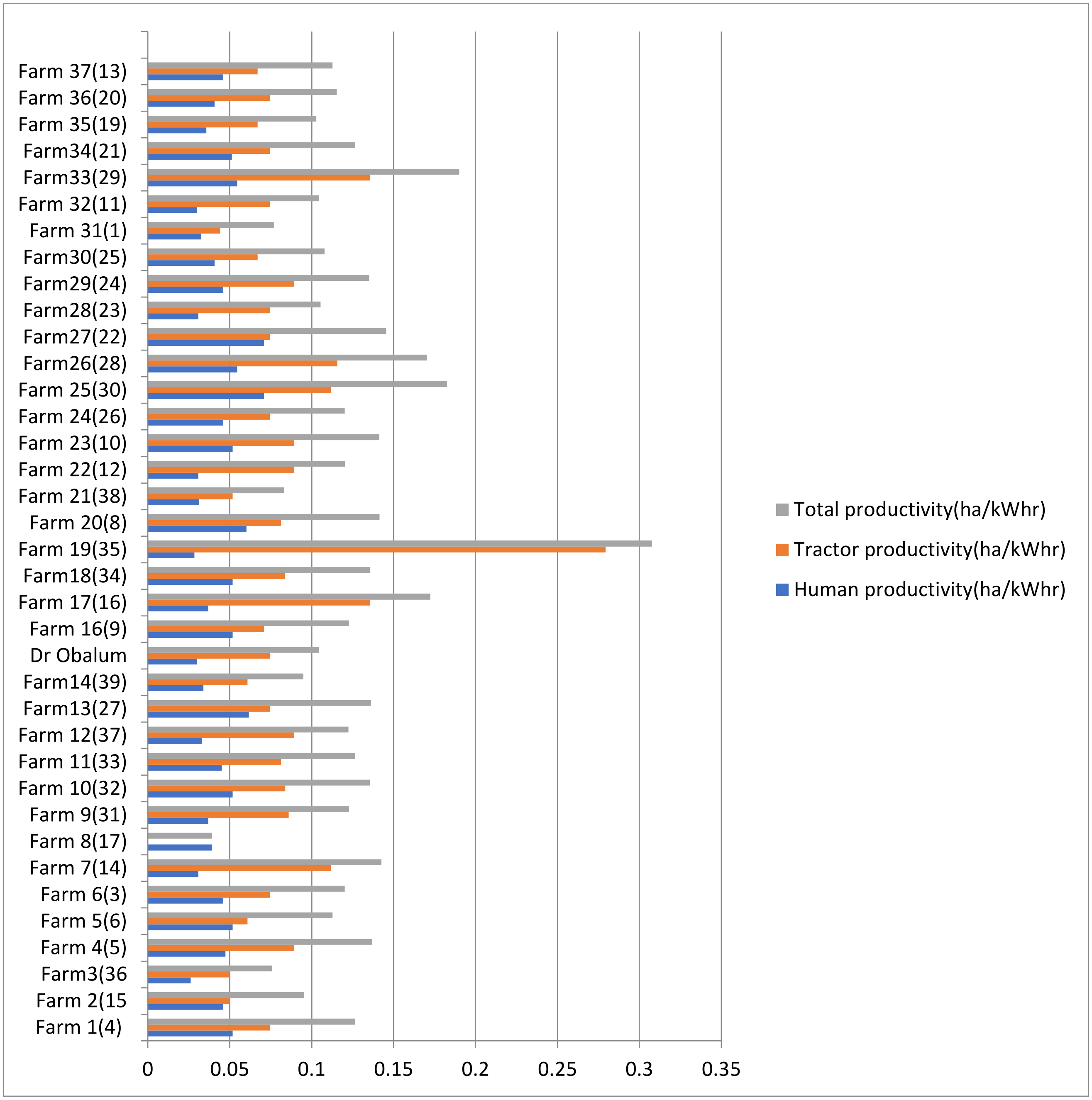

Figure 2: Bar-chart of productivity in Adani

3.4. Justification Of Gross Margin Analysis

The small size of farms of 1-5 ha were allocated to the settlers and small-scale farmers while large scale farmers have land sizes of about 30 to 40ha and above in those areas. This has encouraged the intensity of continuous cultivation on the same piece of land which does not permit good cultural management practices like shifting cultivation recommended for rice and inter-cropping for cassava cultivation. Therefore, there is intensive farming and cultivation of the crops on the same land area which results to loss of fertility in the soil and an absence of soil and moisture conservation. Tables 4, 5, 6 and 7 show that for the same rate of agronomic inputs, the total cost of production inputs, including the cost of performing field operations were estimated at 116,200 Naira per hectare for rice and 39,500 for cassava in Adani and 135,600 Naira for rice at Omor on selectively mechanized and non - mechanized operations from tillage up to harvesting and processing. The output which is also the total revenue was obtained by multiplying P which is the price of a 100kg of the crop and Y which is the yield per hectare of land per planting season. Each plot of land is equivalent to 0.5 ha in both farms which means that 2 plots is equal to a hectare. Due to the initial high cost of production, farmers are usually discouraged from farming on large scales.

Table 4: Gross margin of rice in Adani

Items	Price N/kg/lt	Average Price N/kg/lt	Recommended input kg/lt/ha	Yield/output tons/ha	Average yield tons/ha	Average yield (y) kg/ha	Input N/kg/ha
Improved varieties of rice paddy	7500	7500	100	2-3	2.5	2500 (25 bags)	
Fertilizer application	5500		100				1200
Labour:							
Ploughing							5000
Harrowing							25000
planting							
Pesticides							2000
Herbicides							1500

Weeding/fertilizer application: twice weeding	
Labour	
Harvesting + transportation	25000
Threshing	
	6000
parboiling	
	600per 100kg
Milling	
	150 per 25kg
Winnowing	300per 100kg

Table 5: Gross margin of cassava in Adani

Items	Price N/bundle/Kg	Average Price N/kg/lt	Recommended input (kg/bundles/lt/ha)	Yield/output (tons/ha)	Average yield (tons/ha)	Average yield (y) kg/ha	Input N/ha
Improved varieties of cassava stem cuttings	25	25	20	2	2	2000(20 bags)	250
Fertilizer application	5500 per 50 kg bag		100				11000
Labour:	–						
Ploughing							5000
Harrowing							4000
Ridging							5000
Weeding:							
pesticides							2000
herbcides							1500
Labour Harvesting + Transportation							6000

5000

Table 6: Gross margin analysis of rice in Omor

Items	Price N/100kg/lt	Average Price N/100kg/lt	Recommended input kg/lt/ha	Yield/output tons/ha	Average yield tons/ha	Average yield (y) kg/ha	Input N/ha	Output P x Y (Naira)

Improved varieties of rice paddy	8000-8000	8000	200	2.5	2.5	2000(25 bags)*	16000	8500 x 25 = 212,500
Fertilizer application	5500 per 50kg		2bags				11000	
Labour: Ploughing Harrowing Ridging	–	–		–	–		17000	
Pesticides Herbicides							3000	
Weeding/fertilizer application: twice weeding							9600	
Labour Harvesting + transportation								
Threshing parboiling Winnowing							65,000	

8000

5000

1000

Table 7: Gross margin (profitability) analysis per hectare of land per planting season

Total cost of production, TC in Adani for rice	=	116,200
Total revenue, TR	=	200,000
Gross margin (TR-TC)	=	83,800
Total cost of production, TC in Adani for cassava	=	39,500
Total revenue, TR	=	38,000
Gross margin (TR-TC)	=	-1500
Total cost of production, TC in Omor for rice	=	135,600
Total revenue, TR	=	212,500
Gross margin (TR-TC)	=	76,900

4. Conclusion

The analysis of the level of mechanization and agricultural productivity of some farm settlements in Adani and Omor were successfully carried out. The level of mechanization was established by deriving a relationship between various sources of farm power and the level of human power used in carrying out farm operations. The Agricultural mechanization index was deduced for the various sources of farm power by dividing the machine labour employed, L_M, with the total labour for humans and machines L_T, the value obtained is the mechanization index and the level of productivity for all selected farms in both farm settlements was determined as an inverse of the work outlay of the explicit factors involved in production. The study revealed that there is low production efficiency, drudgery in all operations that involve manual power and there is an under-utilization of mechanical power where it is needed for all other operations aside from tillage operation. According to Segun bello, the author of agricultural machinery and mechanization, a major defect in quantifying a mechanization indicator based on the ratio of mechanical tractive farm power to total farm power is that it does not bring to light the actual use scenario. Results also showed that the highest mechanization index value was recorded at 50.81% for farm 6 at Omor. This is basically because of the under-utilization of tractors of high power rating and the lowest mechanization were recorded at 9.26% for farm 19 at Adani. According to Olaoye and Rotimi (2010), it was deduced that the mechanization of a farm is said to be low if the value of the mechanization index is below 50%; if the value ranges between 50% to 70% the mechanization level is moderate, and for values above 70%, the mechanization is high. From these benchmarks, it can be deduced that the mechanization levels of the farms are high in that aspect. Likewise, according to Olaoye and Rotimi (2010), the level of productivity of a farm is said to be high if the sum of the inverse of the values of the productivity of machine and human labour is between the range of 0.7-0.99, medium if the value ranges between 0.41- 0.69 and low if the value is below 0.4. The highest productivity recorded is at 0.3078 ha/kWhr in farm 8 in Adani which is about 4 ha and the lowest productivity is at 0.0392 ha/kWhr in farm 19 in Omor which is about 2ha. The estimate of crop yield ranges from 2.5 tons / ha for rice being cultivated in Adani and 2 tons / ha for cassava if conditions are favourable. The estimate of crop yield for rice at Omor is about 2.5 tons which indicates relatively high level of productivity. The gross margin analysis shows that for the same rate of agronomic inputs, the total cost of production inputs, including the cost of performing field operations were estimated at 116,200 Naira per hectare for rice and 39,500 for cassava in Adani and 135,600 Naira for rice at Omor on selectively mechanized and non-mechanized operations from tillage up to harvesting and processing. The profit and loss situations in both farm settlements with farmers at Omor earning the profit at 76,900 Naira and farmers in Adani earning at 83,800 Naira per hectare of land per planting season. Due to the initial high cost of production, farmers are usually discouraged from farming large scales.

The level of mechanization, agricultural productivity and gross margin were determined from the analysis. It showed that there was lack of investments on the mechanization inputs for all operations after tillage operations. The two farm schemes are projects that were being run by the government in its early days of development. Due to improper management approaches and under-utilization of both financial and human resources, the projects were abandoned. I strongly recommend that private investors either in Nigeria or from foreign countries invest in the cultivation of rice. Private investors shall help provide better sources of funds, employ better management skills, approaches and provide more machine labour needed for all other operations.

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PROCESSING AND STORAGE

SOME SELECTED PHYSICO-MECHANICAL PROPERTIES OF BAOBAB FRUIT IN RELATION TO PULP EXTRACTION

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Abstract
Baobab fruit (Adansonia digitata) is an economic crop with anti-oxidant rich pulp. Some physical and mechanical properties of baobab fruit which are relevant to its pulp extraction were determined. The percentage of each component of the fruit was evaluated as well as physical properties such as sizes, shapes and density. Mechanical properties determined were static coefficient of friction, hardness and firmness. The mean value of number of seeds present in baobab fruit was estimated to be 239 seeds. Baobab fruit was found to have 39.60, 3.65, 21.22 and 35.54 % for shell/pod, fibre, pulp and seed respectively. The mean values obtained for length, breadth and thickness of baobab fruit were estimated to be 17.08, 10.04 and 9.63cm while the sphericity, aspect ratio and density could be applied in design and construction baobab pulp extractor.were 0.71, 0.61 and 296.44kg/m^3 respectively. The coefficient of friction of baobab fruit on galvanized, stainless steel, aluminum and mild steel surfaces were 0.373, 0.303, 0.408 and 0.481 while the hardness and firmness of baobab fruit were 1.5kN and 0.53 N/mm respectively. The engineering properties investigated

Keywords: Baobab, percentage composition, physical properties and mechanical properties.

1 Introduction

Baobab (*Adansonia digitata*) commonly known as *kuka* in Hausa and*ose* in Yoruba has its provenance in the savannas of sub-Saharan Africa (Kamatou et al. 2011). It is a versatile and economic plant which belongs to *Bombacaceae* family. There are other eight species of *Adansonia* (Wickens, 2008). All the parts of the plant are utilized as food, medicine and raw materials in industry. Some of the useful parts of this plant include its fruit, bark and root just to mention a few (Alba *et al*., 2020).The fruit pulp is applied as a traditional medicine and analgesic in treatment of fever, measles and intestinal parasites. The traditional birth attendants also use the pulp on pregnant and lactating mothers to assist in labour and improve lactation;the fruit of baobab plant is Non-Timber Forest Product (NTFP) which is enriched with anti-oxidant pulp(Iwu, 2014). In 2009, theFood and Drug Administrationapprovedthe use of baobab pulp as a food ingredient in United State; in the same veinEuropean Commission approved the importation of baobab fruit (Buchmann *et al*., 2010; Addy, 2009). This has subsequently brought about demand for baobab pulp (Sanchez *et al*., 2010). In meeting the demands for any agricultural product; agricultural mechanization is key to sustainable production to such product (Emami*et al*., 2018). Mechanization of baobab fruitextractproduction involves application of processing machines to improve and boost the production of baobab fruit extract. In development of processing machines for NTFP or any other agricultural product, engineering properties are necessary in the design and construction of agricultural processing machines. Engineering properties have been obtainedfor so many NTFP and crops such as doum palm, Moringa oleifera, cashew nut, mango, locust beans to mention just a few (Aremu and Fadele, Ajava and Fakayode, 2015; Balasubramanian, 2001; Jha *et al*., 2006; Ogunjimi*et al*., 2002). However, relevant physical and mechanical properties necessary forthe design and construction of baobab pulp extractor are scarce in the literatures.In this study, some physical and mechanical propertiesofbaobab fruit relevant to its processing were established. Baobab pulp as approved by some developed countries as food ingredient has vast potentials in contributing to number three goal of Sustainable Development Goals-i.e. ensuring people live healthy lives in order to reduce child mortality and raise life expectancy.

2. Materials and Methods

Some fruits of baobab (*Adansonia digitata*) were source from Kaduna Metropolis, Nigeria. The fruits were cleaned and stored in cool dry environment at room temperature value of 28±2 °C. The proportions of each component of the fruit were determined to be able to analyze or evaluate the separation efficiency for any components of the fruit. Some physical and properties such as density, moisture content, sizes and shape, static coefficient of friction were evaluated. The baobab fruit used for this experiment is shown in Figure1.

Figure 1: Baobab fruit (*Adansonia digitata*)

2.1 *Evaluation of Percentage Composition of Baobab Fruit*

The components of baobab fruit comprises of pod/shell, fibre, pulp and seed. In evaluating the percentage of each component of the fruit; some baobab fruits were cracked manually. Each of the components was carefully separated and was measured on a digital weighing scale. Their moisture content was also determined.

2.2 *Determination of Sizes and Shape of Baobab Fruit*

The sizes and shapes of baobab fruits were also determined using a digital vernier caliper (Mitutoyo Japan-precision instrument, reading to 0.01 mm). The length, breadth and thickness of the baobab fruit were measured while its sphericity, geometric and arithmetic mean diameters were evaluated.

2.3 *Determination of Density*

The true density of baobab fruit was determined by evaluating the ratio of its unit mass to the corresponding volume as expressed in equation 1. The volume of the fruit was obtained by water displacement method.

$$\rho = \frac{M_f}{V_f} \qquad 1$$

Where ρ is true density of baobab fruit; M_f is unit mass of baobab fruit while V_f is volume of baobab fruit.

2.4 *Determination of Static Coefficient of Friction*

The static coefficient of friction of baobab on some surfaces (viz. stainless steel, mild steel, aluminum and galvanized metal) were also determined using sliding method. The fruit was placed on a surface and connected to a load pan through a twine. The load pan was loaded with load cells until the fruit was about to slide. The proportion of the sufficient load enough to cause the fruit to slide and the mass of the fruit was evaluated as static coefficient of friction as shown in equation 2.

$$\mu = \frac{M_f}{M_l} \qquad 2$$

Where μ is static coefficient of friction of baobab fruit; M_f is unit mass of baobab fruit while M_l is mass of load cells and pan.

2.5 *Determination of Hardness of Baobab Fruit*

The hardness of baobab fruit was determined using a Universal Testing Machine (Techquipment-SM1000, United Kingdom) in Federal College of Forestry Mechanization Afaka Kaduna, Nigeria. The hardness was determined at a loading rate of 80mm/min. The test was stopped at rupturing point.

2.6 *Determination of Firmness*

The firmness of the baobab fruit was also determined. This was evaluated from hardness and deformation as conducted by Olaniyan and Oje (2002) as shown in equation 3.

$$F = \frac{H_o}{D_o} \qquad 3$$

Where F is the firmness of baobab fruit; H_o is hardness of baobab fruit while D_o is deflection.

3 Results and Discussion

The results obtained for the evaluation of some of the physical and mechanical properties of baobab fruit are discussed as follow.

3.1 ***Components of Baobab Fruit***

The components of baobab fruit comprise of pod/shell, fibre, pulp and seeds.Table 1 shows the percentage of constituents of baobab fruit. The average number of seeds present in baobab fruit was estimated to be 239 seeds. The mean values obtained for the component of Baobab fruit was to be 39.60, 3.65, 21.22 and 35.54 % for shell/pod, fibre, pulp and seed respectively. The shell has the highest proportion by mass of the fruit while the least proportion by mass of the fruit was fibre. The pulp of the fruit being the most nutritious component of the fruit is substantialand adequate for extraction. The fibre component of baobab fruit has been reported to be useful in production of nano-filler/epoxy composite (Uzochukwu et al., 2020). The number of seeds present in pod is also sufficient for rapid multiplication baobab seedlingproduction.

Table 1: ***Percentage Constituents of Baobab (Adansonia digitata) Fruit***

Constituents	Minimum	Maximum	Mean	SD
Number of Seed	227.00	250.00	238.50	16.26
Percentage of Shell (%)	38.24	40.95	39.60	1.92
Percentage of Fibre (%)	3.30	3.99	3.65	0.49
Percentage of Pulp (%)	20.92	21.52	21.22	0.42
Percentage of Seed (%)	34.23	36.85	35.54	1.85
Moisture Content of Baobab Fruit (%)	12.31	14.20	13.15	0.96
Moisture Content of Pulp (%)	14.93	21.39	18.16	4.57
Moisture Content of Shell (%)	9.95	12.15	11.05	1.56
Moisture Content of Fibre (%)	16.52	16.98	16.75	0.32
Moisture Content of Seed (%)	10.50	13.23	11.87	1.93

*SD is standard deviation

3.2 ***Sizes and Shapes of Baobab***

The sizes and shapes of baobab fruit were obtained as shown in Table 2. The mean values of length, breadth and thickness were 17.08, 10.04 and 9.63cm while the sphericity and aspect ratio were 0.71 and 0.61 respectively. This is an indication the fruit has a large size which is comparable to small size coconut (Rana *et al*., 2015). Moreover, based on the information obtained for both sphericity and aspect ratio; the fruit would not roll along all its axis.

Table 2: ***Some Physical Properties of Baobab Fruit***

Parameter	N	Minimum	Maximum	Mean	SD
Length (cm)	50	11.49	24.75	17.08	3.97
Breadth (cm)	50	8.33	11.70	10.04	0.89
Thickness (cm)	50	7.98	11.24	9.63	0.94
Sphericity	50	.57	0.90	0.71	0.09
AspectRatio	50	.43	0.94	0.61	0.12

GMD (cm)	50	9.41	14.43	11.74	1.42
AMD (cm)	50	9.59	15.57	12.25	1.73
Density (kg/m^3)	20	226.88	372.26	296.44	41.50

SD is standard deviation; N is number of observations

3.3 *Density of Baobab Fruit*
The density of baobab fruit was found to have a range of 226.88 to 372.26 kg/m^3 while its average value was 296.44kg/m^3 (Table 2). This shows that baobab to have good hydrodynamic properties. The fruit would float and move freely in water despite the geometric and arithmetic mean diameter being 11.74 and 12.25 cm respectively as shown in Table 2.

3.4 *Static Coefficient of Friction of Baobab Fruit*
The static coefficient of friction of baobab of some surfaces were also obtained as shown in Table 3. The average values of coefficient of friction on galvanized, stainless steel, aluminum and mild steel surfaces were 0.373, 0.303, 0.408 and 0.481 respectively. Mild steel plate was found to have the highest value due to its rough rusty surface which enhances its adhesive characteristic while stainless steel has the least value due to its smooth surface. This is in agreement with values obtained by other researchers (Aremu and Fadele, 2011)

Table 3: *Coefficient of Friction (COF) of Baobab Fruit*

Parameter	N	Minimum	Maximum	Mean	SD
COF_G	11	0.31	0.44	0.373	0.042
COF_{SS}	11	0.26	0.41	0.303	0.039
COF_A	11	0.32	0.53	0.408	0.063
COF_{MS}	11	0.25	0.59	0.481	0.112

COF_G, COF_{SS}, COF_A and COF_{MS} are coefficient of friction on galvanized, stainless steel, aluminum and mild steel surfaces.

3.5 *Hardness of Baobab Fruit*
The hardness of baobab fruit was estimated to 1.5kN when subjected to axial loading. This indicated that the fruit would rupture or crack at this value. Figure 2 shows a typical force-deformation curve of baobab fruit under axial loading. The hardness of baobab fruit is greater than that of cucumber and bael fruits (Moradi *et al*., 2019; Sonawane*et al*., 2019). The hardness of baobab fruit could be applied in developing a cracker for the fruit.

3.6 *Firmness of Baobab Fruit*
The firmness of baobab fruit was found to be 0.53 N/mm. This indicates the elastic properties of the fruit under loading. The elastic behaviour of baobab fruit is depicted in curve shown in Figure 2

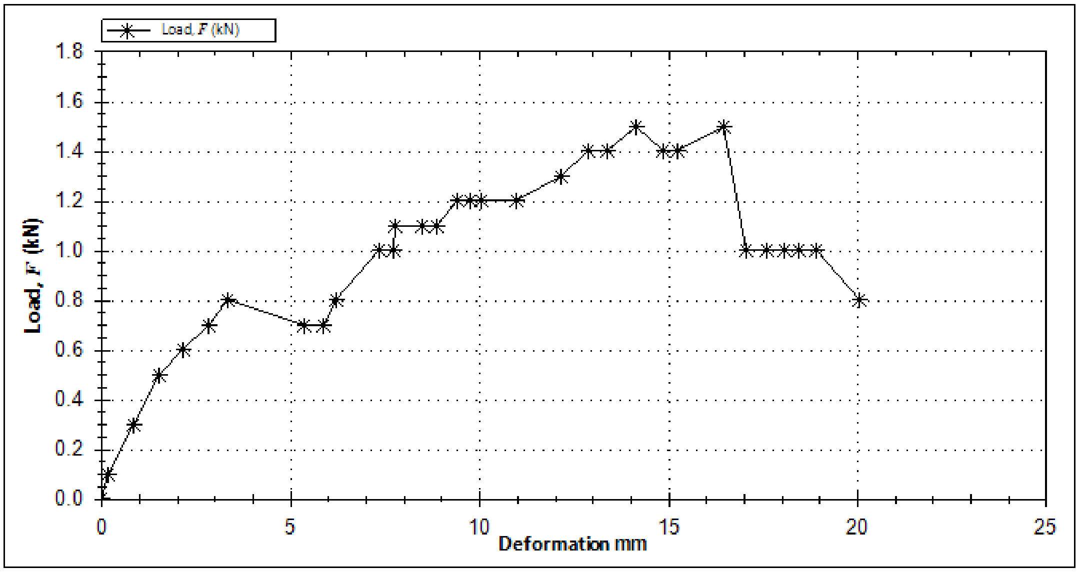

Figure 2: Force-deformation curve of baobab fruit

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4. Conclusion

Some physical and mechanical properties which could be useful in extracting pulp from baobab fruit were established.The number of seeds present in baobab fruit was estimated to be 239 seeds. Baobab fruit was found to have 39.60, 3.65, 21.22 and 35.54 % for shell/pod, fibre, pulp and seed respectively.The length, breadth and thickness of baobab fruit was estimated to be 17.08, 10.04 and 9.63cm while the sphericity, aspect ratio and density were 0.71, 0.61 and 296.44kg/m^3 respectively.The coefficient of friction of baobab fruit on galvanized, stainless steel, aluminum and mild steel surfaces were 0.373, 0.303, 0.408 and 0.481 while the hardness and firmness of baobab fruit were 1.5kN and 0.53 N/mm respectively. The engineering properties obtained could be applied in extraction of pulp from baobab fruit which in turn would contribute to achieving the third SDGs on ensuring people live healthy lives in order to reduce child mortality and raise life expectancy.

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DEVELOPMENT AND PERFORMANCE EVALUATION OF A DRIED GRAIN COLLECTING MACHINE

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Abstract

A study was conducted to design a grain collecting machine for different grains. The grains considered in this study were rice, millet and guinea corn and the total tome duration for collecting each grain was 40 minutes. The grain collecting machine was carefully designed based on economic consideration which is the basis of any design. The materials used were carefully selected so that it can serve the specific purpose for which it is meant, while at the same time maintaining economy.

The machine was tested by subjecting about 40kg of different grains which includes rice grain, millet grain and guinea corn grain at different time interval. The Average weight value, average collecting capacity, average suction loss value and average collection efficiency computed was 18.89 kg, 0.89kg/h, 4.75kg and 81% respectively for rice grain. Also, the Average weight value, average collecting capacity, average suction loss value and average collection efficiency computed was 9.88 kg, 0.42kg/h, 2.34kg and 79.38% respectively for millet *grain while the average weight value, average collecting capacity, average suction loss value and average collection efficiency computed was 18.84 kg, 0.85kg/h, 3.09kg and 86.35% respectively for guinea-corn grain.*

keywords: Grains, Pipeline, Suction, Capacity, Efficiency.

1. Introduction

The traditional methods of drying and packing grains are so tedious that they discourage increased production of grain crop. It introduces impurities to the grain, causes grain damage (visible and internal); and also reduces the grain quality. Therefore, a study of development of a grain packing machine becomes necessary to overcome the aforementioned problems. Physical, mechanical and aerodynamic properties of grain are necessary for the design of equipment to handle and package the grains. The immediate adoption of new technologies to aid storage system was as a result of a greater demand to increase production to cope with the fast-growing population of Nigeria which was estimated to grow to about 200 million by the year 2019 (UN, 2019). Another factor for adopting the technology for packing was as a result of government encouragement for the citizen to patronise local production of grain (rice) which also lead to increased production, (Adeyemo*et al.,* 2013). The adoption of improved production technology increases yield and likewise gives birth for new challenges on how to deal or handle tons of wet grains that need to be dried to maintain good quality, storability and high commercial value.

Packing of grain seeds from the concrete floor is the process of using either manual method or mechanical methods to pack grain seeds into the storage system after being dried for some time. A long-standing problem in managing the behaviour of a collection of solid grains concerns the nature of the grain packing, a property that is typically controlled by how the grains are poured or shaken (Chen *et al.,* 2006). Packing problems have been much studied in the past decades, in particular, to their wide range of applications in many settings of theoretical and practical interest, including packing/loading, scheduling, and routing (Pergola *et al.,* 2013c).

There is a great importance in mechanising the process of collecting the grains spread on the wide pavement and also worthy of note that the difficulty of the manual collection of grainswas stressed as one of the major problems of most grains packer because of the lack of technology that can be used for that project and the speed they require. This is important when packing up the grains when the rain is about to start, it will take more than an hour or more when manually collecting the grains depending on the size of the field. The larger the drying field, the more man power you need to quickly collect the grains since they're process of collecting is only by sweeping the grain.

2 Methodology

2.1 *General Description of the Machine*

The grain packing machine is made up mild steel sheet, angle iron and flat bar. This is as a result of its workability, durability and its availability.

The belt and the bearings were selected in such a way that can be able to withstand the expected maximum load, stress and power of transmission. The motor selected is such that can provide the required wattage for the maximum load of the grain packing machine.

2.2 *Design Consideration and Assumptions*

Economic consideration is the basis of any design. The simplest solution to a design problem may not only be the cheapest, but may also be the best. In designing the grain packing machine, the basic factors considered include the choice of materials, in addition to their availability and cost which are always of primary consideration. These materials were chosen on the basis of their properties.

The physical characteristics of grains that were examined are shape, size, density, weight while the aerodynamic characteristics studied are the drag coefficient and the terminal velocity of grains.

2.3 *Design Calculation*

The calculations of each of the parameters were based on the functions to which they performed

2.3.1 *Calculation of the Suction Pipe*

To design the pipeline which pack spread grain by suction and conveyed it to the bag in air-grain mixture from the starting point to the delivery point, let's consider two sections of the pipe which is placed horizontally and vertically. The vertical height 800mm was chosen in such a way to accommodate the bag to which the grains will be packed and the horizontal pipe of 200mm was selected

2.3.2 *Determination of the Pipeline Section*

The suction pipe diameter is determined from David Mills (Akhil, 2017) suction pneumatic conveying system design guide. The solid – air loading ratio (φ) is 0.3, the density of the air is 1.2 Kg/m^3, the required mass flow rate (m) =1500kg/hr = 0.42kg/s

The velocity of air to convey the grains is 33m/s in order to enable the machine to convey grains like rice, wheat and corn, (Steinke and Kandlikar, 2005),

$$m = \varphi \times \rho \times A \times V \qquad (2.1)$$

$$D = 0.211m = 211mm$$

2.3.3 *Determination of Pipe Pressure*

The velocity pressure will be given as expressed below

$$V_p = \frac{1}{2} P v^2 \qquad = 653.4pa \qquad (2.2)$$

2.3.4 *Determination of the Size of Aperture of the Collector*

The air discharge through the blower by suction to drive the dried grain, cited by (Ghafori*et al.,* 2011)

$$AirDischarge = A \times V \qquad = 1.1548m^3/s \qquad (2.3)$$

2.3.5 *Determination of Fanning Friction*

Several equations that we have seen have included terms to represent dissipation of energy due to the viscous nature of fluid flow such as air. This factor is termed fanning coefficient. The ratio of the wall shear stress to the flow kinetic energy per unit volume (Steinke and Kandlikar, 2005)

$$N_{Re} = \frac{D V_g \rho_g}{\mu_g} \qquad = 0.452 \qquad (2.4)$$

$\mu_g$is the gas viscosity in 18.5 Kg/ms at stp (Calısır*et al.,* 2005)

$$f = \frac{0.331}{\left[\left(\left(\frac{\varepsilon}{3.7 \times D}\right) + \left(\frac{7}{N_{Re}}\right)\right)\right]^2} = 0.2337 \qquad (2.5)$$

Where, ε is the pipe roughness factor which can be estimated as 0.00015 for smooth pipes or 0.0005 for shot-peened pipes.

2.3.6 *Determination of Actual Pressure Loss*

Head losses experienced in pneumatic conveying systems are the result of the following forces.

Friction of the gas on the inside of the pipe + forces required to move the solids through the pipe + forces required to support the weight of the solid and the gasses in vertical pipe runs + forces required to accelerate the solids + friction between the solids and the inside of the pipe.The total pressure loss of the parameter system (expressed in psi or ibs/in) can be expressed as

$$\Delta P_T = \Delta P_{acc} + \Delta P_g + \Delta P_s + \Delta H_g + \Delta H_s + \Delta P_{misc} \qquad (2.6)$$

Where,ΔP_T = total pressure loss in the system, ΔP_{acc} = pressure loss due to accelerate of the solids from their 'at rest' condition at the pick-up point, ΔP_g = frictional pressure loss of the gas, ΔP_s = frictional pressure loss of the solids, ΔH_g = elevation pressure loss of the gas, ΔH_s = elevation pressure loss of the solids, ΔP_{misc} = pressure loss from miscellaneous equipment.

Total pressure loss: $\Delta P_T = 0.7401 + 24.34 + 5.9 + 0.0083 + 0.01042 = 30.999m$

2.3.7 *Determination Power required*

Power delivered at the output of the blower is the product of density of solid material conveyed, volumetric rate of the material movement, acceleration due to gravity and total head of mixture. This is also the power required to ascertain the volumetric discharge and drives the materials (Agarwal, 2011)

$P_{out} = \rho \times Q \times g \times H \ = 0.1276KW$ (2.7)

Considering factor of safety;

If factor of safety of 1.5 is considered suitable for this design, the safe power output is

$$P_{out} = 0.1914KW$$

To ensure that optimum performance is achieved by the blower we are selecting the blower efficiency to be 60%. (Ghafori*et al.,* 2011)

Input power is therefore related to the output power as thus;

$P_{in} = \frac{P_{out}}{Blowerefficiency} \ = 0.3KW$ (2.8)

2.3.8 *Determination of RPM of motor (N)*

The velocity of the air exiting the suction pump is proportional to the rotation of the motor (rpm), and it is therefore given as the function diameter of the pipe section of the conveyor and the rotation of the motor (Srivastava*et al.,* 2006)

$$v = \frac{\pi \times N \times D}{60} \quad (2.9)$$

$$N = \ 2985.65rpm$$

2.4 *Principle of Operation*

The grain collecting machine works on the principle of pneumatic conveying of product from the ground to a storage medium. The machine consists of three major parts. The power, the sucking and the storage sections. The centrifugal fan would be powered with a diesel engine. As the blade in the centrifugal fan rotates, it sucks in the mixture of air and grain with an high velocity. The grains would be allowed to pass through the centrifugal fan, the effect of damages on grains through the fan is taking care of by using a forward curved fan which are useful for high air flow work.

The grain is discharge into a container capable of holding 100kg of grains, this is removed and replaced when full. The machine is provided with wheel for easy movement from one place to another.

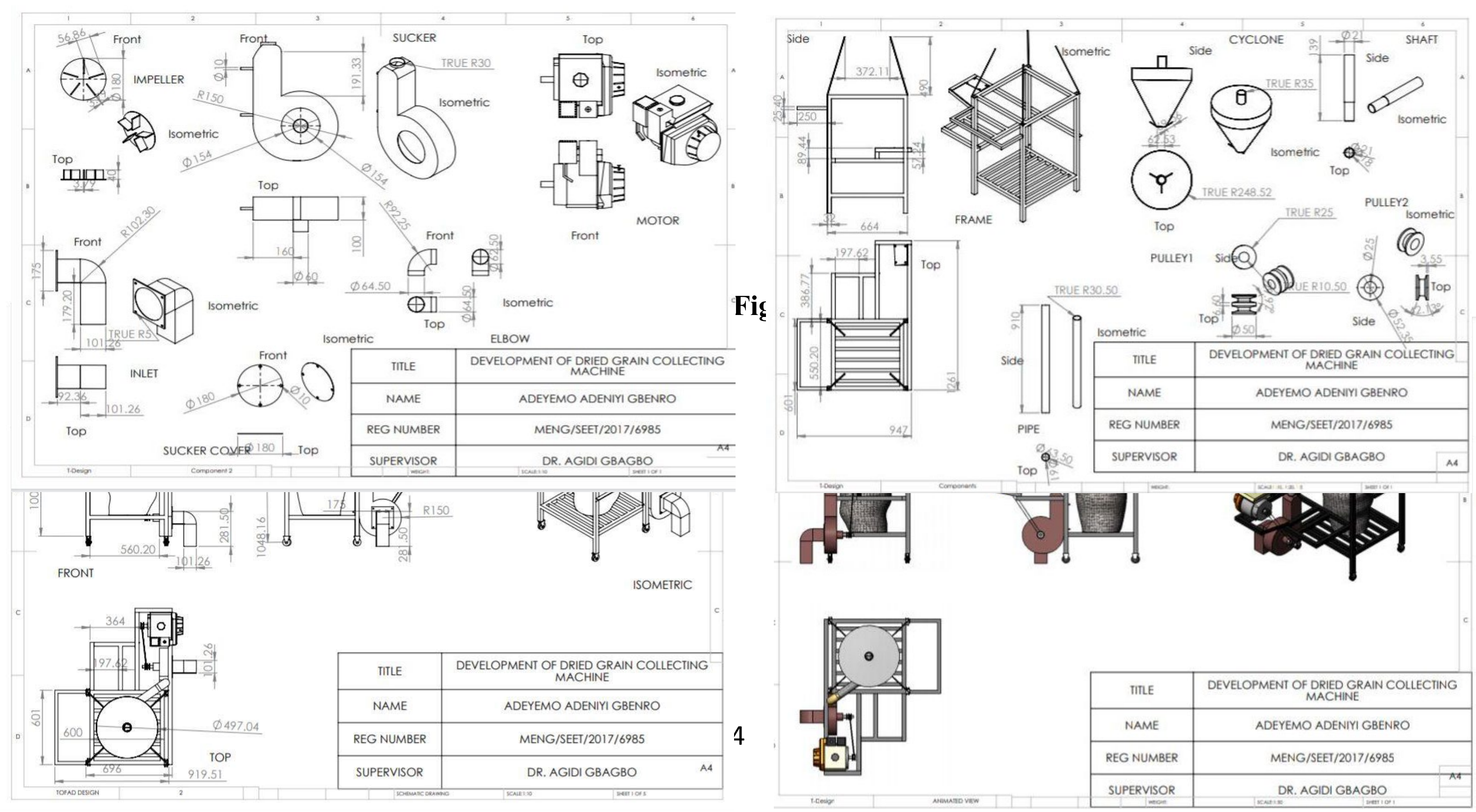

Fig. 2.3: ***Isometric View of the Machine*** **Fig. 2.4:** ***Orthographic View of the Machine***

2.5 *Procurement of Sample Materials*

The samples of grains used as materials were directed gotten from locals after harvesting. 40kg bags of paddy rice, millet and guinea corn were collected to carry out the text on the machine. The samples collected were examines to ascertain the level of quality of the grains before being collected by the machine.

2.6 *Sample Preparation*

Before the grains are being collected by the machine, the quality of the grains were noted and after each text trial, the collected grains were examined to determine the impact of the machine on the grains

2.7 *Performance Evaluation*

40 kg of grains (rice, millet and guinea corn) were used as test materials. The grains were spread manually on a 1.5 x 15m concrete pavement evenly at approximately 3m thick. The two parameters that were used for the evaluation of the machine area collecting capacity and collecting efficiency.

2.7.1 *Collecting Capacity*

This refers to the quantity of grains collected per unit time. Collecting capacity of the machine was determined using

$$Fc = \frac{W_{pc}}{T} \quad \text{(Sony et al., 2013)} \quad (2.10)$$

where: Fc = Collecting capacity, kg/h, W_{pc} = Weight of collected grains, kg, T = Total time of collection,

2.7.2 *Collecting Efficiency*

The collecting efficiency of the machine is the ratio of grains collected and the sum of grains collected and suction losses. A single pass over the 2-4 cm thick grain using the suction pipe of the machine will be done to collect the grains spread on a 1.5 x 15 m concrete pavement. The collecting efficiency of the machine was determined using

$$C_e = \frac{W_{pc}}{W_{pc} + S_l} x\ 100 \quad \text{(Sony et al., 2013)} \quad (2.11)$$

where: C_e = collecting efficiency(%), W_{pc} = weight of grains collected(kg), S_l = Suction loss(kg)

2.8 *Data Analysis*

All the data gathered were analyzed using single factor experiment arranged in completely randomized design with five replicates. Analysis of variance (ANOVA) was used to determine if there were significant differences among treatment means.

3.0 Results and Discussion

3.1 *Collecting Efficiency for Rice, Millet and Guinea Corn*

Tables 3.1, 3.2 and 3.3 show five parameters that were used to carry out the performance evaluation of the grain packer which includes time, weight of collected grain, collecting capacity, suction loss and collection efficiency. The machine was tested using rice, millet and guinea corn which were subjected to pack grains within a stipulated time frame of 40 minutes at a fragment of 5 minutes each to determine the weight of grain collected, collecting capacity, suction loss and collecting efficiency respectively. At every increment in time there is increase in efficiency, therefore the average efficiency of grain packer subjected to pack rice, millet and guinea corn grains is 84.695% at the end of 40minutes.

From the ANOVA analysis carried out, it can be deduce that the performance evaluation has a strong positive result from the analysis carried out. The multiple R has an average value of 0.9989 which represent the correlation relationship between the five parameters, time (min), weight of collected grain (Wpc kg), collecting capacity (Cc kg/h), suction loss (St kg), collecting efficiency (Ce %) indicating that time has a strong positive influence on the other four parameters.

Table 3.1 ***Collecting Efficiency for Rice***

'no	Time (min)	Weight of collected Grain (kg)	collecting capacity(kg/h)	suction loss(kg)	Collecting efficiency %
	5	5.5	1.1	0.5	91.70
	10	10	1	2.2	81.97
	15	13.4	0.89	4.0	77.01
	20	17.2	0.86	4.8	78.18
	25	20	0.8	5.2	79.37
	30	24	0.8	6.4	78.95
	35	29	0.83	7	80.56
	40	32	0.8	7.9	80.26

Table 3.2 ***Collecting Efficiency for Millet***

'no	Time (min)	Weight of collected Grain (kg)	collecting capacity(kg/h)	suction loss(kg)	Collecting efficiency %
	5	4.2	0.84	0.4	91.30
	10	5.0	0.5	0.9	84.75
	15	5.8	0.39	1.5	79.45
	20	6.2	0.31	2.0	75.61
	25	6.6	0.26	2.9	69.47
	30	7.2	0.24	3.2	69.23

35	12	0.34	3.8	75.95
40	32	0.5	4.0	88.89

Table 3.3 ***Collecting Efficiency for Guinea corn***

'no	Time (min)	Weight of collected Grain (kg)	collecting capacity(kg/h)	suction loss(kg)	Collecting efficiency %
	5	5.3	1.06	0.8	86.89
	10	10.2	1.02	1.3	88.70
	15	12.9	0.86	2.0	86.58
	20	16.8	0.84	2.5	87.05
	25	20	0.67	3.4	85.47
	30	25.5	0.73	4.1	86.15
	35	29	0.83	5.1	85.04
	40	31	0.78	5.5	84.93

4.0 Conclusions

This study was conducted to design, fabricate and carry out performance evaluation on a dried grain machine collector. The machine was tested by subjecting it to three different grains which includes rice grain, millet grain and guinea corn grain at different time interval. It was concluded that guinea had the highest collecting efficiency of 86.35% then followed by rice with collecting efficiency of 81% and lastly millet with the collecting efficiency of 79.38% respectively.

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EVALUATION OF QUALITY AND SHELF-LIFE OF FRESH AND FLESHY CUCUMBER STORED IN CHARCOAL COOLER BIN IN THE TROPICS

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Abstract

Adiabatic evaporative cooling is a concept and process adopted for extending shelf-life of fresh fruits and vegetables in tropics. This study evaluated the performance of Charcoal Cooler Bin (CCB) and its effects on the quality and shelf-life of cucumber. The storage microclimate and ambient conditions (air temperature and relative humidity) were measured using data logger. By monitoring the physiological and quality parameters, the effects of the storage media: CCB, open-air, refrigerator and laboratory conditions on the storability of cucumber fruits, and effectiveness of the CCB for fresh cucumber preservation through percentage weight loss, visual quality, degree of shriveling, colour changes andlife expectancywere evaluated. The CCB markedly maintained the freshness, reduced weight loss (with weight loss of 3.4696% after the storage period relative to cucumber samples stored in the refrigerator, laboratory and open-air condition with 8.4176%, 9.8260%, and 11.2696% respectively) and extended the shelf-life of cucumbers fruits at CCB environmental conditions. Therefore, CCB is a passive system is an inexpensive and reliable storage medium forreducing postharvest losses in a sustainable manner.

Keywords: Charcoal cooler bin, cucumber**,** shelf-life,quality, evaporative cooling system

1. Introdution

Cucumbers (Cucumis sativus L.) are fruit vegetables containing high amount of nutrient, vitamins and antioxidants. According to Dzivama *et al.* (2006), fruits and vegetables should be consumed in a fresh form for maximum usefulness and optimum nutritive value. Fruits and vegetables are generally regarded as essential herbaceous plants with high moisture content in their fleshy forms (Mogaji and Fapetu, 2011). Cucumber is a fruit vegetable of great importance all over the world today due to the social and economic value and are consumed in several ways. Based on the values and freshness for consumption of cucumbers, it is important to study various ways to maintain the freshness of cucumbers after harvest to the point of consumption. The appropriate techniques and technology suitable for rural, small and medium scale farmers and fruits and vegetable dealers is the evaporative cooling storage (e.g. CCB). Charcoal cooler Bin technology is known and used to avert post-harvest losses and deterioration. Knowledge of the relationship between temperature and relative humidity of the air in the storage structure vis a vis evaporation in the storage bin is required in a passive system condition. The evaporative processes of CCB are used for all types of agricultural produce especially tropical fruits and vegetables. According to Ronoh *et al.*(2018), the evaporative cooling process is used to extend shelf-life of agricultural produce by slowing down of the rate respiration. The stored produce tends to take a considerably longer time for deterioration to be evident or undergo structural decay because of a reduced risk of microbial growth facilitated by lower temperatures and a higher relative humidity within the cold storage facility (Wills and Golding, 2016). The use of simple systems like evaporative coolingsystem (e.g. the CCB) would help in solving preservation problems in such marginalized areas (Liberty *et al*., 2013b). This study tends to proffer solution on Postharvest handling of fleshy and fresh cucumbers to extend the shelf life as well as reduce the rate of deterioration of the fruit after harvesting. The objective of this study was to evaluate the quality and shelf-life of tropical cucumbers stored in charcoal cooler bin based on physical, chemical and physiological changes in cucumber during storage.

2. Materials and Methods

2.1 *Fruit Preparation*

Cucumber(Cucumis sativus L.)used for this research and analysis were obtained froma local farm in Nsukka, Enugu state, Nigeria on the 16th of December 2020. The cucumber fruits were properly washed with clean water for eliminating microbial contamination and preventing fungal infections. Before storing the fruits in different medium (CCB, Open-Air, Laboratory and refrigerator), the cucumber fruits were then randomly distributed intofour groups of five (5) each for the four different storage medium considered and used in this research and labeled accordingly for recognition.

2.2 ***Cucumber Storage Conditions***

The cucumber fruits were stored in a CCB, a Scanfrost refrigerator (at 8ºC), open-air (ambient) and in the laboratory. The external dimensions of the developed Charcoal cooler Bin are 580 mm long, 540 mm wide,500 mm high (front side and rear side). The cooler room has charcoal-laden walls of 50 mmthickness held by weld and chicken wire meshes on the inner and by well perforated mild steel metal sheets on the outside.The cooler has a metal door measuring 2 m by 0.7 m. The cooler was developed at the department of Agricultural and Bioresources Engineering, Faculty of Engineering, University of Nigeria, Nsukka (UNN). Figure 1.1 show the charcoal cooler bin used in this study.

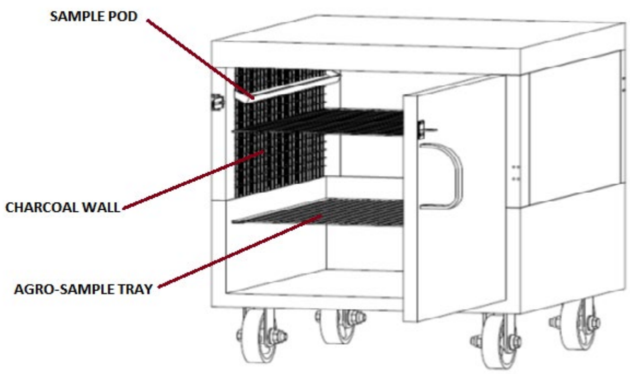


Figure1.1: ***The Charcoal Cooler Bin***

2.3 ***Weight Loss***

The Physiological Loss in Weight were calculated as the difference between the initial weight of the fruit and the weight of the fruit at time of measurement and expressed as percentage. Weight losses were determined by weighing the cucumber samples using an electronic weighing balance and recording every day for allstorage media calculated as a percent of the initial weight using the following equation: (Moalemiyan and Ramaswamy, 2012).

$$WL(\%) = 100 \times (W_A - W_B)/W_A \qquad (1)$$

Where:W_A= the weight on the first day of storage [kg] andW_B= the weight on the tested day [kg].

2.4 ***Quality Parameters***

Visual quality, degree of shriveling and colour changes are important parameters in the evaluation of fruits and vegetables quality and deterioration rates. These quality parameters for different storage conditions were evaluated through the use of the rating charts adopted by Munoz *et al.* (2017) as basis of evaluation. To obtain reliable data on this part of the study, evaluation were conducted with the aid of five (5) students from the University of Nigeria, Nsukka. The data obtained from the result of evaluation were analyzed using a measure of central tendency which is mode, to represent each storage condition and respective quality parameter with respect to storage time on the graph.

2.5 ***Measurement and Data Logging System***

The temperature and relative humidity were measured for the CCB and ambient conditions and stored in a digital data logger developed for the purpose of this research. The temperature and humidity data were used to analyze the behaviour of open-air and CCBsetups.

2.6 *Statistical Analysis*

All measurements were determined in quintuplicate in all storage mediafor analyses purpose and the data generated were statistically analyzed using means for weight losses and modes for other quality parameters in Microsoft Excel 2013. The linear regression model in Microsoft Excel 2013 was used for the life expectancy of the cucumber samples stored in CCB.

3. Results and Discussion

3.1 *The Charcoal Cooler and Environmental Conditions*

The CCB attained a relatively high cooling efficiency varying between 50.05% and 100.05% with 75.56% average throughout the period under consideration,in agreement with Babaremu *et al.* (2018) which found a varying cooling efficiency and an average of 86.01%, figure 3.1 shows the CCB cooling efficiency. The temperature of the Open-air (ambient) varied between 18ºC to 33ºC with an average of27.84ºC while the CCB temperature varied between 18ºC and 26ºC with an average of 23.22ºC throughout the storage period, The relative humidity of the CCB ranged from 93% to 95% (on the average 94.71%) while that of the ambient ranged between 12% and 95% (average of 54.32%). Babaremu *et al.* (2018) also found a significantly varying temperature and relative humidity between an evaporative cooling system and the ambient. Figures 3.2 and 3.3 show the trends in average temperatures and relative humidity for the CCB and open-air conditions respectively.The cooling efficiency (η) of the CCB, indicating the extent to which the dry bulb temperature of the cooled air approaches the wet bulb temperature of the ambient air were calculated asdefined in the following equation (Echiegu and Ugwuishiwu, 2015);

$$\eta = \frac{(To - Ts)}{(To - To,wb)} \quad \textbf{(2)}$$

Where: η = Cooling efficiency [%]; T_O = Outside temperature [˚C]; T_S = the inside air temperature [˚C]; and $T_{o,wb}$ = the outside air wet bulb temperature [˚C].

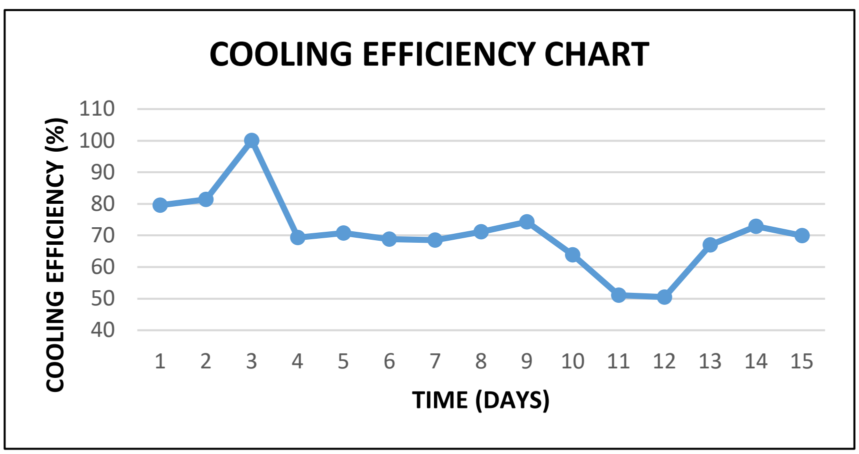
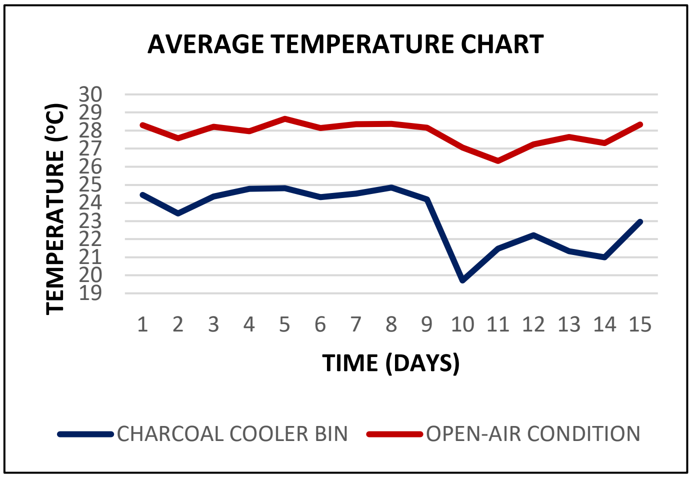


Figure 3.1: ***Cooling Efficiency of the Charcoal Cooler Bin***



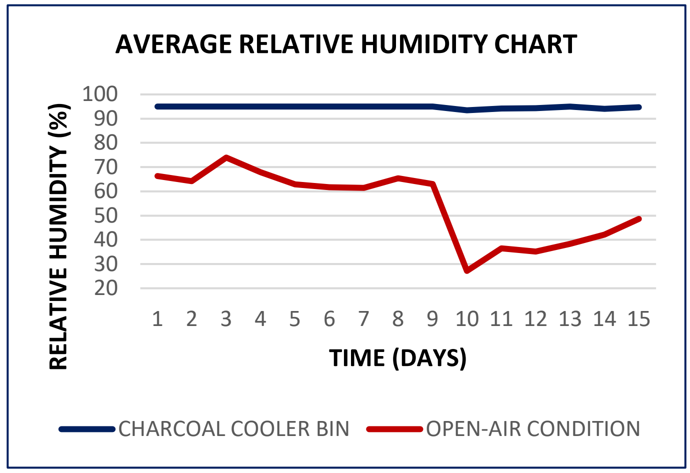


Figure 3.2 : ***Daily Average Temperature*** **Chart**

Figure 3.3 :*Daily Average Relative Humidity Chart*

3.2 *Percentage Weight Loss*

The stored cucumber samples in the CCB, refrigerator, laboratory, and open-air (ambient) had an average daily percentage weight loss of 0.2569%, 0.6099%, 0.7458% and 0.8527%. Cucumber samples in the CCB had the least increase in percentage weight loss after the storage period with 3.4696%, compared to 8.4176%, 9.8260% and 11.2696% forrefrigerated, laboratory and open-air samples respectively (figure 3.5). Figure 3.4below shows the weight loss of cucumber as a function of storage time and temperature, indicatingincreasing percentage weight loss of the samples during the 14 day storage in the media with the storage time.The CCB microclimate (lower temperature and higher relative humidity) reduced the rate of weight loss of cucumber samples agreeing with the findings by Basediya *et al*. (2013) that fresh horticultural produce (such as fruits and vegetables) should generally be stored at lower temperatures because of their perishable nature andindicates a lower weight loss of cucumber samples stored inside the cooler than those stored outside the chamber.

Figure 3.4: ***Percentage weight Loss of Cucumber***

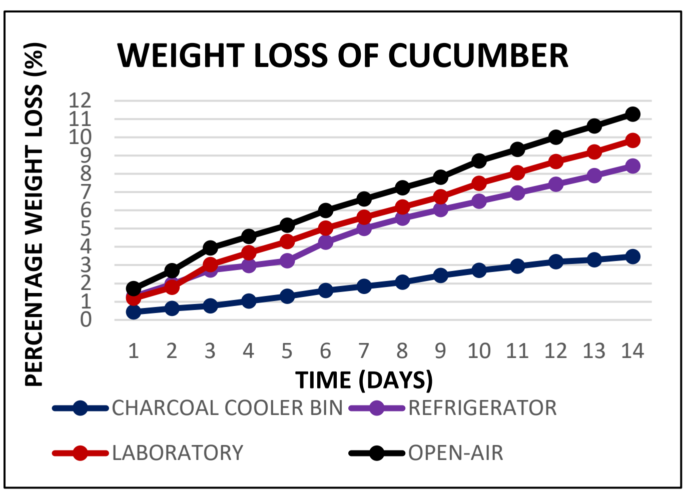
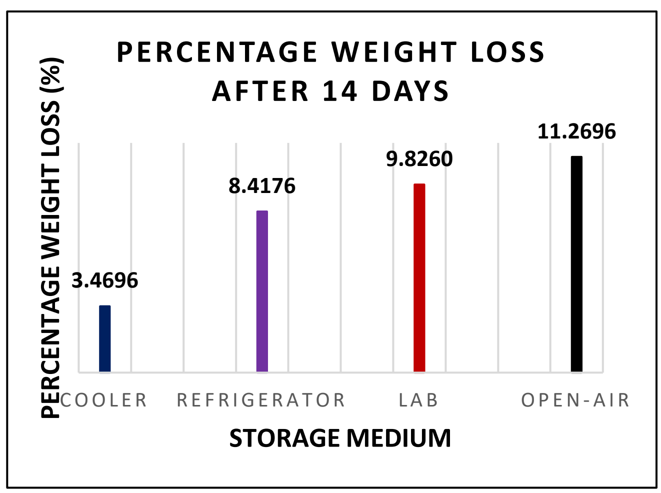


Figure 3.5: ***Percentage Weight Loss After 14 Days***



Phal *et al.* (2013) found that the use of evaporative cooling system (ECS) and high density polyethylene (HDPE) with higher relative humidity (93%) than the ambient reduced the weight loss of cucumber from 21% in the ambient to 3.09% during 8 days storage period with fewer changes in other quality parameters.

3.3 *Quality Parameters*

The cucumber samples in the CCB had better visual quality and remained in good condition (with minor defects) compared to samples stored in other storage media which had poor condition (serious defects and limit of usability) as shown in figure 3.6, also samples stored in the CCB had minor signs of shriveling, wilting or dryness compared to samples stored in other media which either had evidence of shriveling, wilting or dryness or were severly wilted (figure 3.7). As water is lost from the tissue, turgorpressure decreases, and the cell begins to shrink andcollapse, thus leading to loss of freshness (Jadhav, 2018), this can be attributed to the significant loss of freshness for laboratory, open-air and refrigerated fruits due to their increased weight loss. Considering all samples in the different storage medium, cucumbers stored in the CCB maintained the colour of cucumber and had only minor changes in colourcomapared to other samples which had either serious evidence of yellowing or major changes in colour at the end of 14 days (figure 3.8). The reducedloss of quality andcolor changesof fruits in CCB may be due to high CO2 and/or low O2 levels in the internal atmosphere of the fruits(Moalemiyan and Ramaswamy, 2012).Lowering the temperature of cucumberlowers their rate of ripening and deterioration (Kays, 1991), this explains why samples in the CCB retained more of their dark green colour more than fruits in other storage media.

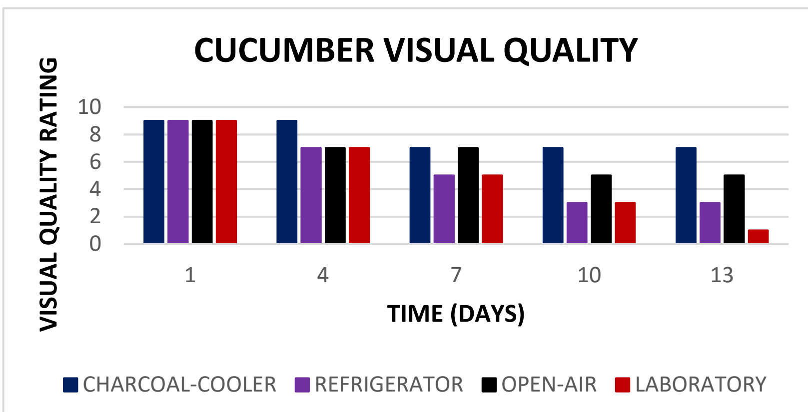


Figure 3.6: ***Cucumber Visual Quality Chart***

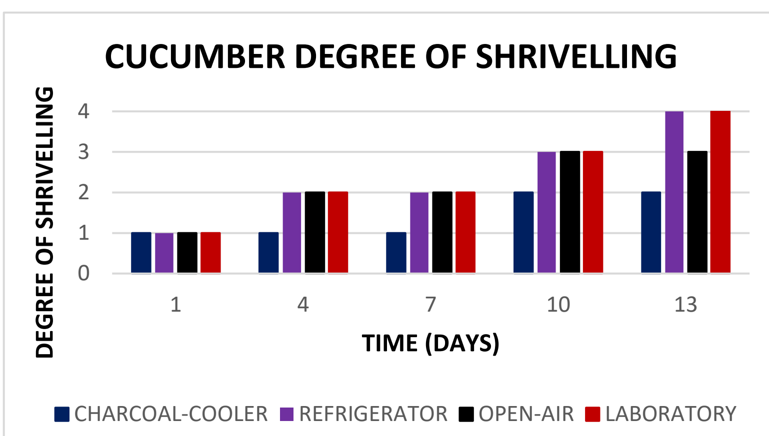


Figure 3.7: ***Cucumber Degree of Shriveling Rating Chart***

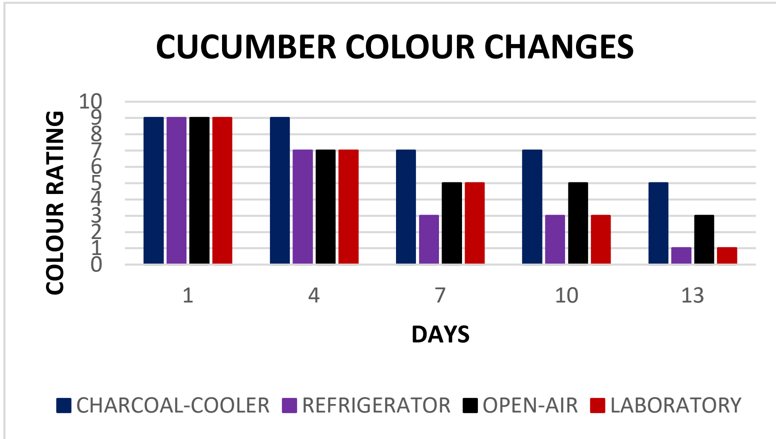


Figure 3.8: ***Cucumber Colour Rating Chart***

The established fact that the CCB reduced the degree of shriveling (wilting or dryness) and maintained good visual quality of cucumber is in agreement with the results of Munoz *et al.* (2017) that evaporative cooling systems preserve the quality of fruits and vegetables.

3.4 ***Shelf-life and Life Expectancy***

After storage period, the data from the weight loss of cucumber stored in the CCB were used to produce a trend line to show the relationship of percentage weight loss with respect to time. These also indicatethe possible percentage weight loss of the cucumber samples for the next six (6) days.According to FAO(1989), when the harvested produce losses 5 or 10 percent of its fresh weight, it begins to wilt and soon becomes unusable. As indicated in the graph, the percentage weight loss of cucumbers in the CCB will reach 5% after 20 days of storage, agreeing with the results of Munoz *et al.* (2017) that commodities stored in an evaporative cooling system has lesser inclination in the trend line from a linear regression model over time accessed in terms of weight loss.This technique wasused to determine the time when the samples will reach its limit in terms of percentage weight loss. Figure 3.9 shows the trend line and the equation derived from the regression method.

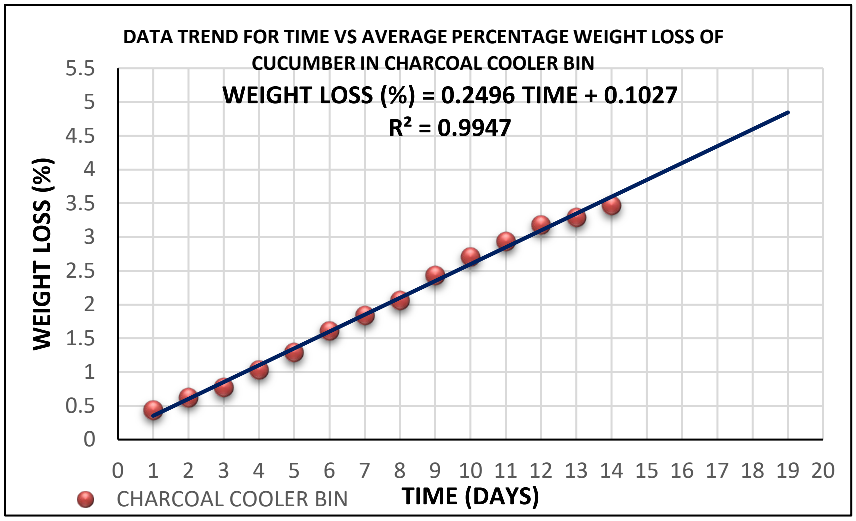


Figure 3.9: ***Data Trend for Time against Percentage Weight Loss of Cucumber in the CCB***

The CCB delayed deterioration and increased the shelf life of cucumber which was detected by observing external appearance, shriveling, the loss of color, and weight loss data. The loss of color, wilting, and weight were greater in cucumbers kept in other storage media than in cucumbers kept in the CCB. Cucumber stored in the CCB were still acceptable for 14 days with weight loss of less than 5% while refrigerated, laboratory and open-air samples were acceptable for 9, 6 and 5 days having weight loss greater than 5% respectively.

4. Conclusions

This research focused on the evaluation of quality and shelf-life of fresh and fleshy cucumber stored in charcoal cooler bin in the tropics. It can be concluded that the CCB was effective for reducing moisture loss and prolonging the storage life of cucumber. The microclimate of the CCB helped to better retain the different quality parameters by reducing changes in color, degree of shriveling and loss in weight. Commodities stored inside the evaporative cooler show better conditions in terms of weight, visual quality and degree of shriveling compared to those stored in other media. The study proved that the use of evaporative CCB can prolong the shelf-life of cucumber and other fruits and vegetables and therefore, proffer a solution to the issues of postharvest losses.

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ERGONOMIC STUDY OF GARI FRYING POPULATION IN SOUTHWESTERN NIGERIA

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Abstract

Disregard for ergonomics in designing a workstation has been identified as a major cause of inefficiency, low productivity and injury to personnel especially among indigenous food processing operators. Operations such as gari-frying require an ergonomic workstation but due to unavailability or insufficient data this has not been possible. This study focused on the collection of anthropometric data of the gari-frying population in the six southwestern states of Nigeria in order to provide data needed for designing gari-frying facilities that fit the target population. Twenty-five body dimensions were measured among 120 gari-frying processors from six states. Statistical analysis was performed using SPSS package. Results show that there is statistically significant *difference in variability of data across and within the states in all the body dimensions measured at P≤0.05, with Ekiti and Ondo state having more anthropometric parameters which differ from that of the reference (Ogun State). The differences in the mean age, weight and lumbar height observed in all the states compared to Ogun state was between 11.42 and 24.25%. The result indicates that a workplace designed based on anthropometric data from another population (even in the same location) will not be ergonomically suitable for the target population. The work, thus recommended that work station should be designed with percentile values in order to cover a larger number of the target population*

.

Keywords: Ergonomic, Workstation, *Gari*-frying, Design to fit, Anthropometry.

1 Introduction

Gari *(Manihot Spp.)* is slight sour tasting gelatinized granular flour which can either be whitish or yellowish in colour. It is made from fresh cassava tubers and commonly consumed in Western part of Africa. *The processing of gari involves several unit operation*s such as peeling, washing and grating, fermentation, dewatering, pulverizing, sieving, and frying. *Gari*-frying (*Garification)* which is about the last operation in *gari* production and, to a large extent, the determinant of the final product involves simultaneous cooking and dehydration, that is, heat treatment of dewatered cassava mash, which has been pulverized into grains, to produce the gelatinized and dried granules known as *gari*.

Methods used in the processing of cassava into *gari* can be categorized into two: traditional and improved methods. Improved methods are subdivided into improved traditional and fully mechanized methods. The unit operations of *gari* production in the improved methods are the same as in the traditional method, except for the type of equipment and machinery in use.

Traditionally, *gari* is fried by women in cast-iron pans over fire from wood. The women sometimes sit sideways by the fireplace and continuously turn the mash in the pan with a small paddle until the batch is ready. This operation is quite tedious and uncomfortable and usually these women maintain this posture for a minimum of 30 minutes before a batch of gari is finally formed. The discomfort of the operator, the heat, the sitting posture required and smoke disturbance have been of concern to researchers. In the improved traditional method the workplace and utensils used are re-designed to ease operation but unfortunately some of these developed machines are either not using appropriate technology and so are only adaptable by the target end user. They are also not only expensive to acquire, operate and maintain but are beyond the technical know-how of the rural processors. Though, they do not satisfy most of the crucial considerations for agricultural processing machines as stated by Kepner *et al.,* (1978). According to them, agricultural machines must be rural integrated, simple, easy to handle and at an affordable cost for an average farmer. They should also be easy to maintain by the operators within the available farm power, or at worst the most available nearest farm power resources and they should enhance retention of quality of desired processed products.

A fully mechanized method involves the use of various equipments for each unit operation. Some of which have been commercialized while others are still undergoing further developments and perfection. Most of these mechanized equipments are almost devoid of human interaction during the garification process as an operator can successfully operate several gari frying machine at once, thus increasing the value per worker. However, this solution does not encourage rural entrepreneurship especially in a country like Nigeria with increasing population growth, especially in cities. A close examination of the existing improved traditional garification equipment and work station in Nigeria shows that none is yet to fully satisfy all the criteria identified by by Kepner *et al.,* (1978). Meeting these criteria in order to develop improved and adaptable traditional equipment, is important, especially in Nigeria, which is regarded as an agricultural economies state with about 80% of her population residing in the rural areas and over 90% of these rural dwellers are farmers (Asoegwu, 1991). These small-scale rural farmers and processors produce the bulk of farm produce, hence technology that would suit them should be considered. Such technology should be able to increase their productive abilities and general well-being.

Basically, ergonomics is about the relationship between the human and the product while anthropometric is the science of using human body measurement to make a product feel comfortable and easy to use. On the whole, anthropometry is a major component in the total systems point of view that is a hallmark of good human factors or ergonomics practice (Reobuck, 1995). Anthropometry involves the systematic measurement of the physical properties of the human body, primarily dimensional descriptors of body size and shape (Hossain, 2000). To effectively design affordable and sustainable technology that will not only increase the productivity of rural gari processors but also to improve their health, moral and general well being, the need to determine the anthropometry data during garification can never be underestimated. These data collected will be adopted for the design of the gari-frying work station. It is however, sad to note that little or no anthropometric data is available for gari-frying population in Nigeria. The few researches done on anthropometric database in Nigeria are for the agricultural communities and traditional processing centres. One of such researches conducted based on anthropometric survey of Nigerian farm workers in the South-Eastern Zone of Nigeria was reported by Onuoha, *et al.,* (2012). The study showed significant differences among various body dimensions in comparison with South-Western Nigeria bus passengers. Also, Shiru and Abubakar (2012), measured anthropometric parameters of cassava grating machine operators in Niger State of Nigeria and observed that the operators differ in both anthropometry and age. A similar study as reported by Onuoha *et al*. (2013), measured ten anthropometric variables relevant to the design of hand tools for agricultural workers in Ebonyi state Nigeria. It was observed that the percentage difference in dimensions between male and female genders ranged from 0.58% to 9.25%. This will help in designing suitable equipment and machines for the two genders. Some researchers (IITA, 1995; Aiyelari et al, 1997; and Igbeka, 2003) after appraising the various innovations and improvements on *garification* process have concluded that improved traditional fryer is most adequate for rural *gari* producers. This position was taken because the fully mechanized methods have shortcomings that make them not to conform to the requirements for agricultural equipment and machineries. The challenge, therefore, is for researchers to continue to develop ways of alleviating the risks involved in this operation, especially the eventual musculo-skeletal disorders that may result in the course of performing this manual task. To this end, it is incumbent on researchers to carry out ergonomic study of the agrarian population of Nigeria. It is also imperative to take the anthropometry measurement of all sectors of agricultural production and its value into consideration when designing and developing suitable working tools that will improve efficiency, productivity and overall well being of the user.

This work responds to these challenges by taking the anthropometry data of gari processors in six states of the South Western part of Nigeria. The data generated aimed at developing equipment for gari frying operations that will be easy for the processor, safe for the processors health and with increased efficiency and productivity which will impart positively on the processors health and invariably output and income. This study therefore study how the posture adopted by gari frying population in South Western Nigeria affects the final output from the gari frying operation by generating anthropometry data and fit the result obtained into gari frying facilities for use in gari frying work station.

2. Methodology

Anthropometric measurements of 120 subjects, selected by random sampling, were taken in the six south western states of Nigeria (Lagos, Oyo, Ogun, Osun, Ondo and Ekiti states), following standard measurement procedures. The age of the population under study ranged from 17 to 65 (mean = 42.23 years; SD = 12 years). Women are most active in this enterprise; hence they were respondents in this research. Their consents had earlier being sought before taking the measurements. Fig 1 depicts the anthropometric dimensions taken. The instruments used included vernier caliper, stadiometer, measuring tape and folding rule. Each body dimension was measured three times and the average taken to ensure reliability. The subjects selected did not have any physical deformity or handicap.

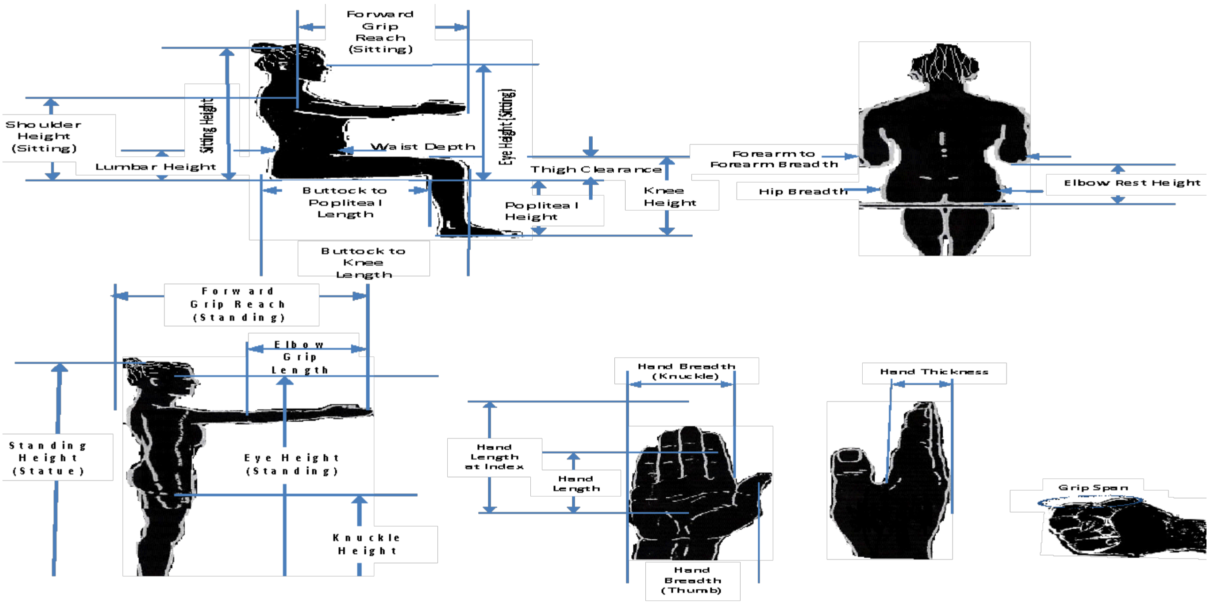

Fig. 1: ***Anthropometric Dimensions of a Matured Female***

Table 1: ***Anthropometric Definition of Parameters Measured***

S/N	Anthropometric Dimension	Definition
1	Shoulder Height (SI)	The vertical distance from the sitting surfaces to the uppermost point on the lateral edge of the shoulder with the subject sitting erect
2	Sitting Height	The vertical distance from the sitting surface to the top of the head. To measure, the subject sits erect, looking straight ahead, with the knees at right angles.
3	Stature	The vertical distance from the floor to the top of the head (vertex). To measure, the subject stands erect and looks straight ahead
4	Thigh Clearance (SI)	The vertical distance from the sitting surface to the top of the thigh at its intersection with the abdomen
5	Waist Depth	The horizontal distance between the back and abdomen at the level of the greatest lateral indentation of the waist; (if this is not apparent, at the level at which the belt is worn).
6	Popliteal Height (SI)	The vertical distance from the floor to the underside of the thigh immediately behind
7	Knuckle Height	The vertical distance from the floor to the largest knuckle of the middle finger, where the finger meets the palm (metacarpal-phalangeal joint of digit 3)
8	Knee Height (SI)	The vertical distance from the floor to the uppermost point on the knee. To measure, the subject sits erect with his knees at right angles
9	Hip Breadth (SI)	The maximum horizontal distance across the hips when seated. To measure, the subject sits erect, knees and ankles supported at right angles; knees and heels together.
10	Hand breadth at metacarpal	The maximum breadth across the hand where the fingers join the palm. To measure, the right hand is extended straight and stiff with the fingers held together.
11	Hand length at index	The maximum distance between the back and palm surfaces of the hand at the knuckle (metacarpal-phalangeal joint) of the middle finger where it joins the palm of the right hand when the fingers are extended.
12	Forearm-forearm breadth	The horizontal distance from the tip of the right elbow to the tip of the left elbow

13	Eye height (SI)	The vertical distance from the sitting surface to the lateral (outer) corner of the eye (ectocanthus
14	Eye height (ST)	The vertical distance from the floor to the lateral (outer) corner of the eye (ectocanthus).
15	Hand thickness	The depthof the hand measured transverselyfrom the level of middle portion of the palm to the opposite surface.
16	Elbow rest height (SI)	The vertical distance from the sitting surface to the bottom of the right elbow
17	Elbow height	Vertical distance between the floor to the radiale
18	Forward grip height (SI)	Vertical distance from the centre or a cylinderial rod fully grasped in the palm of the hand which is horizontally raised forward at shoulder level to the shoulder blade while sitting.
19	Lumbar height Grip span	Vertical distance from the centre or a cylinderial rod fully grasped in the palm of the hand which is horizontally raised forward at shoulder level to the shoulder blade while sitting.

Preliminary Survey

Twenty processors were surveyed in each state of the six Southwestern states, totaling 120 subjects. Information was collected through questionnaires, oral interview, personal observation and direct anthropometry data measurement during visits to the processing centres. Some major parameters were observed in each data collection centre, namely processor characteristics, workplace characteristics and socio-economic characteristics. The processor characteristics observed include number of persons at a frying point, number of hands in use and posture at fireplace, position of other working tools. Observed workplace characteristics include whether location was enclosed, parameters relating to the effectiveness of frying pan with respect to shape, size and number of frying containers as well as smoke control mechanism. Socio-economic characteristics: includes ownership of business venture, willingness to transfer business to their children and ward, profitability of the business. The output in each method was measured, and converted to kg/8hr-day. Anthropometric data collected on the subjects are shown in Fig.1. Production data collected include average production per day. Data on socio-economic aspects include ownership of business venture, willingness to transfer business to their children and ward, profitability of the business. Ownership of working tools, stations and farms as well as ease of getting raw materials. The anthropometry data generated which is the focus of the study were then used for the experimental aspect of the research.

Anthropometric Data of Subjects

The height and weight of the subjects were measured. For the height, a metal standiometer, graduated in centimeter, designed for this purpose, was used. With light clothes on, barefoot and head uncovered, the subjects were made to stand erect with the back touching the metal scale and the sliding perpendicular pointer made to rest gently on the head of the subjects. Their heights were read off the scale. Three replications of each measurement were taken and the average recorded. In the same manner, the weights were measured using weighing balance (Hanson, Model: H89 Light Green), graduated in kg and lb. Subjects' weights were read off the scale, as they stood erect on the machine with light clothes on. Three replications of each measurement were taken and the average recorded. Other body dimensions were taken with tape rule, venier caliper and folding rule. A chair of known dimension and platform on which to place the chair was used for the measurements requiring sitting position. The chair platform is imperative judging by the uneven terrain off the environments. The ages of the subjects were elicited from the circulated questionnaire. Each body part was measured in triplicate to guide against errors and average recorded. Data are collected for the subjects when they are sitting in front (SIF), sitting beside (SB), standing (S) and at alternative sit stand postures by the workstation. The data collected were analysed using descriptive and inferential statistical analysis with the aid of SPSS 20 software. The descriptive analysis and frequency distribution were carried out for each of the states under investigation. This involved the determination of the following: mean, mode, standard deviation, minimum and maximum values. In order to satisfy the different population targets workplace designers would have, different percentiles (2^{nd}, 5^{th}, 25^{th}, 50^{th}, 75^{th}, 95^{th} and 98^{th}) were calculated for each of the states for all the data. This further assisted in investigating the discrepancy between the data collected from each of the states. For the inferential statistical analysis, Analysis of Variance of Means (ANOVA) was carried out so as to know whether there was any significant difference between each of the measurements taken the across different states. In carrying out the analyses, Ogun state was used as the reference factor during the comparison. This was done at 5% level of significance.

3. Results and Discussion

Sitting in Front (SIF)

Sitting Beside (SB)

Standing (S)

Alternating Sit Stand (ASS)

Fig 1: Different Postures of Subjects during Gari Frying Operation at the Work Station (Samuel, 2011)

Table 2: ***Variations in the Ergonomic Characteristics of Improved Traditional Garification Method in Southwestern Nigeria***

features	Processors characteristics			Workplace characteristics	Heating process		Estimated output kg/8hr
Type	No of operators	No of hands used	Posture	In/outdoor	Frying medium (shape/size)	Smoke control mechanism	
1	1	single	SB	Outdoor	Circular	chimney	40
2							60
3					Trapezoid (Med)	Not provided	145
4	2				Trapezoid (large)	Low wall shield	250
5	1		SIF	Indoor	Trapezoid (Med)	Chimney and enclosed	135
6				Outdoor		Not provided	150
7		both	Standing		Trapezoid (Large)		220
8			ASS				230

Table 2 shows that the postures observed in the south western states of Nigeria correlates with the reports of Kolawole (2012) and Samuel and Adetifa (2013). These are SIF (Sitting In Front), SB (Sitting Beside), S (Standing) and ASS (Alternating Sitting and Standing). For some of the postures some processors use their two hands to stir the cassava mash, this produces more yield. Of particular interest is the ASS data which has the highest yield. This shows that the processor has higher stamina and could produce more using both hands to process. Also, alternating between sit and stand positions improves the efficiency and productivity of the operator according to Samuel (2011) and Kolawole (2012. From the oral interviews and analysis of the questionnaires from the processors it was deduced that majority are hired hands or laborers employed to fry gari and about 35% are actual business who have their own farms and process cassava from their farms that's typically the case in Ogun and Oyo state. Most of the processing centres have off-takers for their produce and about 40% sell the processed gari in local markets. They all complained of pain in the waist, back, neck and wrist and some other health challenges like coughing and frail health. From further oral investigations, most of the processors are unwilling to continue with the job and do not wish their children or wards follow in their steps because of the hardship, stress, low income and inherent health hazards involved. It was deduced further that the best sitting location is sitting in front (SIF) with the use of both hands as this gives the processor a good view of the gari being fried with adequate arm reach and less burden is exerted on the hands.

Table 3: ***ANOVA Table of Anthropometry of Gari-Frying Workers in Western State of Nigeria***

Parameters	Ekiti			Lagos			Ondo			Osun			Oyo		
	F	P	I	F	P	I	F	P	I	F	P	I	F	P	I
Age (Yr)	1.59	0.29	+	2.38	0.15	+	0.81	0.65	+	0.84	0.63	+	1.37	0.37	+
Weight (kg)	0.56	0.82	+	0.49	0.87	+	1.31	0.41	+	0.61	0.79	+	3.97	0.07	+
Height	1.3	0.41	+	0.7	0.72	+	4.61	0.05	+	1.52	0.34	+	1.78	0.27	+
Shoulder Height (SI)	1.3	0.41	+	0.7	0.72	+	4.61	0.05	+	1.52	0.34	+	1.78	0.27	+
Eye Height (ST)	1.16	0.44	+	1.79	0.23	+	0.39	0.93	+	1.38	0.35	+	3.58	0.05	+
Eye Height (SI)	0.63	0.77	+	1.53	0.47	+	1.4	0.5	+	1.06	0.59	+	5.79	0.16	+
Forward Grip Reach (ST)	4.31	0.02	-	0.33	0.96	+	0.33	0.95	+	4.79	0.02	-	0.96	0.54	+
Forward Grip Reach (SI)	1.6	0.35	+	1.62	0.34	+	2.94	0.15	+	0.67	0.75	+	2.24	0.23	+
Sitting Height	1.05	0.66	+	1.36	0.6	+	0.9	0.7	+	2.38	0.48	+	0.62	0.78	+
Buttock-Popliteal Length	0.41	0.9	+	1.31	0.47	+	1.36	0.46	+	3.02	0.2	+	0.92	0.62	+
Buttock-to-Knee Length	3.62	0.11	+	7.02	0.04	-	6.9	0.04	-	1	0.56	+	0.83	0.65	+
Popliteal Height (SI)	10.9	0.04	-	3.1	0.19	+	0.54	0.82	+	0.2	0.99	+	0.71	0.72	+

Knee Height (SI)	1.08	0.51	+	1.26	0.43	+	4.87	0.04	-	1.53	0.34	+	2.48	0.16	+
Thigh Clearance	0.35	0.93	+	0.88	0.64	+	0.45	0.88	+	0.41	0.9	+	3.71	0.15	+
Forearm Breadth	3.64	0.39	+	4.33	0.36	+	738	0.03	-	0.25	0.94	+	0		-
Waist Depth	35.8	0.13	+	3.3	0.41	+	1.13	0.64	+	0.55	0.81	+	0.46	0.84	+
Elbow Rest Height (SI)	28.7	0.03	-	8.41	0.11	+	0.34	0.92	+	0.26	0.96	+	0.19	0.98	+
Knuckle Height	0.19	0.99	+	0.41	0.92	+	0.75	0.69	+	3.18	0.08	+	1.39	0.36	+
Elbow Grip Length	0.88	0.66	+	0.93	0.64	+	2.3	0.35	+	0.22	0.97	+	0.47	0.85	+
Hip Breadth (SI)	0		-	0		-	0		-	0		-	0		-
Hand Length	0.45	0.89	+	0.94	0.56	+	1.32	0.37	+	2.15	0.16	+	1.28	0.38	+
Hand Breadth at Thumb	0.67	0.74	+	1.52	0.28	+	0.59	0.79	+	1.68	0.24	+	0.97	0.54	+
Hand Breadth at Knuckles	0.84	0.63	+	0.65	0.76	+	1.25	0.41	+	1.16	0.46	+	0.54	0.83	+
Hand Thickness	0.67	0.73	+	0.52	0.85	+	1.37	0.33	+	0.82	0.63	+	0.42	0.91	+
Grip Span	2.25	0.1	+	2.72	0.06	+	1.38	0.3	+	0.26	0.96	+	1.31	0.33	+
Hand Length at Index	1	0.49	+	0.36	0.92	+	3.59	0.03	-	0.82	0.6	+	3.6	0.03	-
Lumbar Height	1.35	0.46	+	1.09	0.55	+	0.86	0.65	+	1.94	0.32	+	0.58	0.8	+

Note F = F ratio, P = P-Value, I = Inference, + = Accept null, - = Reject null

Comparative Analysis

From Analysis of Variance (ANOVA) in Table 3, it is obvious that some variation exist in some of the parameters analyzed between the states. The parameters which are significantly ($p<0.05$) different between at least two states and the reference state include; forward grip reach (standing), buttock-to-knee length, forearm-to-forearm breadth, hip breadth (sitting) and hand length (at index). Ekiti and Ondo states have 4 and 5 anthropometric parameters that differ from that of the reference Ogun state ($p< 0.05$). The variation shows that a workplace designed based on anthropometric data from another population (even in the same location) will not be ergonomically suitable for the target population and this might imply that anthropometry data for different population may not tally hence there is need to always take the data of the specific population.

4. Conclusion

From the data generated, it is apparent that the anthropometry measurement varies even within a target population. Therefore to design an ergonomic work station and tools, the anthropometry of a representative number of the end users has to be taken into consideration. The percentiles representative of best fit used in designing tools in the work station should capture a large portion of the target group.
The information provided in this paper will help in solving problems of fit in respect of the *gari*-frying working population as it presents data that can be used in designing an appropriate *gari*-frying workplace in each of the six southwestern states of Nigeria with its attendant safe operation of workers and higher productivity which could not have been without it. The information provide will help in developing an ideal gari frying work station for on-farm processing of gari and suitable as an energy-saving equipment for small and medium scale gari industries.

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DEVELOPMENT AND PERFORMANCE EVALUATION OF A DRIED GRAIN COLLECTING MACHINE

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Abstract

A study was conducted to design a grain collecting machine for different grains. The grains considered in this study were rice, millet and guinea corn and the total tome duration for collecting each grain was 40 minutes. The grain collecting machine was carefully designed based on economic consideration which is the basis of any design. The materials used were carefully selected so that it can serve the specific purpose for which it is meant, while at the same time maintaining economy.

The machine was tested by subjecting about 40kg of different grains which includes rice grain, millet grain and guinea corn grain at different time interval. The Average weight value, average collecting capacity, average suction loss value and average collection efficiency computed was 18.89 kg, 0.89kg/h, 4.75kg and 81% respectively for rice grain. Also, the Average weight value, average collecting capacity, average suction loss value and average collection efficiency computed was 9.88 kg, 0.42kg/h, 2.34kg and 79.38% respectively for millet grain while the average weight value, average collecting capacity, average suction loss value and average collection efficiency computed was 18.84 kg, 0.85kg/h, 3.09kg and 86.35% respectively for guinea-corn grain.

Keywords: Grains, Pipeline, Suction, Capacity, Efficiency.

1. Introduction

The traditional methods of drying and packing grains are so tedious that they discourage increased production of grain crop. It introduces impurities to the grain, causes grain damage (visible and internal); and also reduces the grain quality. Therefore, a study of development of a grain packing machine becomes necessary to overcome the aforementioned problems. Physical, mechanical and aerodynamic properties of grain are necessary for the design of equipment to handle and package the grains. The immediate adoption of new technologies to aid storage system was as a result of a greater demand to increase production to cope with the fast-growing population of Nigeria which was estimated to grow to about 200 million by the year 2019 (UN, 2019). Another factor for adopting the technology for packing was as a result of government encouragement for the citizen to patronise local production of grain (rice) which also lead to increased production, (Adeyemo*et al.,* 2013). The adoption of improved production technology increases yield and likewise gives birth for new challenges on how to deal or handle tons of wet grains that need to be dried to maintain good quality, storability and high commercial value.
Packing of grain seeds from the concrete floor is the process of using either manual method or mechanical methods to pack grain seeds into the storage system after being dried for some time. A long-standing problem in managing the behaviour of a collection of solid grains concerns the nature of the grain packing, a property that is typically controlled by how the grains are poured or shaken (Chen *et al.,* 2006). Packing problems have been much studied in the past decades, in particular, to their wide range of applications in many settings of theoretical and practical interest, including packing/loading, scheduling, and routing (Pergola *et al.,* 2013c).

There is a great importance in mechanising the process of collecting the grains spread on the wide pavement and also worthy of note that the difficulty of the manual collection of grainswas stressed as one of the major problems of most grains packer because of the lack of technology that can be used for that project and the speed they require. This is important when packing up the grains when the rain is about to start, it will take more than an hour or more when manually collecting the grains depending on the size of the field. The larger the drying field, the more man power you need to quickly collect the grains since they're process of collecting is only by sweeping the grain.

2 Methodology

2.1 *General Description of the Machine*

The grain packing machine is made up mild steel sheet, angle iron and flat bar. This is as a result of its workability, durability and its availability.
The belt and the bearings were selected in such a way that can be able to withstand the expected maximum load, stress and power of transmission. The motor selected is such that can provide the required wattage for the maximum load of the grain packing machine.

2.2 *Design Consideration and Assumptions*

Economic consideration is the basis of any design. The simplest solution to a design problem may not only be the cheapest, but may also be the best. In designing the grain packing machine, the basic factors considered include the choice of materials, in addition to their availability and cost which are always of primary consideration. These materials were chosen on the basis of their properties.
The physical characteristics of grains that were examined are shape, size, density, weight while the aerodynamic characteristics studied are the drag coefficient and the terminal velocity of grains.

2.3 *Design Calculation*

The calculations of each of the parameters were based on the functions to which they performed

2.3.1 *Calculation of the Suction Pipe*

To design the pipeline which pack spread grain by suction and conveyed it to the bag in air-grain mixture from the starting point to the delivery point, let's consider two sections of the pipe which is placed horizontally and vertically. The vertical height 800mm was chosen in such a way to accommodate the bag to which the grains will be packed and the horizontal pipe of 200mm was selected

2.3.2 *Determination of the Pipeline Section*

The suction pipe diameter is determined from David Mills (Akhil, 2017) suction pneumatic conveying system design guide. The solid – air loading ratio (φ) is 0.3, the density of the air is 1.2 Kg/m^3, the required mass flow rate (m) =1500kg/hr = 0.42kg/s

The velocity of air to convey the grains is 33m/s in order to enable the machine to convey grains like rice, wheat and corn, (Steinke and Kandlikar, 2005),

$$m = \varphi \times \rho \times A \times V \qquad (2.1)$$

$$D = 0.211m = 211mm$$

2.3.3 *Determination of Pipe Pressure*

The velocity pressure will be given as expressed below

$$V_p = \frac{1}{2} Pv^2 \qquad = 653.4pa \qquad (2.2)$$

2.3.4 *Determination of the Size of Aperture of the Collector*

The air discharge through the blower by suction to drive the dried grain, cited by (Ghafori*et al.,* 2011)

$$AirDischarge = A \times V \qquad = 1.1548m^3/s \qquad (2.3)$$

2.3.5 *Determination of Fanning Friction*

Several equations that we have seen have included terms to represent dissipation of energy due to the viscous nature of fluid flow such as air. This factor is termed fanning coefficient. The ratio of the wall shear stress to the flow kinetic energy per unit volume (Steinke and Kandlikar, 2005)

$$N_{Re} = \frac{DV_g \rho_g}{\mu_g} \qquad = 0.452 \qquad (2.4)$$

$\mu_g$is the gas viscosity in 18.5 Kg/ms at stp (Calısır*et al.,* 2005)

$$f = \frac{0.331}{\left[\left(\left(\frac{\varepsilon}{3.7 \times D}\right) + \left(\frac{7}{N_{Re}}\right)\right)\right]^2} = 0.2337 \qquad (2.5)$$

Where, ε is the pipe roughness factor which can be estimated as 0.00015 for smooth pipes or 0.0005 for shot-peened pipes.

2.3.6 *Determination of Actual Pressure Loss*

Head losses experienced in pneumatic conveying systems are the result of the following forces.

Friction of the gas on the inside of the pipe + forces required to move the solids through the pipe + forces required to support the weight of the solid and the gasses in vertical pipe runs + forces required to accelerate the solids + friction between the solids and the inside of the pipe.The total pressure loss of the parameter system (expressed in psi or ibs/in) can be expressed as

$$\Delta P_T = \Delta P_{acc} + \Delta P_g + \Delta P_s + \Delta H_g + \Delta H_s + \Delta P_{misc} \qquad (2.6)$$

Where,ΔP_T = total pressure loss in the system, ΔP_{acc} = pressure loss due to accelerate of the solids from their 'at rest' condition at the pick-up point, ΔP_g = frictional pressure loss of the gas, ΔP_s = frictional pressure loss of the solids, ΔH_g = elevation pressure loss of the gas, ΔH_s = elevation pressure loss of the solids, ΔP_{misc} = pressure loss from miscellaneous equipment.

Total pressure loss: $\Delta P_T = 0.7401 + 24.34 + 5.9 + 0.0083 + 0.01042 = 30.999m$

2.3.7 *Determination Power required*

Power delivered at the output of the blower is the product of density of solid material conveyed, volumetric rate of the material movement, acceleration due to gravity and total head of mixture. This is also the power required to ascertain the volumetric discharge and drives the materials (Agarwal, 2011)

$$P_{out} = \rho \times Q \times g \times H = 0.1276KW \qquad (2.7)$$

Considering factor of safety;

If factor of safety of 1.5 is considered suitable for this design, the safe power output is

$$P_{out} = 0.1914KW$$

To ensure that optimum performance is achieved by the blower we are selecting the blower efficiency to be 60%. (Ghafori*et al.,* 2011)
Input power is therefore related to the output power as thus;

$$P_{in} = \frac{P_{out}}{Blowerefficiency} = 0.3KW \qquad (2.8)$$

2.3.8 *Determination of RPM of motor (N)*

The velocity of the air exiting the suction pump is proportional to the rotation of the motor (rpm), and it is therefore given as the function diameter of the pipe section of the conveyor and the rotation of the motor (Srivastava*et al.,* 2006)

$$v = \frac{\pi \times N \times D}{60} \qquad (2.9)$$

$$N = 2985.65rpm$$

2.4 *Principle of Operation*

The grain collecting machine works on the principle of pneumatic conveying of product from the ground to a storage medium. The machine consists of three major parts. The power, the sucking and the storage sections. The centrifugal fan would be powered with a diesel engine. As the blade in the centrifugal fan rotates, it sucks in the mixture of air and grain with an high velocity. The grains would be allowed to pass through the centrifugal fan, the effect of damages on grains through the fan is taking care of by using a forward curved fan which are useful for high air flow work.
The grain is discharge into a container capable of holding 100kg of grains, this is removed and replaced when full. The machine is provided with wheel for easy movement from one place to another.

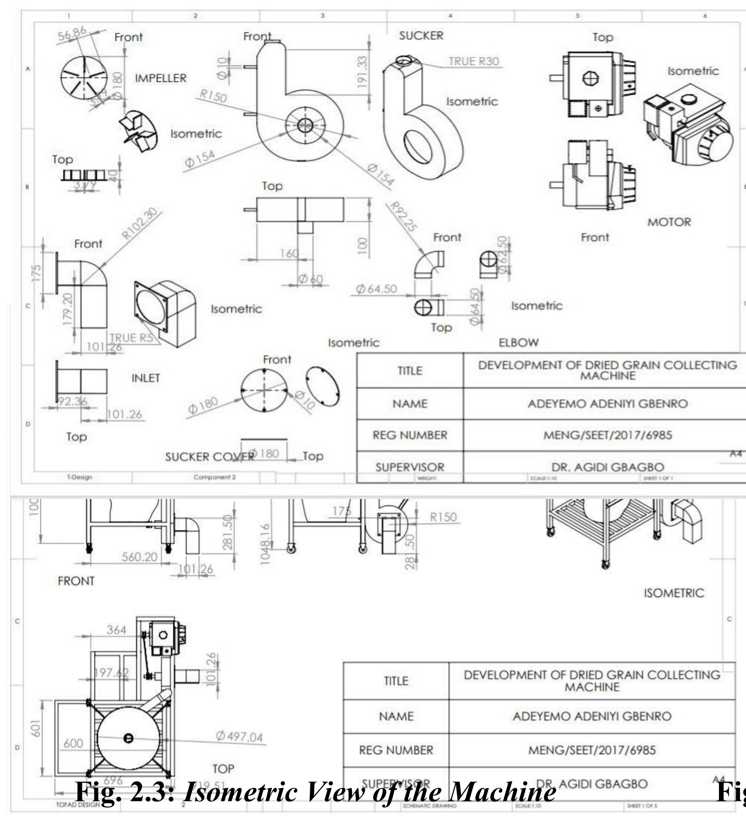

Fig. 2.3: *Isometric View of the Machine*

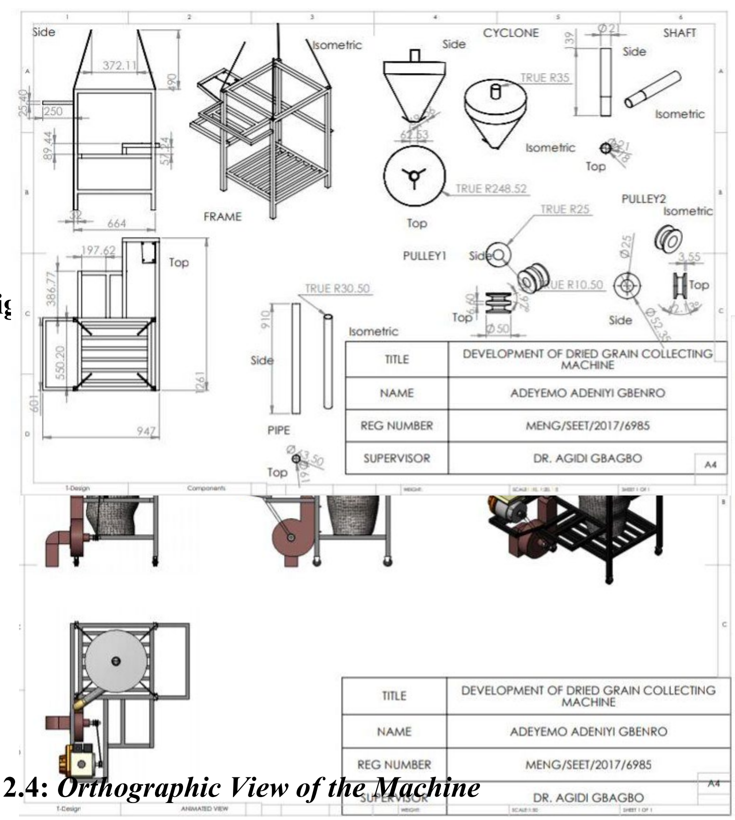

Fig. 2.4: *Orthographic View of the Machine*

2.5 *Procurement of Sample Materials*

The samples of grains used as materials were directed gotten from locals after harvesting. 40kg bags of paddy rice, millet and guinea corn were collected to carry out the text on the machine. The samples collected were examines to ascertain the level of quality of the grains before being collected by the machine.

2.6 *Sample Preparation*

Before the grains are being collected by the machine, the quality of the grains were noted and after each text trial, the collected grains were examined to determine the impact of the machine on the grains

2.7 *Performance Evaluation*

40 kg of grains (rice, millet and guinea corn) were used as test materials. The grains were spread manually on a 1.5 x 15m concrete pavement evenly at approximately 3m thick. The two parameters that were used for the evaluation of the machine area collecting capacity and collecting efficiency.

2.7.1 *collecting capacity*

This refers to the quantity of grains collected per unit time. Collecting capacity of the machine was determined using

$$Fc = \frac{W_{pc}}{T} \quad \text{(Sony et al., 2013)} \quad (2.10)$$

where: Fc = Collecting capacity, kg/h, W_{pc} = Weight of collected grains, kg, T = Total time of collection,

2.7.2 *collecting efficiency*

The collecting efficiency of the machine is the ratio of grains collected and the sum of grains collected and suction losses. A single pass over the 2-4 cm thick grain using the suction pipe of the machine will be done to collect the grains spread on a 1.5 x 15 m concrete pavement. The collecting efficiency of the machine was determined using

$$C_e = \frac{W_{pc}}{W_{pc} + S_l} x\ 100 \quad \text{(Sony et al., 2013)} \quad (2.11)$$

where: C_e = collecting efficiency(%), W_{pc} = weight of grains collected(kg), S_l = Suction loss(kg)

2.8 *Data Analysis*

All the data gathered were analyzed using single factor experiment arranged in completely randomized design with five replicates. Analysis of variance (ANOVA) was used to determine if there were significant differences among treatment means.

3.0 Results and Discussion

3.1 *Collecting Efficiency for Rice, Millet and Guinea Corn*

Tables 3.1, 3.2 and 3.3 show five parameters that were used to carry out the performance evaluation of the grain packer which includes time, weight of collected grain, collecting capacity, suction loss and collection efficiency. The machine was tested using rice, millet and guinea corn which were subjected to pack grains within a stipulated time frame of 40 minutes at a fragment of 5 minutes each to determine the weight of grain collected, collecting capacity, suction loss and collecting efficiency respectively. At every increment in time there is increase in efficiency, therefore the average efficiency of grain packer subjected to pack rice, millet and guinea corn grains is 84.695% at the end of 40minutes.

From the ANOVA analysis carried out, it can be deduce that the performance evaluation has a strong positive result from the analysis carried out. The multiple R has an average value of 0.9989 which represent the correlation relationship between the five parameters, time (min), weight of collected grain (Wpc kg), collecting capacity (Cc kg/h), suction loss (St kg), collecting efficiency (Ce %) indicating that time has a strong positive influence on the other four parameters.

Table 3.1 ***Collecting Efficiency for Rice***

'no	Time (min)	Weight of collected Grain (kg)	collecting capacity(kg/h)	suction loss(kg)	Collecting efficiency %
	5	5.5	1.1	0.5	91.70
	10	10	1	2.2	81.97
	15	13.4	0.89	4.0	77.01
	20	17.2	0.86	4.8	78.18
	25	20	0.8	5.2	79.37
	30	24	0.8	6.4	78.95
	35	29	0.83	7	80.56
	40	32	0.8	7.9	80.26

Table 3.2 ***Collecting Efficiency for Millet***

'no	Time (min)	Weight of collected Grain (kg)	collecting capacity(kg/h)	suction loss(kg)	Collecting efficiency %
	5	4.2	0.84	0.4	91.30
	10	5.0	0.5	0.9	84.75
	15	5.8	0.39	1.5	79.45
	20	6.2	0.31	2.0	75.61
	25	6.6	0.26	2.9	69.47
	30	7.2	0.24	3.2	69.23
	35	12	0.34	3.8	75.95
	40	32	0.5	4.0	88.89

Table 3.3 ***Collecting Efficiency for Guinea corn***

'no	Time (min)	Weight of collected Grain (kg)	collecting capacity(kg/h)	suction loss(kg)	Collecting efficiency %
	5	5.3	1.06	0.8	86.89
	10	10.2	1.02	1.3	88.70
	15	12.9	0.86	2.0	86.58
	20	16.8	0.84	2.5	87.05
	25	20	0.67	3.4	85.47
	30	25.5	0.73	4.1	86.15
	35	29	0.83	5.1	85.04
	40	31	0.78	5.5	84.93

4.0 Conclusions

This study was conducted to design, fabricate and carry out performance evaluation on a dried grain machine collector. The machine was tested by subjecting it to three different grains which includes rice grain, millet grain and guinea corn grain at different time interval. It was concluded that guinea had the highest collecting efficiency of 86.35% then followed by rice with collecting efficiency of 81% and lastly millet with the collecting efficiency of 79.38% respectively.

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DRYING CHARACTERISTICS OF SLICED CHILI PEPPER UNDER NATURAL CONVECTION SOLAR ENERGY DRYER USING TWO GLAZING MATERIALS

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Abstract

This study focused on the determination of drying characteristics of sliced chili pepper under natural convection solar energy dryer using glass and polythene glazing materials. Natural convection solar energy dryers were developed as part of the study. The study became imperative in order to address the highly perishing nature of chilies as they contain 70 - 80% moisture content on wet basis after harvest. The developed natural convection solar dryer reduced the moisture content appropriately to a safe level using good glazing covers in order to avoid the development of micro-flora and subsequent loss of quality or total spoilage extending the shelf-life of harvested chilies. The experiment was conducted with fresh red chilies, with 0.3056kg of it introduced into each of the two dryers and dried simultaneously. The samples were washed and sliced into two equal halves and dried for

10hrs/day at an interval of 2hrs drying period for three days under two glazing materials. The data collected during the experiment were temperature, relative humidity and moisture content, and were compared and analyzed graphically. The initial moisture contents of the fresh samples range between76.5 - 79.2% and were reduced by 26.88% in the glass covered dryer and 19% in the polythene covered dryer during the first drying period. It took the chili pepper in the glass covered dryer 30 hours to reach the safe moisture content of 10% while it took that in the polythene covered solar dryer 52 hours to reach the safe moisture content. A maximum temperature of 49°C and 46°C were recorded in the glass covered and polythene covered dryers respectively. The results obtained revealed that the glass covered dryer traps more heat than the polythene covered which showed a slower drying rate. This implies that the drying rate with the glass glazing material is better than the polythene material. Hence, presents better quality and shelf-life of dried chilies.

Keywords: Drying, Chili, Pepper, Glazing, Glass and Polythene

1.Introduction

The use of solar energy technologies in meeting our daily needs becomes imperative as solar radiation appears abundantly in many regions of the world. Solar radiation intensity on a horizontal surface is said to vary between 0 – 1070W/m^2 at sea level to noon maximum on clear sunny days. This makes it easier for people to extend the shelf-life of perishable fruits and vegetables either directly by sun drying or solar drying, or indirectly by the use of more sophisticated dryers. Open Sun drying been the widely adopted method of drying is actually simple and cheaper but poses dirt and foreign materials into the dried products thereby reduces its quality and value. Hence, the use of solar dryers becomes necessary in achieving good quality and economically viable products.

Drying as a means of preserving fruits and vegetables involves the removal of moisture from produce so as to provide a product that can be safely stored, hence preventing the growth of micro-organisms. It involves the application of heat to vaporize the moisture contained in a solid and some means of removing vapor after its separation (Jayamaran and Gupta, 2006).

Chili pepper (C*apsicum annuum*) belong to *solanaceae* family, it grows with a height of 2-4ft (0.6m – 1.2m) tall and has a shelf-life of two to three days based on12 - 15% cumulative loss when freshly harvested (Kaleemullah and Kailappan, 2004). Drying of fruits and vegetables is a simultaneous heat and mass transfer process which helps in reducing its bulkiness and thereby reducing the costs of packaging, storing and transportation, since the weight and volume of the final product has been reduced (Idah *et al*., 2014).

During drying, water migrates from the interior of the drying product on to the surface from which it evaporates through heat transfer from the surrounding air to the surface of the product. Most fruits and vegetables contain more than 80% water and therefore are said to be highly perishable. Water loss and decay account for most of their losses, which are estimated to be more than 30% in the developing countries due to inadequate handling, transportation and storage as reported by Jayaraman and Gupta (2006) and Kaya *et al.*(2007).

The objective of this study was to determine the drying characteristics of sliced chili pepper under natural convection solar energy dryer using two glazing materials.

2.Materials And Methods

2.1 *Materials*

The experiment was conducted with two equally dimensioned direct mode natural convection solar energy dryers which were all constructed locally. One of the dryers was covered with 1220mm x 595mm x 3mm regular transparent glass and the other with 1220mm x 72mm x 0.01mm polythene sheet. Fresh red Chilies were used as the experimental test crop, and 0.3056kg of it was put into each dryer at the beginning of the drying process. 100^0C capacity mercury in glass thermometer was employed for temperature test, a digital smart sensor (model AR837) and weighing balance were used for relative humidity and weight measurement.

2.2 *Description of the Dryer*

The dryer is a direct mode natural convection solar energy dryer which consists of drying chamber and solar energy collector unit. The drying chamber consist of three drying trays and a vent hole located at the top end of the chamber to provide exit for moisture laden air from the chamber. It is also embedded with absorber plate made up of coated zinc sheet and insulated with saw dust beneath. One of the drying chambers was covered with a 3.0mm thick regular transparent glass cover and the other with a polythene sheet.

The solar energy collector is a rectangular box made of metal, wood, and black plate, it was covered with a transparent glass and polythene sheet to study the heat trapping process in each. The covers are opaque to infrared radiation.

2.3 *Experimental Procedure*

Fresh red Cayenne chilies used for the experiment were obtained from Samaru Market, Sabon Gari LGA, Kaduna State. The pepper was not pretreated in any form in order to maintain its true quality after drying. The samples were washed and sliced into two equal halves with 0.3056kgof it introduced into each of the two dryers. The sliced pepper was weighed and spread in a single layer on the drying trays inside the drying chamber, and the dryers were placed appropriately in the open to commenced the drying process.

The first round of experiment was conducted from 8th to 11th of August, 2017, and replicated from 11th to 13th of August, 2017 using another sample. The data collected during the experiments were temperature, moisture content and relative humidity of the outlet air from the drying chamber. The data were compared and analyzed graphically.

2.4 *Drying Test*

The drying method used was a thin layer drying with0.3056 kg of chili pepper introduced in each of the dryer at initial moisture contents of 79.2 and 77.28 for sample in the polythene and glass covered dryers respectively. The reduction in samples weight was monitored by reweighing after every two hours starting from 8am to 4pm daily for three consecutive days.

The percentage moisture contents corresponding to different stages of the drying process were determined on wet basis using Equation1, while the drying rate was estimated using equation 2.

$$MC_{wet} = \frac{M_w - M_d}{M_w} \times 100 \ldots\ldots (1)$$

Where MC_{wet} *is moisture content* (%), M_w is mass of chili pepper, $M_d$is mass of oven dried pepper

$$R = \frac{M_{ci} - M_{cf}}{t} \quad \text{...(2)}$$

Where, M_{ci} is initial moisture content of pepper before drying, M_{cf} is final moisture content of pepper after drying and t is the drying time in hours

3. Results and Discussion

During the experimentation period, the daily mean values of the drying chamber air temperature and the drying chamber relative humidity ranged from 22 to 46^{0}C and 37.5 – 87.3% in the polythene covered dryer and 22.4 to 49^{0}C and 30.4 – 82.7% in the glass covered dryer, respectively.

3.1 *Effect of Glazing Type on Residual Temperature from Drying Chamber*

The result of variation in temperature during the first experimental trial in the two dryers is as presented in Figure 3.1 and 3.2.

From Figure 3.1 and 3.2, it is evident that the drying temperature continuously varied with an increase in drying time. The results revealed a maximum drying temperature of 49 ^{0}C and 33.2^{0}C in the glass covered dryer during the peak hours of the third day period in both experiments.

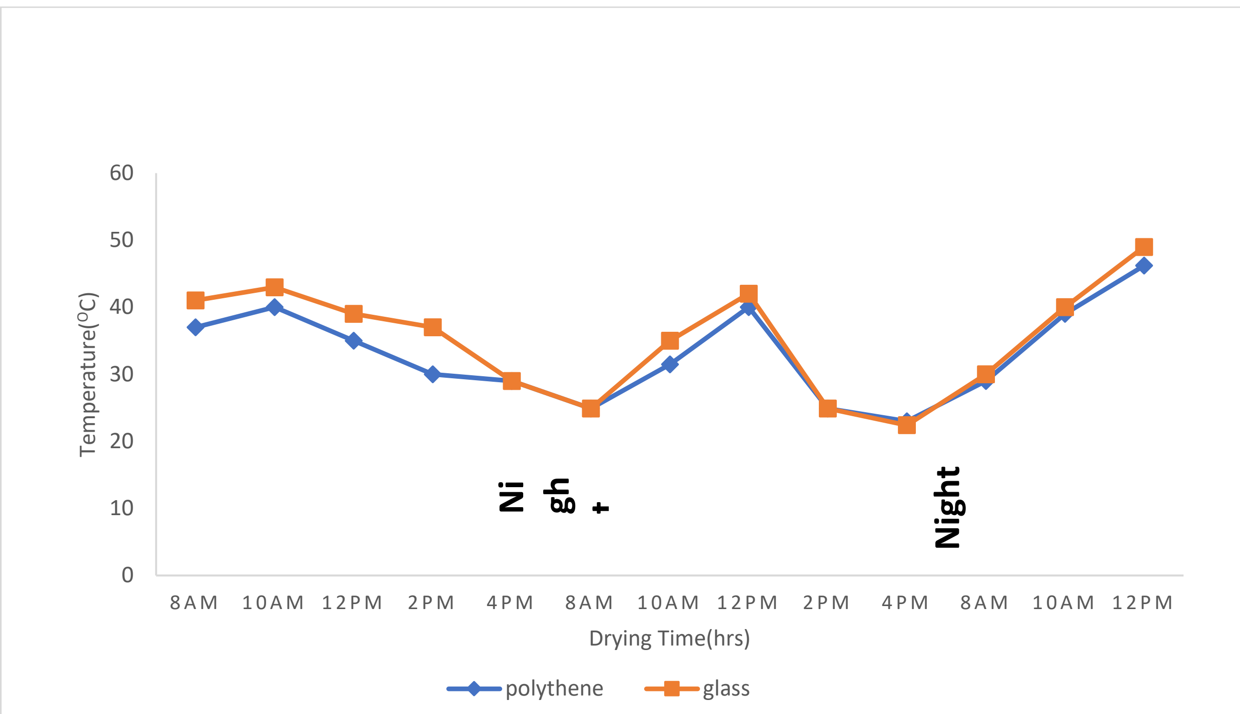

Figure 3.1: Variation in temperature in the glass and polythene covered dryers in the first experimental trial.

Figure 3.1 shows that the ambient air temperature was higher in the glass cover than in the polythene cover. This implies that the glass cover trapped more heat from the surrounding than the polythene cover. A fluctuation in temperature was observed in day 1 and 2 because the experiment was conducted in the peak of rainy season (8th to 13th of August, 2017).

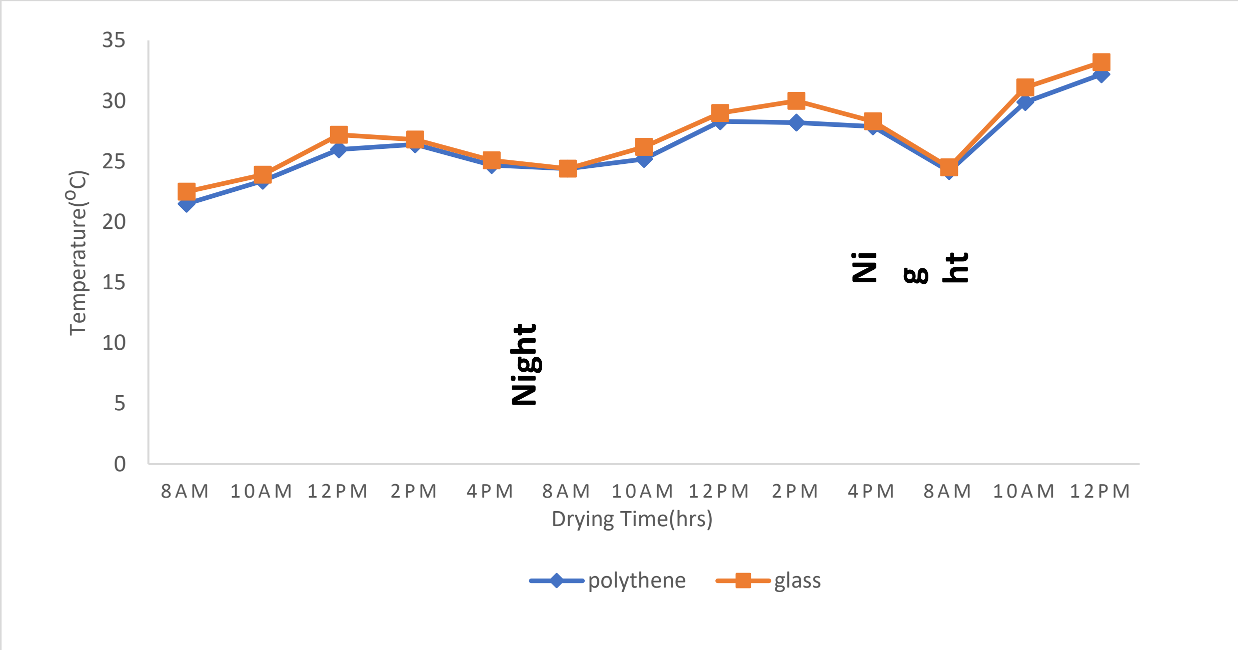

Fig 3.2: ***Variation of air temperature from the glass cover and the polythene cover in experiment 2***.

Similarly, Figure 3.2 also shows a higher ambient air temperature in the glass cover than in the polythene cover. This signifies that the glass cover trapped more heat from the surrounding than the polythene cover. The temperature at 8am was low and increased gradually around 10am to 2pm and dropped gradually up to 4pm due to low solar radiation. The same pattern was observed for the remaining two days as shown in Figure 3.2.

3.2 *Residual Relative Humidity from Drying Chamber*

The graphs of relative humidity for the two experiments are as shown in Figure 3.3 and 3.4.

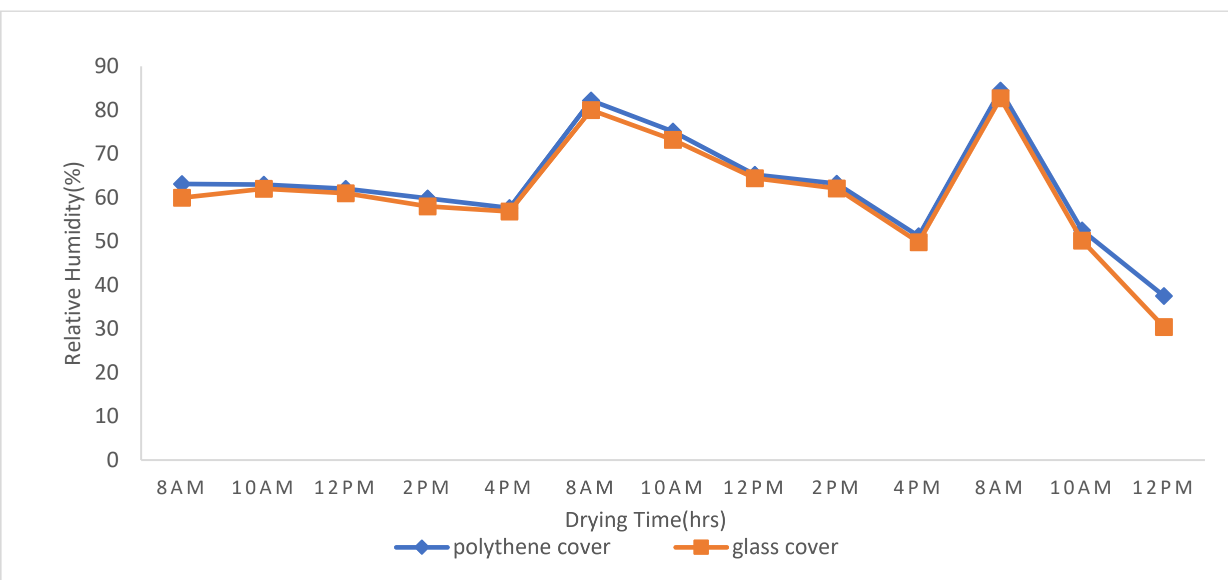

Fig 3.3: ***Residual relative humidity from glass and polythene covers.***

From Figure 3.3, it shows that the relative humidity in the glass covered dryer is lower than that of the polythene covered dryer. Thus, the polythene cover retained more moisture than the glass cover from the surrounding. The Figure also reveals that air humidity level is higher at early hours and late hours but reduced during the sun shine hours when the temperature was high.

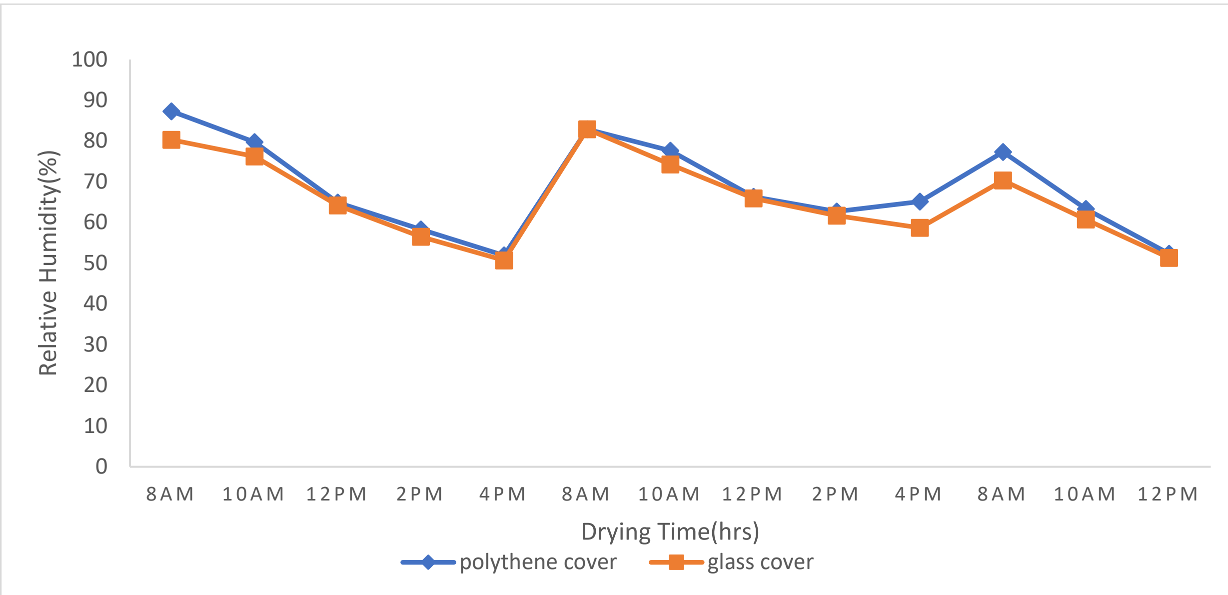

Fig 3.4: ***Residual relative humidity from glass and polythene covers.***

Figure 3.4 also shows that the relative humidity in the glass cover is lower than the polythene cover. The polythene cover also retained more moisture than the glass cover from the surrounding. The relative humidity was higher at night when there was no drying (drying is constant).

3.3 *Effect of Types of Glazing Material in Drying Rate of Chili Pepper.*

The graph of drying rate is as shown in Figure 3.5 and 3.6.

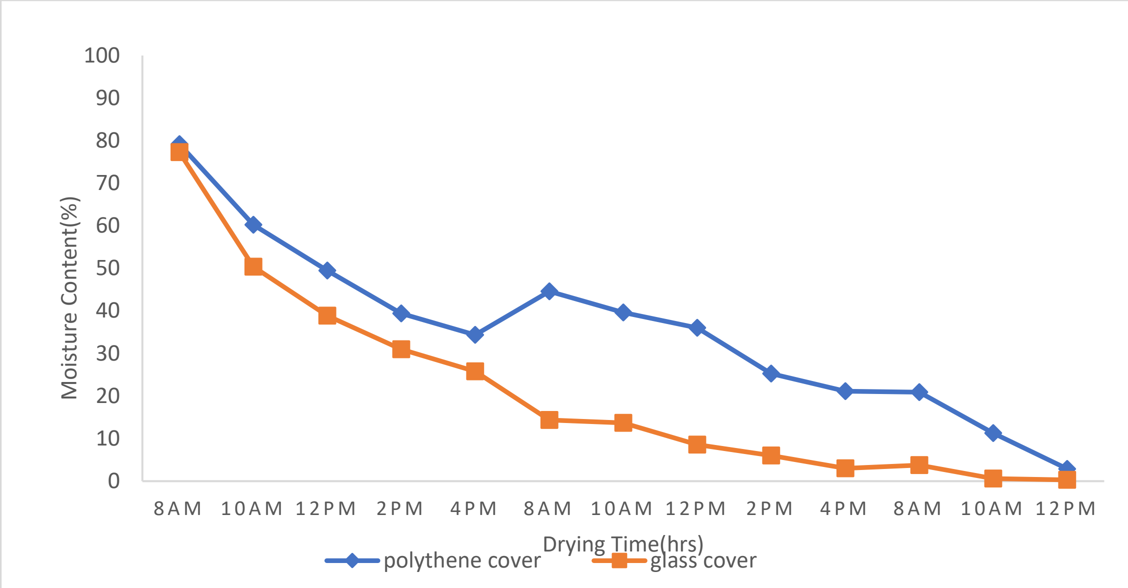

Fig 3.5: ***Drying curve of glass and polythene covered dryers.***

Figure 3.5 shows that drying rate is higher at the initial period of drying and reduces in subsequent days. The high drying rate experienced in the first day reveals a lower resistance to moisture evaporation. Moisture reabsorption was observed in the polythene covered dryer during the night hours of the first trial as the results of moisture content in the morning hours (8 - 10am) of day two rise up, though controlled in subsequent trials.

It took the glass covered and the polythene covered solar dryers 28 hours and 50 hours respectively to reach a safe moisture content level of 10%. The performance of the glass covered dryer conforms to the work of Duraisamy *et al*., (2019) who recorded 30hrs drying period to a safe moisture content of 10%.

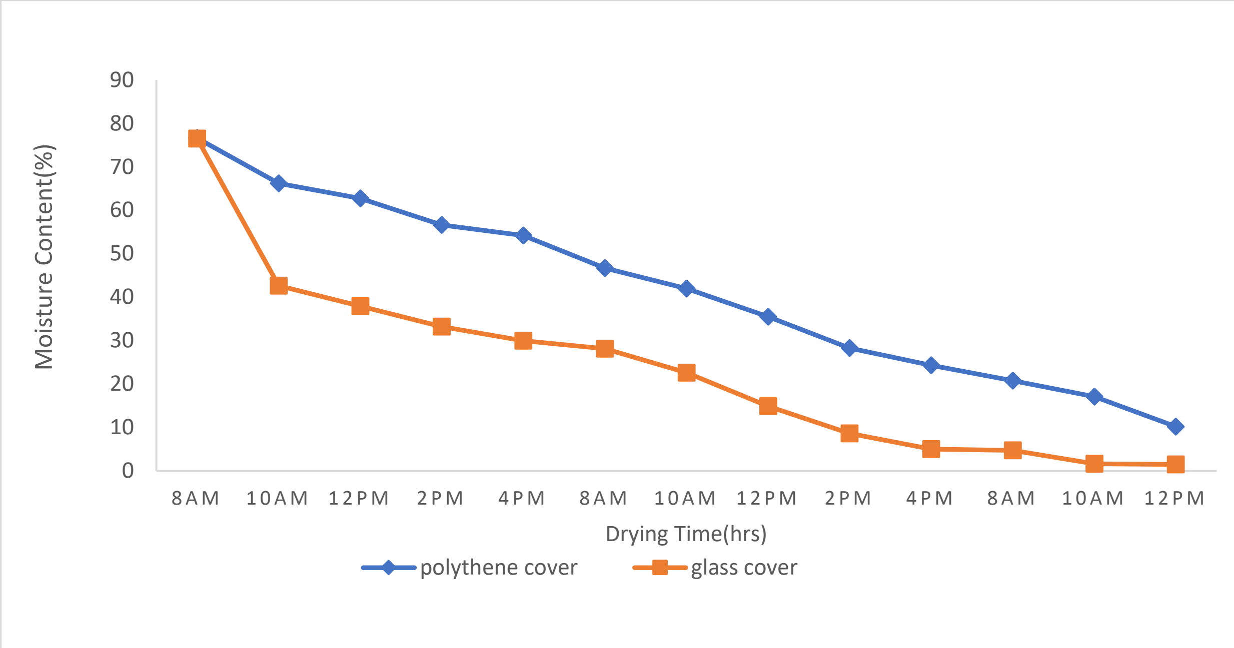

Fig 3.6: ***Drying curve of glass and polythene covered dryers.***

Figure 3.6 shows the drying rate of the two glazing materials in the second test.
The figure also indicates a higher drying rate at the initial period of the first day and a gradual decrease in subsequent days.

In this experiment, just like in the first trial, the drying rate in the glass covered dryer is faster than that of the polythene covered dryer as it took it30 hours to reach the safe moisture content as against the polythene covered that spent 52 hours. The performance of the glass covered dryer agrees to the work of Ahmad *et al.* (2014) who recorded a reduced moisture content from 80% (w.b) to 10% (w.b) in 33 h.

3. Conclusion

The study which was aimed at selecting the best glazing material for drying chili pepper in natural convection solar energy dryers was successful. The experimental results revealed a high degree of moisture loss in the glass covered dryer and a slow moisture loss in the polythene covered dryer. This stems from the fact that the glass glazing material traps more heat and permits higher proportion of visible light penetration and was also observed to possess a highly desirable property for transmitting as much as 90% of the coming short-wave radiation than the polythene material.

A safe moisture content level of 10% was achieved after 30 and 52hrs in the glass and polythene covered dryers respectively. Hence, the glass glazing material traps more heat than the polythene material. In line with the aforementioned, the glass glazing material is recommended for use in engineering design of dryers and/or application for drying over the polythene material.

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EXTRUSION PARAMETERS IMPACT ON COOKING QUALITIES OF PLANTAIN - WHEAT INSTANT NOODLES

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Abstract

This study investigated extrusion parameters impact on the cooking qualities of instant noodles produced from plantain - wheat composite flours. Plantain - wheat composite flours in ratios 0:100; 5:95; 10:90; 15:85; 20:80 and 25:75 were processed into instant noodles using a laboratory model rotating screw extruder at different extrusion conditions considering barrel temperature (60 – 100 °C) and screw speed (85 – 125 rpm). The cooking properties of the instant noodles were investigated and data obtained were analyzed using Design Expert Software. The results showed that extrusion parameters affected the cooking properties of the instant noodles. The data obtained will provide valuable information for industries in process control and design of plantain – wheat instant noodle.

Keywords: Plantain; composite flour; extrusion parameters; instant noodles; cooking properties.

1. Introduction

Instant noodle has become an important food item globally, with annual production of 101,420 million packs in 2012, and a steady increase of 3% annually since 2010 (WINA, 2013). Most instant noodles are made of wheat as the base material, thus instant noodle consumption led to dependency on massive importation of wheat in non-wheat producing countries Nigeria inclusive. Apart from high cost of wheat importation, excessive consumption of wheat has been associated with allergy, diabetics, asthma, autoimmune response, and gluten sensitivity (Rosell et al., 2013) in some parts of the world. Several works have been done on composite flour instant noodles using different flours, although rice flour seems to be the best replacement due to its small granule sizes to benefit noodle textural characteristics (Inglett et al., 2009; Yadav et al., 2011; Heo, et al., 2013). Some other raw materials for composite flour instant noodles include sorghum (Liu et al., 2012), and corn starch (Yuan et al., 2008; Yousif et al., 2012), or corn flour (Padalino et al., 2013). Lately, pigeon pea and rice (Yadav et al., 2011), pseudo-cereal such as amaranth flour in combination with cassava starch (Fiorda et al., 2013) have also been incorporated. The weakening of protein matrix in composite flour instant noodle often adversely affects noodle quality; hence composite flour instant noodle requires treatment to improve its consumers' acceptability.

In process control and design, processing data are very useful for evaluating performance during processes such as mixing, sheeting, proofing, and baking (Love et al., 2002; Morgenstern et al., 2002; Binding et al., 2003). These information also predict functionality, acceptability and storability of the product.

Consequently, in this work, impact of extrusion parameters on the cooking quality of instant noodles produced from plantain and wheat flours are investigated with the view to providing baseline information on the production of instant noodles from plantain fruits.

2. Materials and Methods

2.1 *Source of Materials*

Freshly harvested bunches of plantain fruit (Plate 1) at stage one maturity using colour as basis of clarification (Ahenkora et al., 1997; Dadzie & Orchard, 1997) were obtained from Obafemi Awolowo University Teaching and Research Farm, Ile-Ife. Other materials such as white wheat flour (Dangote brand), iodized table salt (Dangote brand), potato starch, guar gum, potassium carbonate (food grade), sodium carbonate (food grade) and sodium tripolyphosphate (STTP, food grade) were bought from a local market in Ile-Ife, Osun State. The chemicals used for analysis were of analytical grade.

Plate 1: A freshly harvested matured plantain (agbagba) fruits

2.2 *Preparation of Musa spp flour*

About 10 kg of freshly harvested debunched plantain fruits were immersed in a plastic bowl containing potable water on individual variety basis for 5 min. The fruits were removed from the bowl and peeled with the aid of a stainless kitchen knife. The pulp was sliced into cylindrical discs with thickness of about 5 mm and dipped in citric acid (CIT) (1% w/v) for 1 min to prevent enzymatic browning reaction (Adeyemi & Oladigi, 2009). Accumulation of moisture on the sliced surface as a result of the pretreatment was drained with a cheesecloth before samples were transferred to a dryer set at 70 °C (Adeniji, Tenkouano, Ezurike et al., 2010).

The citric acid treated sliced plantain fruits were dried in an air-oven set at 70 °C (±1°C) using convective air flowing at a velocity of 2.2 m/s (Adeyemi & Oladigi, 2009; Adeniji, Tenkouano, Ezurike et al., 2010). Prior to loading of the sliced fruits, the dryer was run for 30 min to reach the set drying air temperature conditions. The drying of the sliced fruits was done in a thin layer form to ensure effective drying. The initial weight of sliced fruits was recorded using the digital balance before loading into the already set oven. The sliced fruits were dried for 48 h and subsequently, the weight of the sliced fruits was measured at interval of 30 min until weight was constant. At this point, the dried chips were considered to have attained equilibrium moisture content (EMC) of the drying conditions. The dried chips were milled using a laboratory milling machine (sieve size) 500 µm aperture) and stored in an airtight bottle until the time of use (Figure 1).

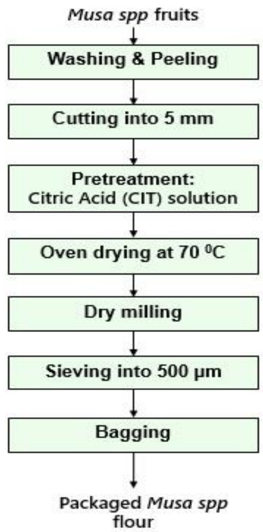


Figure 1: A flow chart showing production of plantain flour (Adeniji, Tenkouano, Ezurike et al., 2010)

***Blend formulation of plantain -wheat composite flour*: **The processed plantain flour was blended with wheat flour at 0, 5, 10, 15 20 and 25% replacement (Arshad, Anium & Zahoor, 2007) using a Kenwood food processor (Model 49074, Kenwood Ltd, Hants, UK) operated at full speed for 10 min. The blends were stored in high density polyethylene bags (0.77 mm thick) prior to use.

***Instant noodle preparation*: **Instant noodle formulations, production flow chart and products developed were given in Table 1, Figure 2 and Plate 2, respectively. A laboratory model rotating screw extruder was used for development of the extrudate (Plate 3). The barrel diameter and length-diameter (L/D) ratio were 37 mm and 27:1 respectively with standardized screw configuration for processing flour-based products was used. The plantain -wheat composite dough extrusion was conducted at a range of extrusion conditions: barrel temperature, 60 – 100 °C and screw rotation, 85 – 125 rpm.

Table 1: Formulation of instant noodle from Musa spp-wheat composite flour

	Formulations					
gredients	%NOD	%NOD	0%NOD	5%NOD	0%NOD	5%NOD
heat flour, g	00	5	0	5	0	5
usa spp flour, g			0	5	0	5
ater, ml	4	4	4	4	4	4
alt, g	6	6	6	6	6	6
otato starch, g	2	2	2	2	2	2
uar gum, g	2	2	2	2	2	2
otassium carbonate, g	12	12	12	12	12	12

odium carbonate, g	8	8	8	8	8	8
TTP, g	1	1	1	1	1	1

0%NOD (Control) =100% wheat flour; 5%NOD = 95% wheat+ 5% *Musa spp* flour; 10%NOD = 90% wheat+ 10% *Musa spp* flour; 15%NOD = 85% wheat+ 15% *Musa spp* flour; 20%NOD = 80% wheat+ 20% *Musa spp* flour and 25%NOD = 75% wheat+ 25% *Musa spp* flour (Hou et al., 1997)

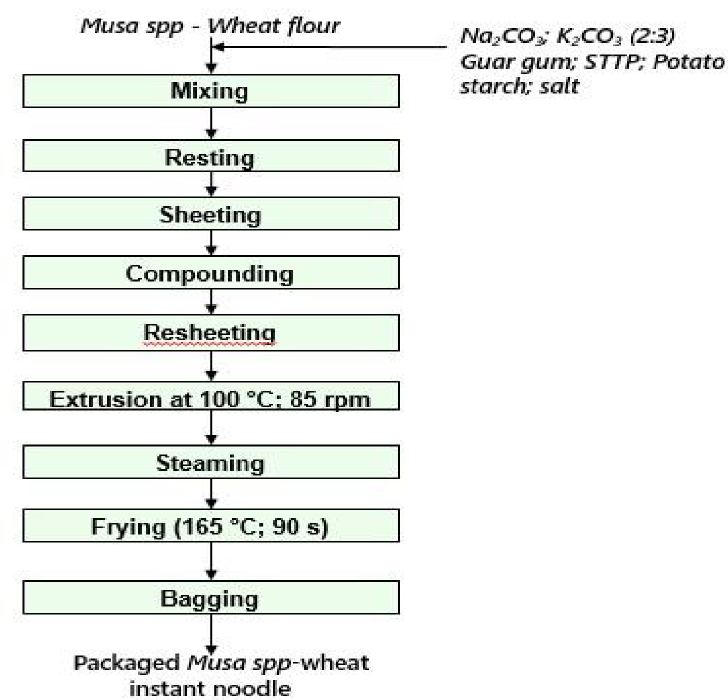


Figure 2: A schematic diagram showing the production of fried instant noodle

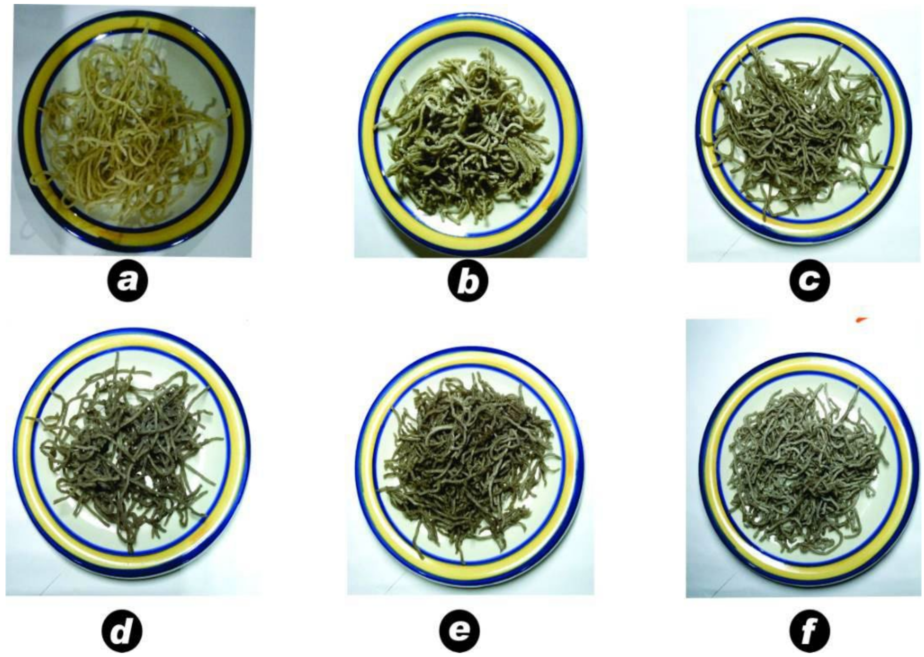


Plate 2: Fried instant noodles produced from plantain-wheat flours:

(a)100% wheat flour instant noodle; (b) 5% plantain flour + 95% wheat flour instant noodle; (c) 10% plantain flour + 90% wheat flour instant noodle; (d) 15% plantain flour + 85% wheat flour instant noodle; (e) 20% plantain flour + 80% wheat flour instant noodle; (f) 25% plantain flour + 75% wheat flour instant noodle again. The percentage weight loss during cooking was obtained by gravimetry. Values reported are average of five replications.

Plate 3: A laboratory model rotating screw extruder

2.3 *Determination of optimum cooking time*

The optimum cooking time was determined following the method of (Widjaya, Cato & Small, 2008). About 10 g of instant noodle was boiled in 1000 ml of boiling distilled water and after each minute of cooking for the first 2 min, noddle was removed and squeezed between clear glass slides. This procedure was then repeated by removing the noodles every 15 s until the white core disappeared. Therefore, the time taken for the white core to disappear when the noodle strand was boiled in the distilled water is referred to as the optimum cooking time.

2.4 *Determination of cooking weight and cooking loss*

Cooking weight and cooking loss were determined by methods of Oh, Seib and Chung, (1985) and AACC International, respectively. Instant noodle (10 g) was cooked in 300 ml of distilled water in a beaker to their optimum cooking time, rinsed with distilled water, drained and left to cool for 5 min at room temperature. The cooled cooked noodles were then reweighed and results recorded as % increase on cooking. Residual water was removed by drying in the oven at 100 °C until no traces of water in the beaker, cooled and weighed. Results are reported as % weight loss during cooking.

$$C_w = \frac{W_C - W_D}{W_D} \times 100 \qquad (1)$$

Where:

C_W = Cooking weight (%)

W_C = Weight of cooked instant noodle, g;

W_D = Weight of dried instant noodle, g.

$$C_L = \frac{W_L}{W_D} \times 100 \qquad (2)$$

Where:

C_L = Cooking loss, %

W_L = Weight of loss solid, g

2.5 *Determination of Fat Content*

Ground instant noodle (3 g) was put into a thimble and extracted with n-hexane for about 6 h using soxhlet extractor. The solvent was removed from the extracted oil by evaporation. The oil was further dried in a hot-air oven at 100 °C for 30 min. to remove residual organic solvent and moisture. The oil was allowed to cool in a desiccator and weighed. The quantity of oil obtained was expressed as percentage of the original sample weight used.

$$\%\, CF = \frac{W_{oil}}{W_{sample}} \times 100 \qquad (3)$$

Where:

$CF = Crude\ fat\ content, \%$

$W_{oil} = Weight\ of\ extracted\ oil, g$

$W_{sample} = Weight\ of\ sample, g$

2.6 ***Statistical Analysis***

The data obtained were analyzed descriptively and inferentially using Turkey's post- test procedures of GraphPad Prism version 4.00 for Windows

3. Results and Discussion

3.1 ***Effects of extrusion parameters on quality assessment of fried instant noodles***

The quality assessments such as cooking time, cooking loss, cooking gain, moisture and fat uptakes are evaluated as affected by extrusion parameters on plantain -wheat instant noodles. Extrusion parameters have been documented to be essential to the quality of the final product as it is thought to contribute to both the color, water and fat uptakes and the textural properties of the product (Park & Baik, 2004; Yu & Ngadi, 2004).

3.2 ***Effect of extrusion parameters on optimum cooking time***

Figure 3 showed the effect of extrusion parameters (barrel temperatures and conveying shaft speeds) on cooking time of plantain -wheat instant noodles at different levels of substitution. The cooking time ranged from 4.38 – 5.4 min; 4.17 – 4.58 min; 4.06 – 4.46 min; 4.09 – 4.40 min; 3.38 – 4.27 min and 3.40 – 4.40 min for the instant noodle samples 0%NOD; 5%NOD; 10%NOD; 15%NOD; 20%NOD and 25%NOD, respectively. The values showed that as conveying shaft speed increased, there was a corresponding increase in cooking time. Whereas, increase in barrel temperatures led to a decrease in cooking time of the instant noodles. There is significant difference ($p< 0.05$) among the instant noodles cooking time at all levels of substitution.

The interactive effects between conveying shaft speed and barrel temperature on cooking time is positive. The minimum cooking time was observed at high barrel temperature and low conveying shaft speed. In order to select a model that best fitted the experimental results, predicted responses, their correlation coefficient (r^2) and desirability were used for evaluation. A quadratic model was selected for data fitting with a coefficient of determination (R^2) of 0.9602 and desirability of 0.972. The numerical model describing the effect of shaft temperature (°C) and conveying shaft speed (rpm) on the cooking time of the instant noodle is shown in equation 4:

$$CT = 4.854 - 1.238E - 3u + 0.0115T + 5.83E - 5\ uT \qquad (4)$$

Where:

CT = cooking time, min
u = conveying shaft speed (rpm) and;
T = barrel temperature, °C.

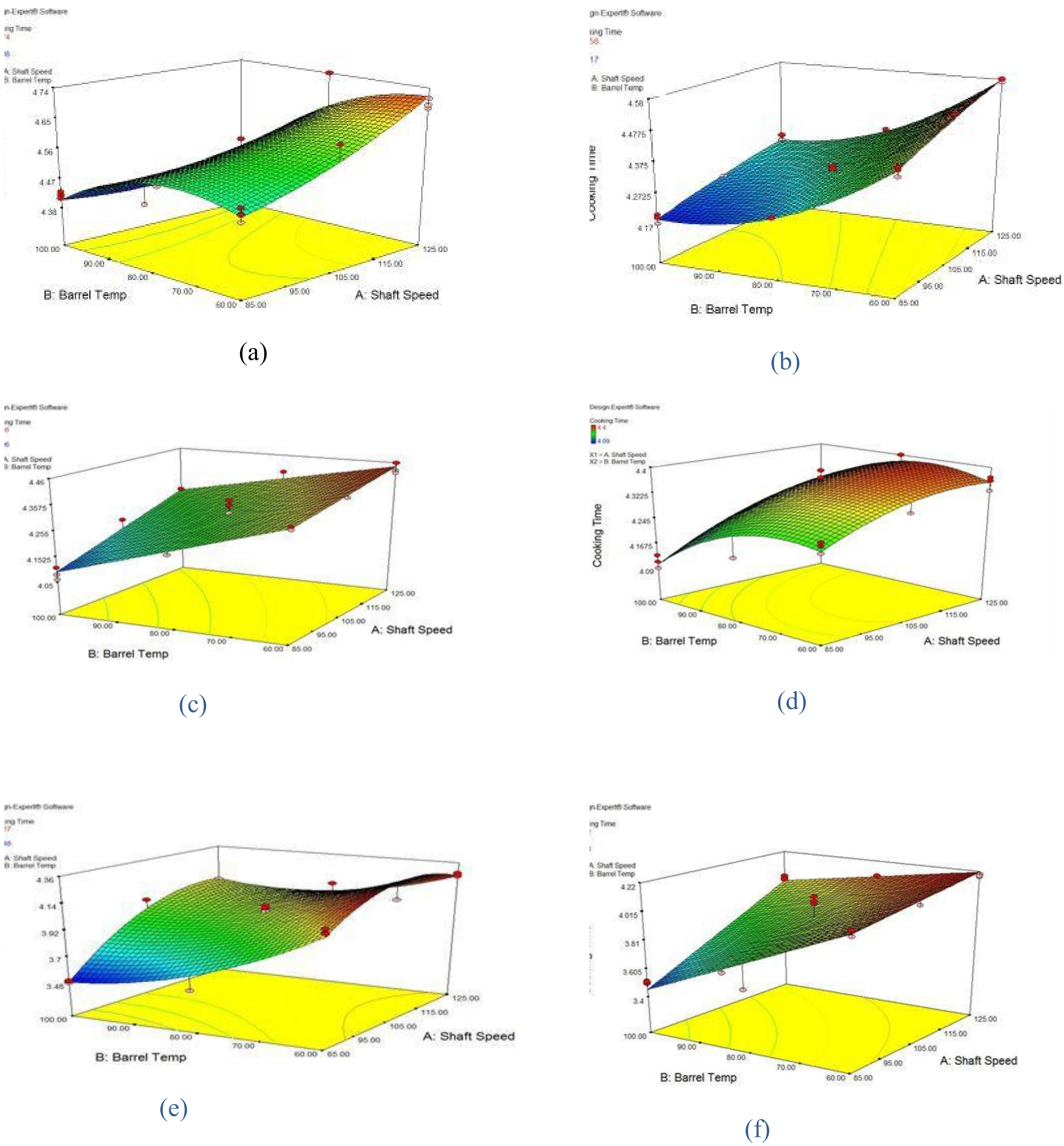


Figure 3: Effect of conveying shaft speed and barrel temperature on optimum cooking time of plantain -wheat instant noodle:

(a) 100% wheat flour instant noodle; (b) 5% plantain flour + 95% wheat flour instant noodle; (c) 10% plantain flour + 90% wheat flour instant noodle; (d) 15% plantain flour + 85% wheat flour instant noodle; (e) 20% plantain flour + 80% wheat flour instant noodle; (f) 25% plantain flour + 75% wheat flour instant noodle

The optimum solution (cooking time of 4.19 min) was found at 100 °C barrel temperature and 85 rpm conveying shaft speed. The cooking time values of plantain -wheat instant noodle compared favourably with 3.11 – 4.77 min for breadfruit-konjac-pumpkin-wheat instant noodle; 4.5 – 8.29 min for plantain-wheat instant noodle and 4.3 – 5.41 min for corn-tapioca-wheat instant noodles (Purwandari et al., 2014; Ojure & Quadri, 2012; Pato et al., 2016) but lower than 5.6 – 6.6 min reported by Ritika et al., 2016 for malted and fermented cowpea-wheat instant noodle; 7.33 – 8.67 min for sago starch-wheat instant noodle (Purwani, Widaningrum & Muslich, 2006); 7.30 min for defatted rice bran-soy-wheat instant noodle (Pakhare *et al.*, 2016) and 7.16 – 9.36 min reported for raw jackfruit-wheat instant noodle (Kumari & Divakar, 2017). The decline in cooking time values of plantain -wheat instant noodles obtained as substitution proportion increased is due to discontinuity within the gluten matrix and results in weak dough properties (Manthey et al., 2004; Omeire, Umeji & Obasi, 2014).

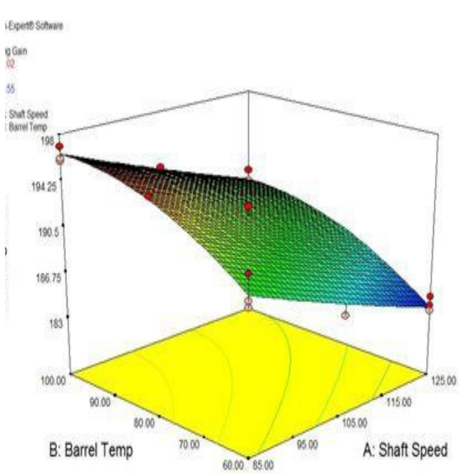
3.3 *Effect of extrusion parameters on cooking gain*

Figure 4 showed effect of extrusion parameters (barrel temperatures and conveying shaft speeds) on cooking gain of plantain -wheat instant noodles at different levels of substitution. The cooking gain values ranged from 183.55 – 197.02%; 173.78 – 187.58%; 173.68 – 182.03%; 173.45 – 182.93%; 169.68 – 181.02% and 168.11 – 179.11%; for the instant noodle samples coded 0%NOD; 5%NOD; 10%NOD; 15%NOD; 20%NOD and 25%NOD, respectively. The values showed that as conveying shaft speed increased, there was a reduction in cooking gain of the instant noodles. Whereas, increase in barrel temperatures led to an increase in cooking gain of the instant noodles. There is significant difference ($p< 0.05$) among the instant noodles cooking gain.

The interactive effects between conveying shaft speed and barrel temperature on cooking gain is positive. The maximum cooking gain was observed at high barrel temperature and low conveying shaft speed. In order to select a model that best fitted the experimental results, predicted responses, their correlation coefficient (r^2) and desirability were used for evaluation. A quadratic model was selected for data fitting with coefficient of determination (R^2) of 0.9941 and desirability of 0.984. The numerical model describing the effect of shaft temperature (°C) and conveying shaft speed (rpm) on the instant noodle cooking gain is then shown in equation 5:

$$CG = 164.98 + 0.166u + 0.533T - 5.81E - 0.004uT + 3.478E - 5u^2 + 2.315T^2 \quad (5)$$

Where:
CG = cooking gain, %
u = conveying shaft speed (rpm) and;
T = barrel temperature, °C.



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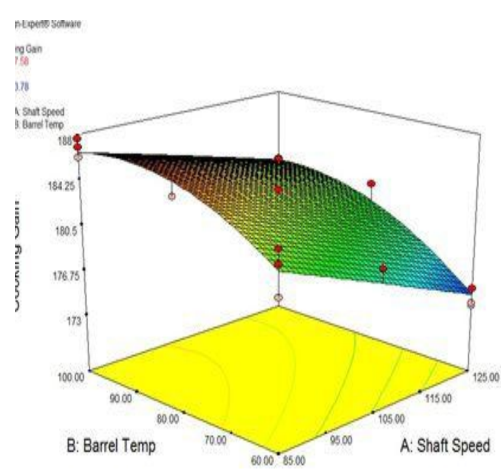

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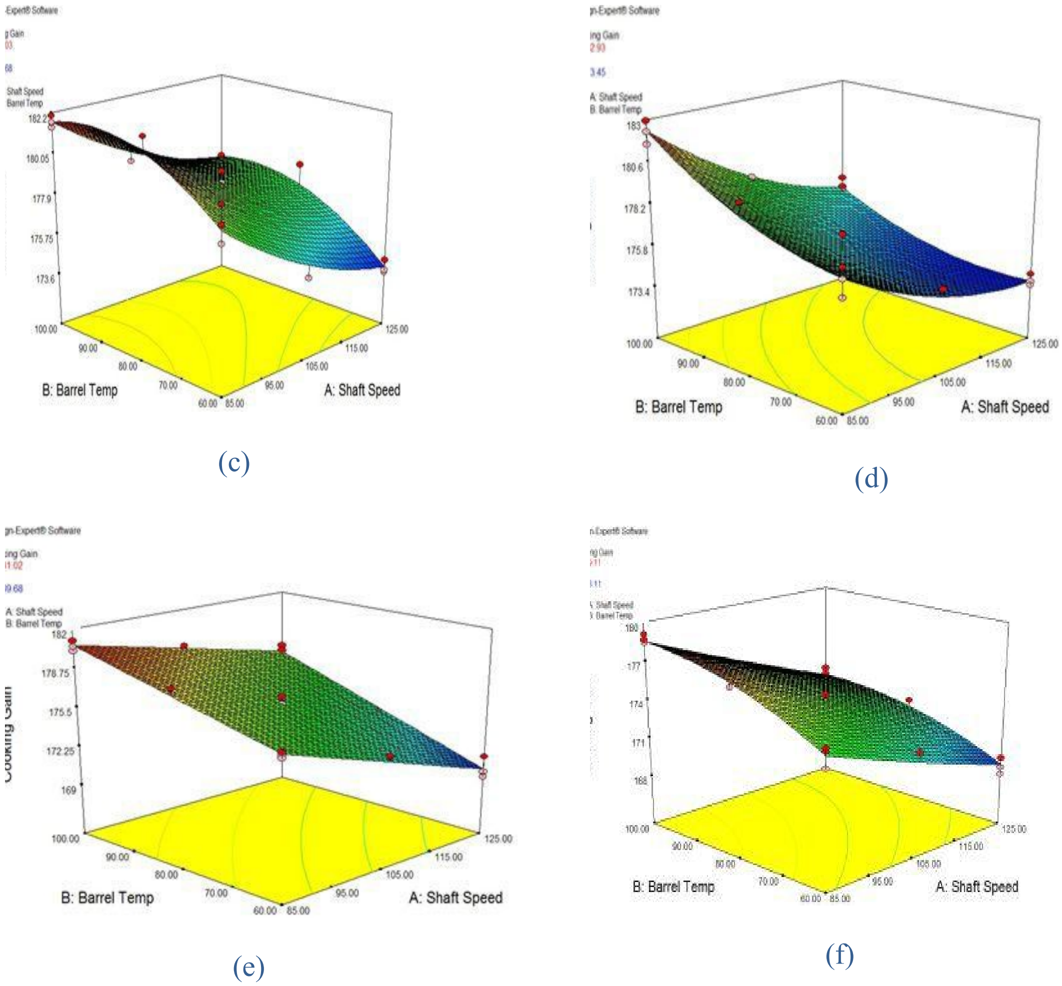


Figure: 4: Effect of shaft speed and barrel temperature on cooking gain of plantain-wheat instant noodle:

(a) 100% wheat flour instant noodle; (b) 5% plantain flour + 95% wheat flour instant noodle; (c) 10% plantain flour + 90% wheat flour instant noodle; (d) 15% plantain flour + 85% wheat flour instant noodle; (e) 20% *Musa spp* flour + 80% wheat flour instant noodle; (f) 25% *Musa spp* flour + 75% wheat flour instant noodle

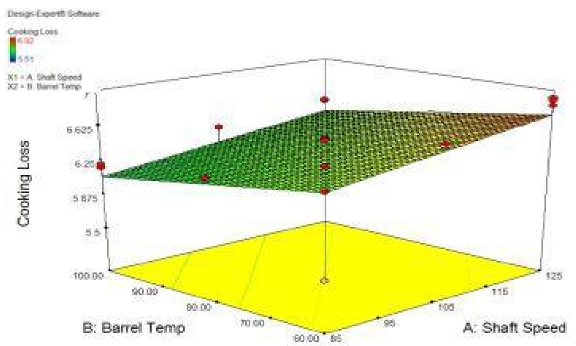
The optimum solution (cooking gain of 181.73%) is found at when 100 °C and 85 rpm conveying shaft speed. The results obtained compared favourably with 120.7 – 160.3% reported Ritika et al. (2016) for malted-fermented cowpea-wheat instant noodle but lower than 252 – 379% and 287 – 362% reported by Purwani et al (2006). for sago starch-wheat instant noodle and Foo et al. (2011) for soy protein isolate-wheat instant noodle respectively.

3.4 *Effect of extrusion parameters on cooking loss*

Figure 5 showed the effect of extrusion parameters (barrel temperatures and conveying shaft speeds) on cooking loss of plantain -wheat instant noodles at different levels of substitution. The cooking loss values ranged from 5.51 – 6.92%; 6.31 – 7.15%; 6.31 – 7.15%; 7.19 – 7.94%; 7.65 – 8.43% and 7.61 – 8.87% for instant noodle samples 0%NOD; 5%NOD; 10%NOD; 15%NOD; 20%NOD and 25%NOD samples, respectively. The values showed that for all levels of substitution, as shaft speed increased, there was an increase in cooking loss. This is associated with incomplete gelation of the noodle starch as a result of low residence time of the dough in the extruder whereas, increase in barrel temperature leads to a reduction in cooking loss. The interactive effect of conveying shaft speed and barrel temperature is quadratic. The minimum cooking loss was observed at high barrel temperature and low conveying shaft speed. In order to select a model that best fitted the experimental results, predicted responses, their correlation coefficient r and desirability were used for evaluation. A quadratic model was selected for data fitting with coefficient of determination (R^2) of 0.9796 and desirability of 0.980. The numerical model describing the effect of shaft temperature (°C) and conveying shaft speed (rpm) on the instant noodle cooking loss is then shown in equation 6:

$$CL = 6.951 + 0.0137u - 4.812E - 3T - 7.083E - 3uT \qquad (6)$$

Where:
CG = cooking loss, %
u = conveying shaft speed (rpm) and;
T = barrel temperature, °C.



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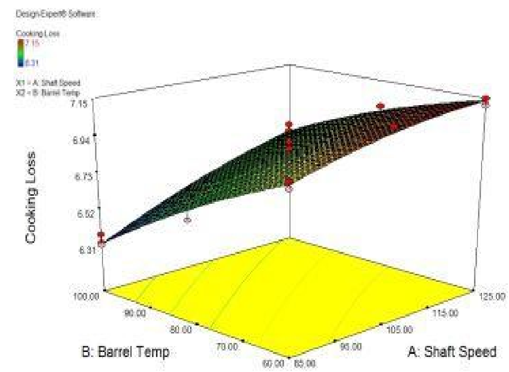

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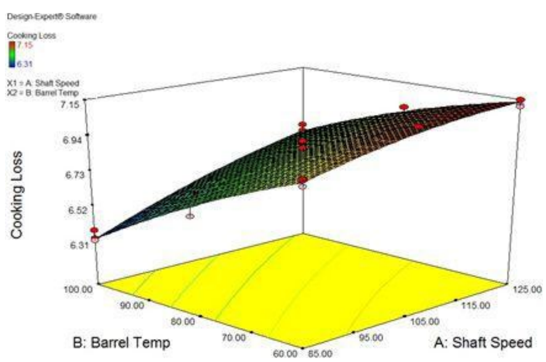

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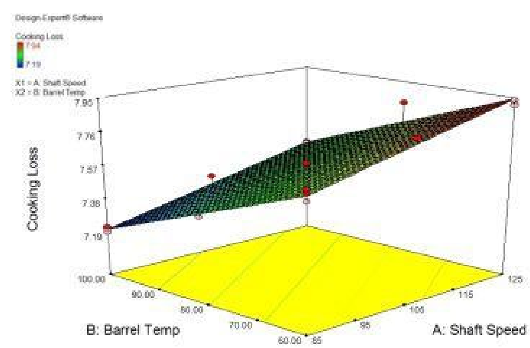

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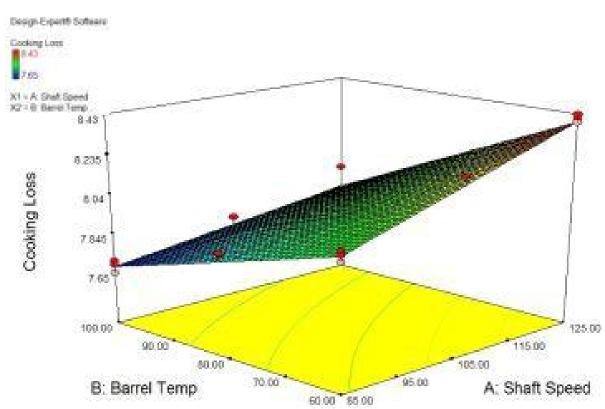
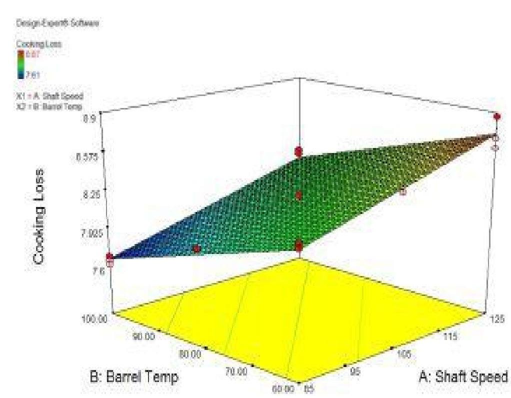




(e) (f)

Figure: 5: Effect of shaft speed and barrel temperature on cooking loss of Musa spp-wheat

instant noodle: (a) 100% wheat flour instant noodle; (b) 5% *Musa spp* flour + 95% wheat flour instant noodle; (c) 10% *Musa spp* flour + 90% wheat flour instant noodle; (d) 15% *Musa spp* flour + 85% wheat flour instant noodle; (e) 20% *Musa spp* flour + 80% wheat flour instant noodle; (f) 25% *Musa spp* flour + 75% wheat flour instant noodle.

The optimum solution (cooking loss of 7.03%) is found at a barrel temperature of 100 °C and 85 rpm conveying shaft speed. The cooking loss results obtained compared favourably with 6.39 – 10.40% reported by Ojure and Quadri (2012) for cassava-wheat instant noodle but higher than 0.93 – 1.63% and 2.01 – 6.19% reported by Ritika et al. (2016) for malted-fermented cowpea-wheat instant noodle and Purwani et al (2006). for sago starch-wheat instant noodle, respectively. Purwandari et al. (2014) reported that cooking loss of instant noodles from blends of breadfruit, konjac, pumpkin and wheat flours, ranged from 12.45 – 17.04%. These results are in the agreement with the study of Martinez et al. (2007) who reported that partial or complete substitution of durum wheat semolina with fibre material can result in negative changes to pasta quality, including increased cooking loss.

The high cooking loss recorded by plantain -wheat instant noodle as substitution increases is due to a weakening of the protein network by the presence of plantain (non-gluten protein) flour which allows more solids to be leached out from the noodles into the cooking water (Yu & Ngadi, 2004; Wu et al , 2006; Aluko & Corke, 2006).

3.6 *Effect of extrusion parameters on moisture uptake*

Figure 6 showed the effect of extrusion parameters (conveying shaft speeds and barrel temperatures) on moisture uptake of plantain -wheat instant noodles at different levels of substitution. The moisture uptake ranged from 9.79 – 10.74%; 10.27 – 11.01%; 10.7 – 11.71%; 11.16 – 12.06%; 11.59 – 12.31% and 12.01 – 12.43% for instant noodle samples 0%NOD; 5%NOD; 10%NOD; 15%NOD; 20%NOD and 25%NOD, respectively. The values showed that at all levels of substitution, as the conveying barrel temperature increased, there was corresponding decrease in moisture uptake of the instant noodles as increased barrel temperature ensured complete gelation of noodle starch. In contrast, as conveying shaft speed increased, there is an increase in moisture uptake due to incomplete gelation of noodle starch in the barrel.

The interactive effects of conveying shaft speed and barrel temperature on moisture uptake are both linear and quadratic. The minimum moisture uptake was observed at high barrel temperature and low conveying shaft speed. In order to select a model that best fitted the experimental data, predicted responses, their correlation coefficient (r^2) and desirability were used for evaluation. A quadratic model was selected for data fitting with coefficient of determination (R^2) of 0.9687 and desirability of 1.00. The numerical model describing the effect of shaft temperature (°C) and conveying shaft speed (rpm) on the instant noodle moisture uptake is then shown in equation 7

$$MU = 6.528 - 4.407E4u - 0.0218T + 1.104E - 4uT \qquad (7)$$

Where:
MU = moisture uptake, %
u = conveying shaft speed (rpm) and;
T = barrel temperature, °C.

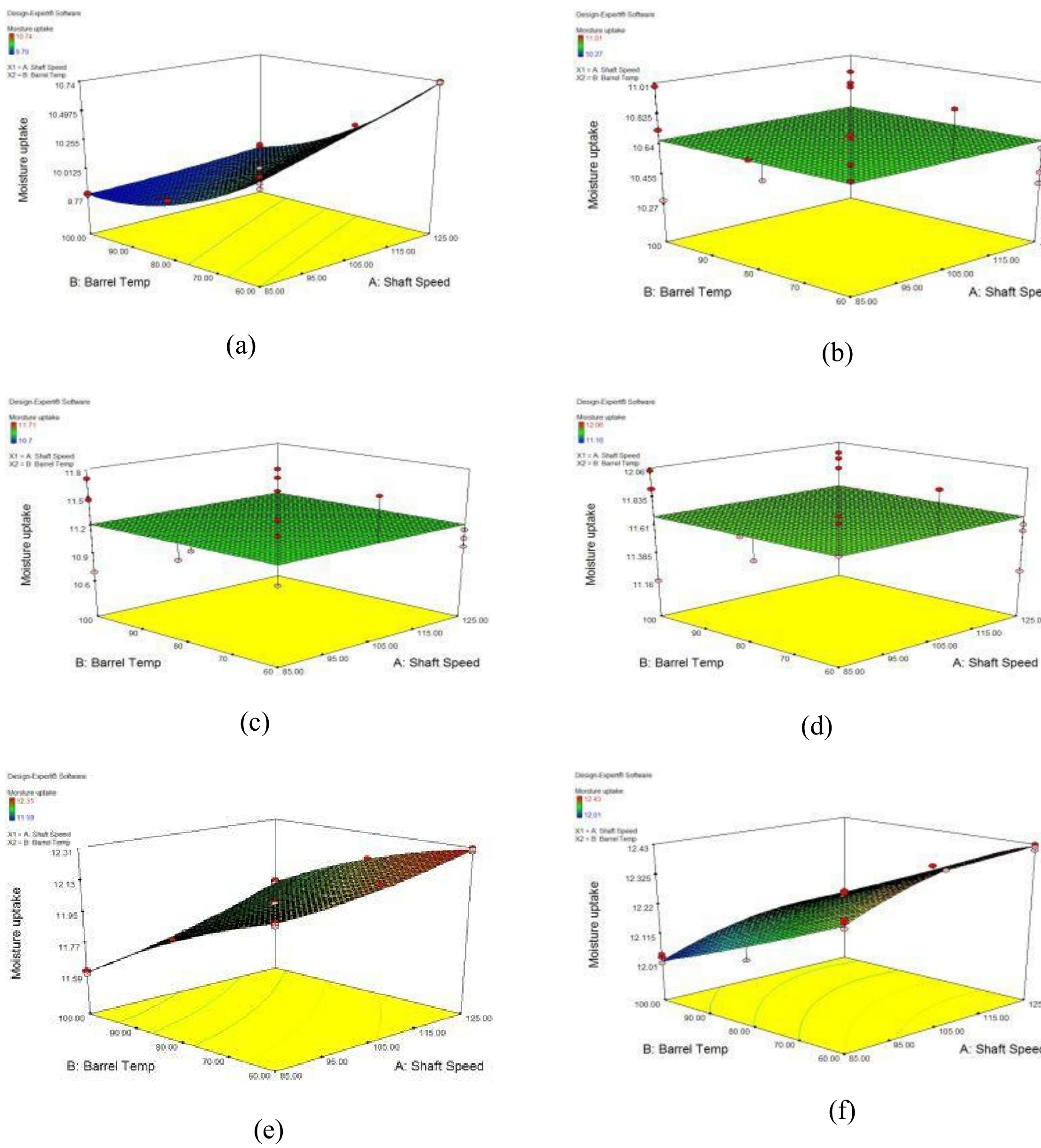


Figure: 6: Effect of shaft speed and barrel temperature on uptake moisture of Musa spp-wheat instant noodle:

(a) 100% wheat flour instant noodle; (b) 5% *Musa spp* flour + 95% wheat flour instant noodle; (c) 10% *Musa spp* flour + 90% wheat flour instant noodle; (d) 15% *Musa spp* flour + 85% wheat flour instant noodle; (e) 20% *Musa spp* flour + 80% wheat flour instant noodle; (f) 25% *Musa spp* flour + 75% wheat flour instant noodle

The optimum solution (moisture uptake of 5.25%) was recorded at 100 °C barrel temperature and 85 rpm conveying shaft speed.

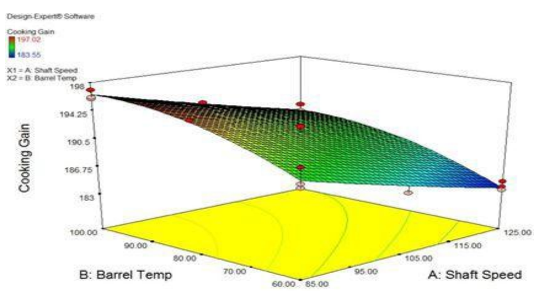
3.7 *Effect of extrusion parameters on fat content*

Figure 7 showed the effects of extrusion parameters (barrel temperatures and conveying shaft speeds) on fat content of plantain -wheat instant noodles at different levels of substitution. The fat content values ranged from 9.37 – 9.99%; 9.94 – 10.42%; 10.01 – 10.69%; 11.17 – 12.02%; 12.47 – 13.32% and 12.82 – 13.85% for instant noodle samples 0%NOD; 5%NOD; 10%NOD; 15%NOD; 20%NOD and 25%NOD, respectively. The values revealed that for all levels of substitution, as shaft speed increased, there was a corresponding increase in fat content,while , increase in barrel temperature leads to a reduction in fat content. This may be associated with the gelation rate of the instant noodle starch as there is complete gelation at high temperature and partial gelation at high conveying shaft speed due to low residence time of the dough in the extruder (Omeire et al, 2014; ; Martinez et al., 2007). Interactive effects of conveying shaft speed and barrel temperature are both linear and quadratic.

The minimum fat content was observed at high barrel temperature and low conveying shaft speed. In order to select a model that best fitted the experimental results, predicted responses, their correlation coefficient r and desirability were used for evaluation. A quadratic model was selected for data fitting with coefficient of determination (R^2) of 0.9958 and desirability of 0.995. The numerical model describing the effect of shaft temperature (°C) and conveying shaft speed (rpm) on the instant noodle fat content is then shown in equation 8:

$$FC = 11.538 - 7.4E3u - 0.0148T - 6.25E - 6uT + 5.956E - 5u^2 + 2.21E - 5T^2 \qquad (8)$$

Where:
FC = fat content, %
u = conveying shaft speed (rpm) and;
T = barrel temperature, °C.



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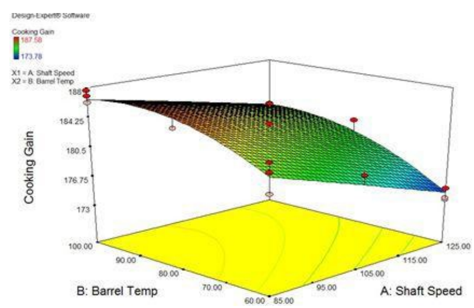

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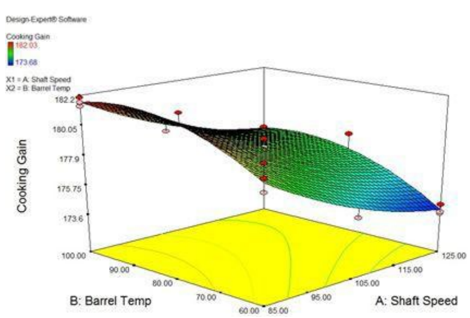

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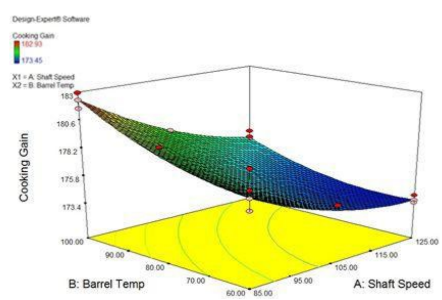

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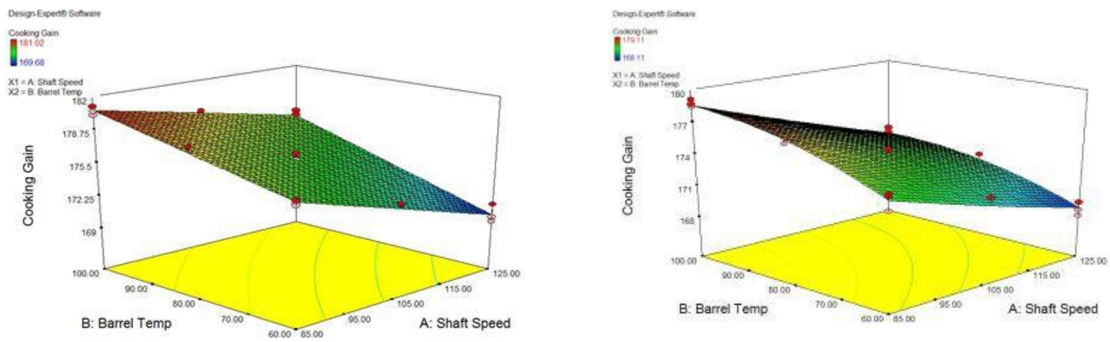

(e) (f)

Figure: 7: Effect of shaft speed and barrel temperature on fat content of Musa spp-wheat instant noodle: (a)100% wheat flour instant noodle; (b) 5% *Musa spp* flour + 95% wheat flour instant noodle; (c) 10% *Musa spp* flour + 90% wheat flour instant noodle; (d) 15% *Musa spp* flour + 85% wheat flour instant noodle; (e) 20% *Musa spp* flour + 80% wheat flour instant noodle; (f) 25% *Musa spp* flour + 75% wheat flour instant noodle

The optimum solution (fat content of 10.02%) was recorded at 100 °C barrel temperature and 85 rpm conveying shaft speed.

4, Conclusions

Impact of extrusion parameters on the cooking quality of instant noodles produced from plantain-wheat composite flour has been documented. The cooking properties data also showed significant correlation between cooking properties and extrusion parameters considered. These data obtained provide baseline information for process control and design in industrial production of instant noodle from plantain fruits; thereby promising value addition to this important tropical food crop which hitherto has suffered enormous postharvest losses.

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RHEOLOGICAL PROPERTIES OF PLANTAIN (*MUSA* SPP*)* - WHEAT INSTANT NOODLE DOUGH

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Abstract

This study investigated viscoelastic properties of plantain – wheat instant noodle dough. The plantain – wheat composite flour in ratios 0:100; 5:95; 10:90; 15:85; 20:80 and 25:75 were processed into instant noodles dough. The viscoelastic properties of the instant noodle dough were investigated using a HAAKE Viscometer 500 (Thermo Fisher Scientific Pty Ltd. D - 76227 Karlsruhe, Germany). The data obtained were fitted into five existing rheological models. The data obtained was analyzed descriptively and inferentially using Turkey's post test procedures of GraphPad Prism version 4.00 for Windows and Design Expert Software. The results showed that percentage substitution of wheat with plantain flour affected the viscoelastic properties of the dough. The data obtained will provides valuable information for industries in process control and design of wheat – wheat instant noodle.

Keywords: Plantain; wheat; dough; viscoelastic properties; instant noodles.

1. Introduction

Instant noodle has become an important food item globally, with annual production of 101,420 million packs in 2012, and a steady increase of 3% annually since 2010 [1]. Most instant noodles are made of wheat as the base material, thus instant noodle consumption led to dependency on massive importation of wheat in non-wheat producing countries Nigeria inclusive. Apart from high cost of wheat importation, excessive consumption of wheat has been associated with allergy, asthma, autoimmune response, or gluten sensitivity in some parts of the world [2]. Several works have been done on composite flour instant noodle using different flours, although rice flour seems to be the best replacement for its small granule sizes to benefit noodle textural characteristics [3]. Some other raw materials for composite flour instant noodle include sorghum [4], and corn starch [5, 6] or corn flour [7]. Lately, pigeonan pea and rice [8], pseudo-cereal such as amaranth flour in combination with cassava starch [9] have also been incorporated. The weakening of protein matrix in composite flour instant noodle often adversely affects noodle quality; hence composite flour instant noodle requires treatment to improve its consumers' acceptability.

Rheology is a valuable tool for quantitative measurement of amount of stress in the dough, which is a function of molecular gluten network [10]. In process control and design, rheological data are useful for evaluating dough performance during processes such as mixing, sheeting, proofing and baking [11, 12 and 13]. These information also predict functionality, acceptability and storability of the product. Consequently, in this work, rheological properties of plantain – wheat instant noodle dough were investigated with the view to providing baseline information on the production of instant noodles from plantain – wheat composite flour.

2. Materials and Methods

2.1 *Source of materials*

Freshly harvested bunches of plantain fruit (Plate 1) at stage one maturity using colour as basis of clarification [14, 15] were obtained from Obafemi Awolowo University Teaching and Research Farm, Ile-Ife. Other materials such as white wheat flour (Dangote brand), iodized table salt (Dangote brand), potato starch, guar gum, potassium carbonate (food grade), sodium carbonate (food grade) and sodium tripolyphosphate (STTP, food grade) were bought from a local market in Ile-Ife, Osun State. The chemicals used for analysis were of analytical grade.

Plate 1: A freshly harvested matured plantain (agbagba) Musa spp fruits

2.2 *Preparation of plantain flour*

About 10 kg of freshly harvested debunched plantain fruits were immersed in a plastic bowl containing potable water on individual variety basis for 5 min. The fruits were removed from the bowl and peeled with the aid of a stainless kitchen knife. The pulp was sliced into cylindrical discs with thickness of about 5 mm and dipped in citric acid (CIT) (1% w/v) for 1 min to prevent enzymatic browning reaction [16]. Accumulation of moisture on the sliced surface as a result of the pretreatment was drained with a cheese cloth before samples was transferred to dryer set at 70 °C [17].

The citric acid treated sliced plantain fruits were dried in an air-oven set at 70 °C (±1°C) using convective air flowing at a velocity of 2.2 m/s [16,17]. Prior to loading of the sliced fruits, the dryer was ran for 30 min to reach the set drying air temperature conditions. The drying of the sliced fruits were done in a thin layer form so as to ensure effective drying. The initial weight of sliced fruits were recorded by means of the digital balance before loading into already set oven. The sliced fruits were dried for 48 h and subsequently, the sliced fruits weight was measured at interval of 30 min until its weight was constant. At this point, the dried chips were considered to have attained its equilibrium moisture content (EMC) of the drying conditions. The dried chips were milled using laboratory milling machine (sieve size: 500 µm aperture) and stored in an air tight bottle until the time of use. Figure 1 shows the flow chart for the production of pretreated plantain flour sample.

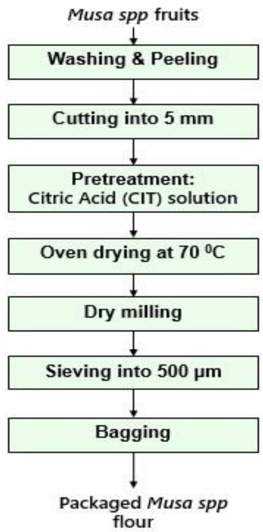

Figure 1: A flow chart showing production of *Musa spp* flour (Adeniji, Tenkouano, Ezurike et al., 2010)

2.3 *Blend formulation of plantain-wheat composite flour*

The processed plantain flour was blended with wheat flour at 0, 5, 10, 15 20 and 25% replacement [18] using a Kenwood food processor (Model 49074, Kenwood Ltd, Hants, UK) operated at full speed for 10 min. The blends were stored in high density polyethylene bags (0.77 mm thick) prior to use.

2.3.1 Instant noodle dough preparation

The plantain – wheat composite flour was mixed in proportion of 0-100; 5-95: 10- 90; 15-85; 20-80 and 25-75% by weight, respectively. Instant noodle formulations and flow chart showing production of the dough were given in Table 1 and Figure 2, respectively.

Table 1: Formulation of instant noodle from plantain-wheat composite flour

	Formulations					
gredients	%NOD	%NOD	)%NOD	5%NOD	)%NOD	5%NOD
heat flour, g	)0	5	)	5	)	5
antain flour, g			)	5	)	5
ater, ml	4	4	4	4	4	4
ılt, g	6	6	6	6	6	6
ɔtato starch, g	2	2	2	2	2	2
uar gum, g	2	2	2	2	2	2

otassium carbonate, g	12	12	12	12	12	12
odium carbonate, g	8	8	8	8	8	8
TTP, g	1	1	1	1	1	1

0%NOD (Control) =100% wheat flour; 5%NOD = 95% wheat+ 5% plantain flour; 10%NOD = 90% wheat+ 10% plantain flour; 15%NOD = 85% wheat+ 15% plantain flour; 20%NOD = 80% wheat+ 20% plantain flour and 25%NOD = 75% wheat+ 25% plantain flour (Hou et al., 1997)

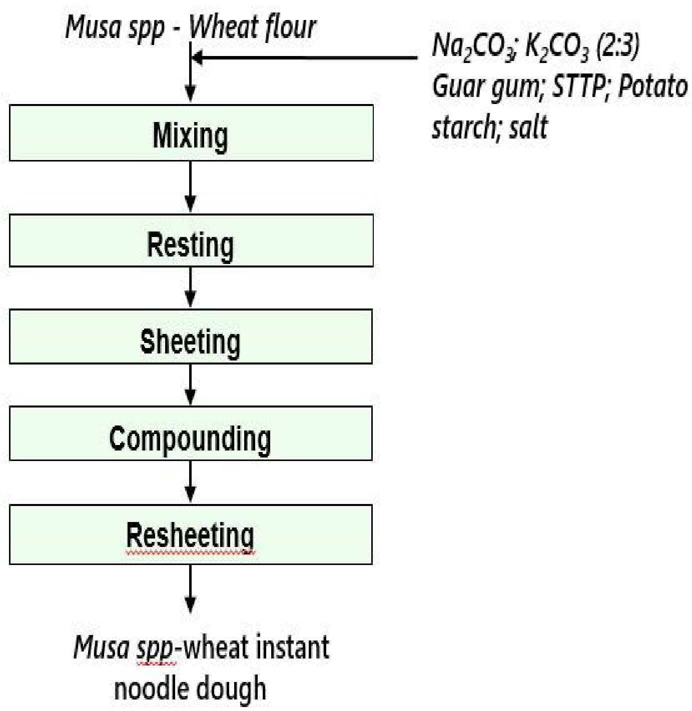

Figure 2: A schematic diagram showing production of plantain – wheat instant noodle dough

2.3.2 Determination of rheological properties of instant noodle dough

The rheological properties of instant noodle dough were investigated using a HAAKE Viscotester 500 (Thermo Fisher Scientific Pty Ltd. D-76227 Karlsruhe, Germany). The prepared dough was transferred into the sensor (DIN 202) of the machine. The spindle speed was preset in the range of (1 – 10) and the flow behavior: shear stress (Pa), shear rate (s^{-1}) and viscosity (Pa.s) were read on the digital LED screen of the equipment. The experimental data were fitted into four rheological flow models (Table 2) as obtained from [19]. The goodness of fit of the models was evaluated by mean relative error (MRE) as a percentage, mean relative percent deviation modulus (E) and determination of coefficient (R^2). A model with MRE value less than 10% was considered acceptable [20, 21]. Consistency index (k) and flow behavior index (n) were obtained using model with the best fit.

Table 2: Rheological models for experimental data fitting

S/N	Isotherm	Model

1	Power Law	$\tau = ky'^n$
2	Bingham Model	$\tau = \tau_0 + \mu y'$
3	Casson Model	$\tau^{\frac{1}{2}} = \tau_0 + k(y')^{\frac{1}{2}}$
4	Herschel-Bulkley	$\tau = \tau_0 + k(y')^n$

τ = shear stress (Pa); τ_0 = yield stress (Pa); y' = shear rate (s^{-1}); n = flow behavior index and k = consistency index and μ= apparent viscosity (Pa. s)

2.4 *Statistical Analysis*

The data obtained was analyzed descriptively and inferentially using Turkey's post test procedures of GraphPad Prism version 4.00 for Windows

3. Results and Discussion

Figures 3 and 4 showed the plots of experimental data obtained for rheological attributes measuring the flow pattern (shear stress vs shear rate and viscosity vs shear rate, respectively) of plantain-wheat instant noodle dough at various levels of substitution using a rotational viscometer (Haake Viscometer 550). The plot of shear stress versus shear rate is linear with non-zero intercept indicating a non-Newtonian nature of the doughs. Reference [22] documented that the plot of shear stress and shear rate for a Newtonian fluid must be linear with zero intercept. This suggests the flow behavior of plantain – wheat instant noodle dough is non-Newtonian because of its non-zero intercepts at all levels of substitution. The non-zero intercept on the shear stress axis of the plot shows the initial shear stress that needs to be overcome before the dough can exhibit any deformation. The initial shear stress is referred to as yield stress [23]. Below the yield stress, the dough exhibits solid like characteristics by storing energy at small strains and does not level out under the influence of gravity to form a flat surface. This characteristic is very important in process design and quality assessment [24].

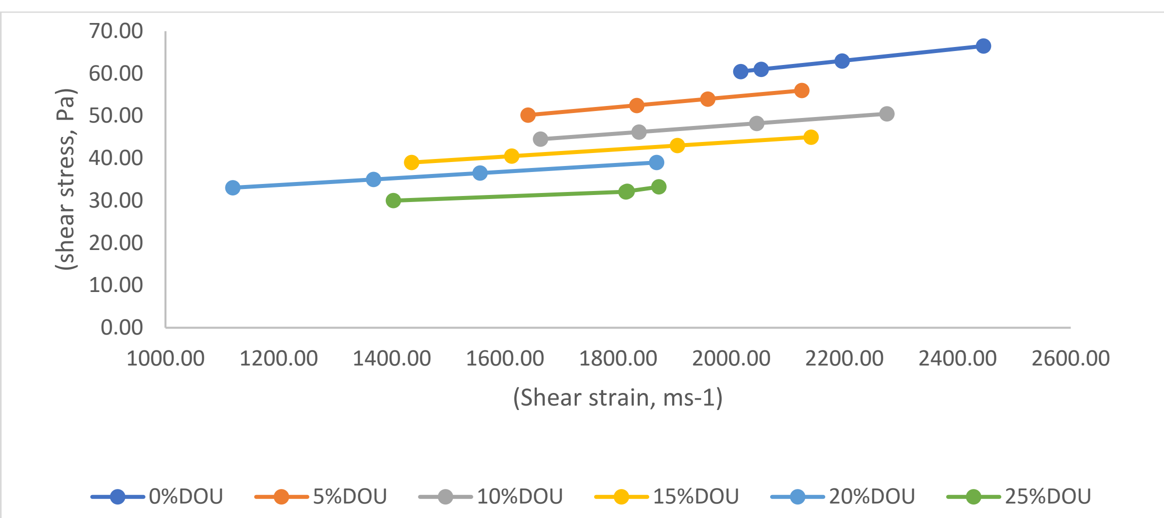

Figure 3: Plot of shear stress against shear rate of plantain – wheat instant noodle dough

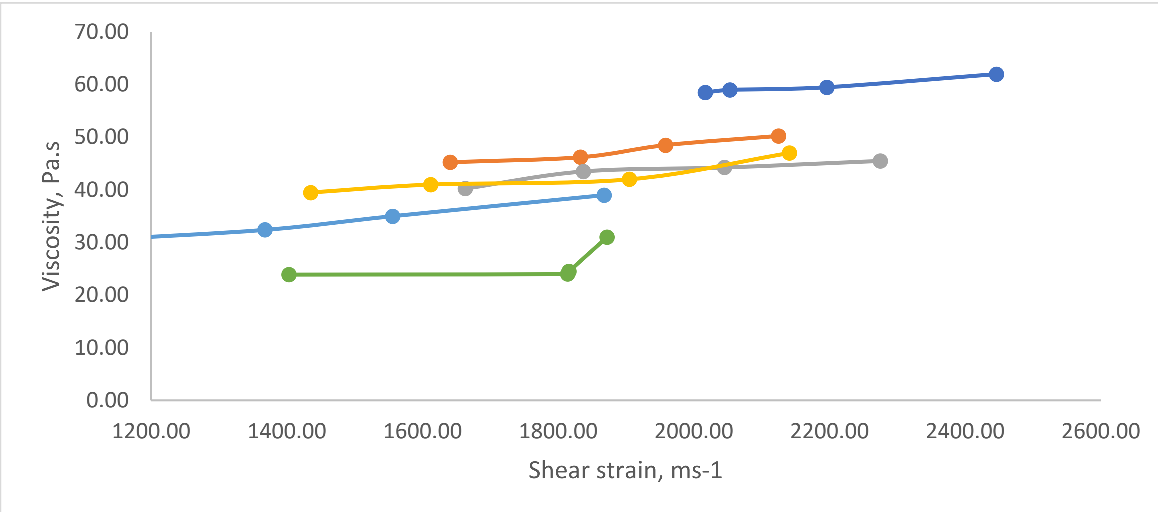

Figure 4: The plot of viscosity against shear rate of plantain – wheat instant noodle dough (experimental data)

It is inferred from Figure 3 that as substitution level increases, there is reduction in the yield stress of plantain – wheat instant noodle dough. The reduction in the dough yield stress may be related to substitution with non-gluten protein (plantain) flour in the dough as well as due to its starch properties. Gluten proteins are necessary for formation of viscoelastic dough capable of trapping air to form well aerated noodle products [23]. A minimum protein content of 11.0% in wheat flour has been proposed as a basic requirement for production of yeast-leavened bread [25]. Conversely, non-wheat starch and proteins have been shown to have deleterious effects on bread making quality of wheat [26, 27]. This effect has been suggested to be a result of dilution, rupture or disruption of the gluten matrix. During proofing, non-wheat flours have been shown to breakdown dough structure [28].

The viscosity-shear rate plot of plantain – wheat instant noodle dough is also in linear form with non-zero intercept on viscosity axis. The plot shows that as levels of substitution increased from 0 to 25%, the intercept on viscosity axis reduces from 50 to 22 Pa.s. The similar trend was observed in shear stress-shear rate plot. This shows that substitution with non-gluten protein (plantain) flour in the instant noodle dough as well as due to its starch properties reduces viscosity of the dough [30]. Gluten proteins are necessary for formation of viscoelastic dough capable of trapping air to form well aerated noodle products [23].

The experimental data for shear stress and shear strain of plantain – wheat instant noodle dough are fitted into four rheological models (Power, Bingham, Carson and Herschel-Bulkley models). The quality of fitness of the models as evaluated by the mean square relative (RSME) and coefficient of determination (R^2) is presented in Figure 5. A model is considered acceptable if R^2 is close to 1 and RSME values are below 10% [20].

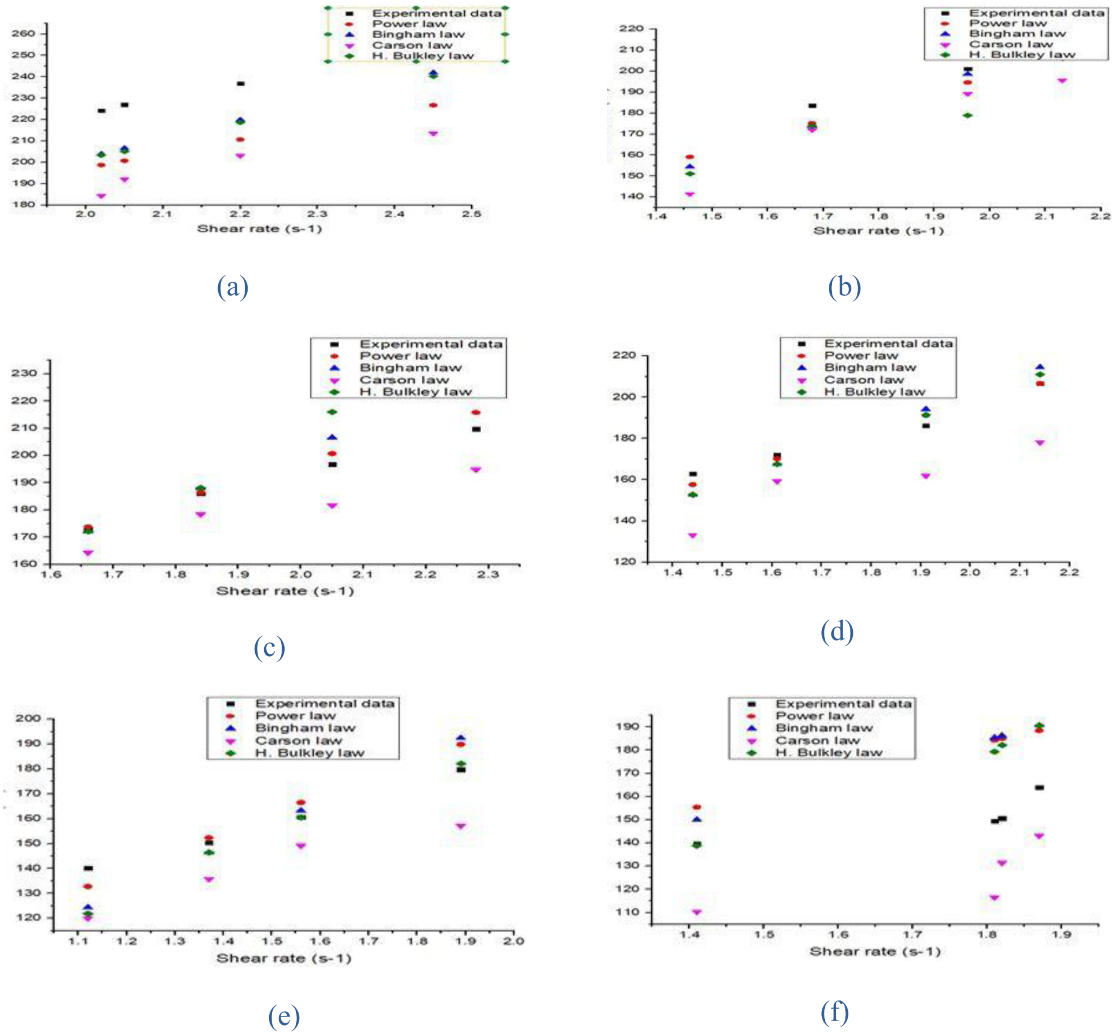

Figure 5: Predicted shear stress and shear strain curves using different rheological models:

(a) 100% wheat flour instant noodle dough; (b) 5% plantain flour + 95% wheat flour instant noodle dough; (c) 10% plantain flour + 90% wheat flour instant noodle dough; (d) 15% plantain flour + 85% wheat flour instant noodle dough; (e) 20% plantain flour + 80% wheat flour instant noodle dough; (f) 25% plantain flour + 75% wheat flour instant noodle dough

The R^2 and RSME values of the models ranged from 0.459 – 0.801 and 9.883 – 14.77 %, respectively. Bingham model has the maximum R^2 value of 0.801 with RSME of 9.883% at all levels of substitution. The R^2 value close to 1 indicates high degree of fit [30] of Bingham law to explain the rheological property of plantain – wheat instant noodle dough in terms of simple mathematical expression. Also, the RSME value of 9.883% of Bingham model at all levels of substitution implied that the model is best statistically to explain the rheological properties of plantain – wheat instant noodle dough. Therefore, as level of substitution of plantain (non-gluten) flour increased in plantain – wheat instant noodle dough, the Bingham stress which is the minimum shear stress the dough needs before undergoing deformation and Bingham viscosity are reduced because gluten proteins are necessary for formation of viscoelastic dough capable of trapping air to form well aerated noodle products [23].

Among the models, Bingham model has the best fit for the shear stress-shear rate data. The yield stress obtained from Bingham from all the samples are generally high (Figure 5). This implies that the products require high shear stress before it can undergo deformation. It is of importance to report that as proportion of substitution with plantain flour into the dough increased, there is reduction in Bingham yield stress as a result of inclusion of plantain (non-gluten protein) flour into the products [23]. Discussion on yield stress is centered on Bingham model. The plot of yield stress against percentage of substitution is presented in Figure 6. The Bingham yield stress of the samples indicate that as percentage of substitution increases, there is reduction in yield stress. This indicates that dough with no substitution has the highest value of Bingham yield stress. The values showed that mixing of the samples will require high energy as high shear stress would be required to initiate flow. Yield stress is an important quality control parameter in process industries. Yield stress could be beneficial for the optimal design of food-processing system such as those required during thermal processing [31].

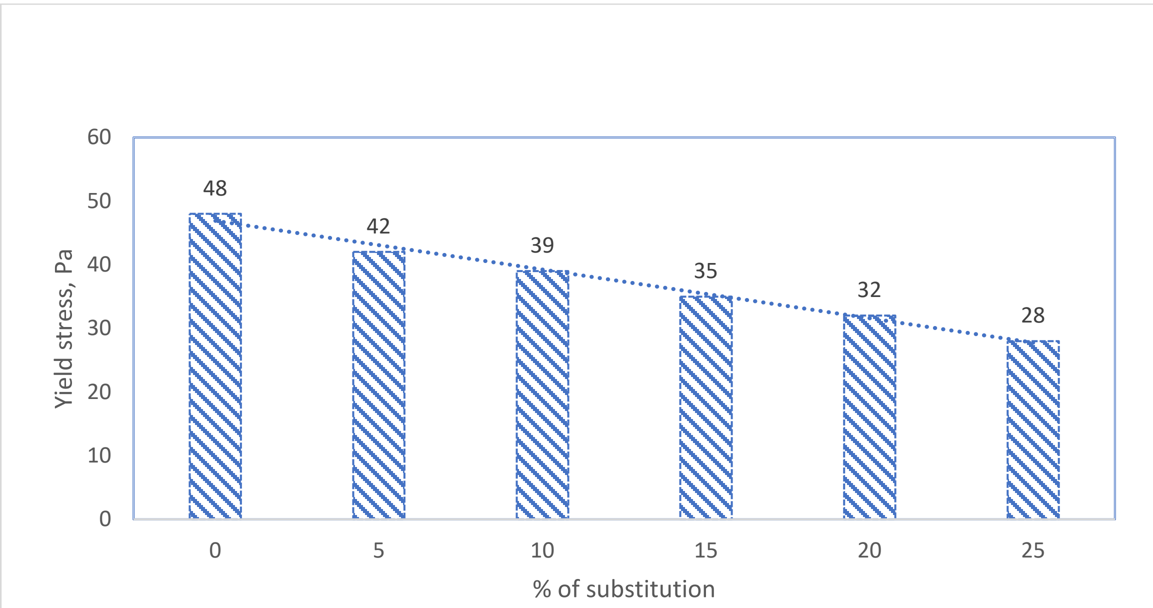

Figure 6: Plot of yield stress versus percentage of substitution of plantain – wheat instant noodle dough

4. Conclusions

Rheological properties of instant noodles dough produced from plantain wheat composite flour has been documented. The flow pattern of the dough is non-Newtonian with relatively high yield stress, although reduced as substitution percentage of plantain flour in the dough increased. These data obtained provide baseline information for process control and design in industrial production of instant noodle from plantain fruits; thereby promising value addition to this important tropical food crop which hitherto has suffered enormous postharvest losses.

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ADAPTIVE PERFORMANCE EVALUATION OF IAR-SORGHUM THRESHER FOR TWO VARIETIES OF WHEAT

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Abstract

With the aim of providing a multi-crop thresher to local farmers, the IAR-Sorghum thresher was evaluated using varieties of wheat. Among the factors which were varied in the Randomized Complete Block Design experiments used in the evaluation were 2 levels of Moisture Content, 2 levels on Feed Rate, 3 levels of Cylinder Speed and 3 replications of each treatment. The indices used to measure the effectiveness and efficiency of the thresher to process wheat were threshing efficiency, cleaning efficiency, scatter loss from thresher and its output capacity. The fuel consumption rates of carrying the tasks out were also determined for the 2 moisture contents of each variety. These indices translate into the economics qualities and quantities which would influence the acceptance or other of the thresher by targeted farmers. It was found that the thresher could thresh the crop to a threshing efficiency of 95%, cleaning efficiency of 82%, scatter loss of 10% achieved by the thresher was rather high, and the output capacity of 9 kg hr^{-1} was not satisfactorily. Hence, the recommendation on how to improve on the thresher performance and the rate of fuel consumption were provided.

Keywords: Threshing Efficiency, Cleaning Efficiency, Scatter Loss, Throughput Capacity, Hard Red Winter Wheat and Hard White wheat.

1. Introduction

In recent time, the government of Nigeria is trying to diversify from mono economic and over dependent on petroleum to multiple economic. Agriculture remains one of the feasible sources of earning foreign exchange and employment of the populace. Maize, rice and wheat are some of the most consumed crops not only in Nigeria but also beyond. Wheat (*Triticum aestivum*) has been rated as the third most essential cereal crop after rice and maize in terms of the cultivated land area and metric tonnes of products, about 232 million hectares of land is used for the production of 595 million metric tonnes of wheat yearly (Mandel and mukhopadhyay, 2015). Nigeria has the conducive climatic condition to be a major producer of wheat and two varieties of wheat have been found to strive very well in certain parts of the country. These two varieties are the Hard Red Winter and Hard White wheats. Some of the states in Nigeria where wheat are popularly grown are Sokoto, Kano, Kaduna, Zamfara, Katsina states. Wheat forms some of the food crop eaten in household in the country as *tuwo*, *fura* and *danwake.* Industrially, flour from wheat can be used for making of bread, cakes, noodle, biscuits and other confectionaries. Wheat is a good source of carbohydrate; it is also source of vegetative protein for human with 13% protein (CORDIS, 2016). People on special diet have always been advised to consume wheat products. Brad and other residues of wheat can be used as animal feed.

Despite the economic and nutritive importance of wheat and Nigeria's potential for its production, only 90 000 tonnes of wheat is produced in the country while 4 000 000 tonnes are consumed in the same country annually (Adetokunbo *et al.,* 2017). Some of the factors for the low production of wheat in Nigeria are low capital investment in agriculture, small farm land hold, low level of mechanized farming, lack of properly fitted farming equipment for the crop production and processing, among others. Because of the high capital cost of purchasing a combine harvester, an average wheat farmer in the country cannot afford to purchase and maintain one; thus uses manual labour entirely for the production of the crop. The farmers harvest the produce using handheld sickles and thresh it either by pounding the harvested earhead in mortal using pestle or flailing the product in sizeable sacks or on paved floors after which women are engaged to winnow the threshed crop for the purpose of cleaning and separating the kernels from the chaff. Mande (2011) and Afolabi *et al.* (2019) reported that manual threshing and cleaning of crops are time-consuming, labour intensive, reduces quality of product, causes contamination by the inadvertent introduction of foreign material and discourages the production of the crop by local farmers. Besides cultivation of wheat, local farmers also plant other cereals. Hence the farmers would value a single machine which may be used for the processing of more than one of their produces.

The aim of this study is to investigate the suitability of IAR Sorghum Thresher for wheat and to give recommendation for its redesign to become a multi-crop thresher for sorghum, wheat and possibly rice. This is aimed at improving the living standard of local farmers by increasing the market values of the produces, reduce drudgery of threshing and cleaning the farm produce and lower the cost of the production by handling down to the local farmers a multi-crop thresher.

2. Materials and Methods

2.*1 Materials Selection*

The materials used for the evaluation were: the existing IAR-Sorghum thresher, Digital tachometer (DT2235B), E200 Electronic weighing balance of sensitivity of 0.01 kg, Eijkelkamp Oven dryer, Quartz Stopwatch, and two varieties of unthreshed wheat varieties namely, Hard White Wheat and Hard Red Winter Wheat. Each of the varieties of wheat was purchase from a local farmer in Karfi village of Kura Local Government Area in Kano state who cultivated it.

2.2 *Determination of Moisture Content of Grains*

The moisture contents of the wheat varieties were determined using the standard oven-dried method (ASAE, 1998). The initial and final weights of the two varieties of wheat before and after oven-drying were measured using the electronic weighing balance. Threshed wheat grains of the two varieties were oven-dried at 105^{0}C for 24 hours (Ndirika, 1994; Afolabi *et al.,* 2019). Two levels of crop moisture contents for each variety were used for the performance evaluation of the IAR sorghum thresher. The moisture contents were 4.4 and 3.6% dry basis (for Red Wheat) and 4.7 and 4.0% dry basis (for White Wheat), these were the natural moisture contents of the varieties; the upper and the lower moisture contents for each variety were its values 2 and 3 weeks respectively of storage after harvest.

The expression used for the determination of the moisture contents was as given by Mohsenin (1980) and ASAE (1998):

$$M_C = \frac{W1-W2}{W2} \times 100\% \quad 1$$

Where; M_C = crop moisture content (%)

W_1 = weight of grains before oven-drying (kg)

W_2 = weight of grains after oven-drying (kg)

2.3 *Determination of Cylinder Speed*

The cylinder speeds of the thresher during its performance evaluation were measured using the tachometer. The thresher was evaluated at three set levels of cylinder speeds of 600, 700 and 800 revolutions per minute (corresponding to peripheral speed of 11.0, 12.8 and 14.6 ms^{-1} respectively). These three levels of cylinder speeds were used to evaluate both varieties of wheat. The speeds were selected based on the speed required to thresh the crop effectively without unnecessarily overturning the machine after preliminary test.

2.4 *Determination of Feed Rate*

The feed rates of the thresher were determined by weighing out 0.4 and 0.6 kg of the un-threshed wheat at the stated moisture contents. These masses of the un-threshed crop were measured using the E200 electronic weighing balance. The time to manually feed in the weighted masses of the wheat crop into the thresher were measured with the quartz stopwatch and converted into kilogramme per hour (kg hr^{-1}). The feed rates of 24 and 36 kg hr^{-1}were therefore used for the evaluation of the thresher. These feed rates were selected based on the quantity of un-threshed crop available and the mass of un-threshed crop that a man (operator) can manually and conveniently feed into the thresher through the chute per unit time.

2.5 *Performance Evaluation Parameters of the IAR Sorghum Thresher*

In order to evaluate the performance of the IAR sorghum thresher, selected evaluation indices were considered:

Threshing efficiency (T_ε)

The threshing efficiency (T_ε) is defined as the percentage ratio of the threshed grain to the total quantity of sample grain after a threshing process. It is given by Kumar *et al.,* (2016) and Afolabi *et al.,* (2019) as:

$$T_\varepsilon = 100 - \frac{Qu}{Qt} \times 100 \quad 2$$

Where;T_E = Threshing efficiency (%)

Q_U = Mass of unthreshed earhead in a sample (kg)

Q_T = Total mass of the sample (unthreshed and threshed in kg)

Cleaning efficiency (C_ε)

The cleaning efficiency (C_ε) is the ratio by weight of the pure grains collected at grain outlet to the total weight of the chaff and grains collected at the same outlet expressed in percentage. The equation is given by Gbabo *et al.,* (2013) and Kumar *et al.,* (2016) as:

$$C_\varepsilon = \frac{Wt - Wc}{Wt} \times 100 \qquad 3$$

Where; C_ε = cleaning efficiency (%)

W_t = total weight of grain and chaff collected at the outlet (kg) and,

W_C = weight of chaff only collected at the outlet (kg)

Scatter losses (S_l)

During the operation, some grains were lost as scatter loss from the thresher; there were not collected with others at the grains outlet. The equation use to determine scatter losses from the thresher was given by Ndirika (1994) and Kumar *et al.,* (2016) as:

$$S_\ell = \frac{Ql}{Qt} \times 100 \qquad 4$$

Where; S_ℓ = Scatter loss (%)

Q_l = the quantity of grains scattered from machine (kg)

Q_t = total quantity of grains threshed (kg) (Scattered plus grains collected at collector)

Throughput capacity (T_C)

Throughput capacity of the thresher is expressed as the total quantity of cleaned grains collected at grains outlet per unit threshing time. The equation is given by Kumar *et al.,* (2016) as:

$$T_C = \frac{Q}{T} \qquad 5$$

Where; T_C = Throughput capacity (kg min^{-1})

Q = Quantity of grain collected (kg)

T = Time taken for complete operation (min).

However, throughput was converted to kg/hr in order to determine the quantity of grain that the thresher can process per hour.

Germination viability (G_V)

Viability was evaluated by planting the two varieties of threshed wheat grains in small transparent containers. The equation used to evaluate the germinate rate was given by Roberts (1988) as;

$$Germination\ rate = \frac{Germinated\ seeds\ x100}{Total\ number\ of\ seeds} \qquad 6$$

Fuel consumption (F_C)

Fuel consumption was evaluated to determine the amount of energy that would be needed to thresh a unit mass of each of the varieties of wheat at each of the two levels of moisture contents. This was done to ease the difficulty of measuring the fuel per treatment as the amount of fuel consumption per treatment was infinite.

2.6 *Experimental Procedure and Design*

The performance evaluation of the IAR-Sorghum Thresher using wheat varieties (Hard Red Winter Wheat and Hard White Wheat) was carried out at the Department of Agricultural and Bioresources Engineering, Ahmadu Bello University, Zaria. The weighed masses of unthreshed wheat were fed into the Thresher per unit time for the machine to perform its two simultaneous tasks of threshing and cleaning the grains while discharging the desired product at the grains outlet and blowing off the chaff and other unwanted materials. The evaluation was carried out using the Randomized Complete Block Design (RCBD) in which four parameters were considered viz; 2 varieties of wheat, each at 2 levels of moisture contents, 2 levels of manual Feed Rates, 3 levels Cylinder Speed (Table 1) and 3 replications of each treatment. The effects of the variation of each of the 4 independent factors and their interactions on the performance of the Thresher were evaluated using the analysis of variance (ANOVA) and Duncan Multiple Range test (DMRT). The DMRT was only used to rank the means of the dependent parameters where they were either significant or highly significant. Plate 1 shows the thresher during its performance evaluation.

Table 1: ***Levels of variables used for Thresher's Evaluation***

ariables	alues of Levels
arieties' Nature Moisture Contents (%)	6, 4.4 (Hard Red winter wheat Variety) 0, 4.7 (Hard white wheat)
ed Rate (kg hr^{-1})	4, 36
ylinder Speed (ms^{1})	.0, 12.8, 14.6

Plate I: ***The thresher during its performance evaluation***

3. Results and Discussion

3.1 *Performance Evaluation*

Table 2 presents the F-values obtained from the ANOVA for threshing and cleaning efficiencies, scatter losses and throughput capacity investigated, and Table 3 shows the DMRT, where needed. The results show that there is no significant difference in the replications of the experiments which means that there was no biasedness in the treatment. From Table 1, the interaction of all the four independent factors namely, variety, moisture content, cylinder speed and feed rates are not significant. This implies that all the four main effects were not being influenced by their interactions (Walpole *et al.,* 2010). These lend credence to the ANOVA results of the main effects for all the test parameters investigated.

The F-values of the moisture content show that the levels of moisture content of the crop have no significant effect on all the tested parameters. This implies that the moisture contents evaluated are adequate for the threshing and cleaning of the crop using the Thresher. The F-values of Feed Rate for threshing and cleaning efficiencies were found to be 0.13 and 0.12 respectively which imply that the feed rates is not significant to these efficiencies obtain from the Thresher. The F-value of scatter loss for Feed Rate was gotten as 5.09 and indicates that the Feed Rate is significant (at 5% level of confidence) to the scatter loss from the thresher. The F-value of 182.81 for Feed Rate on throughput indicates that the Feed Rate is highly significant to the throughput from Thresher. Table 3 shows that the scatter loss decreases with the Feed Rate while the Throughput increases with the Feed Rate.

Table 2: ANOVA results of the Performance Evaluation of the Thresher

	F				
EP		45^{ns}	62^{ns}	12^{ns}	29^{ns}
OIS		39^{ns}	27^{ns}	98^{ns}	89^{ns}
EED		13^{ns}	12^{ns}	09*	32.81**
ARE		17**	10^{ns}	.41**	89*
PED		33^{ns}	.82**	73*	.96**
ARE*MOIS		13^{ns}	30^{ns}	76*	.24**
ARE*FEED		92^{ns}	03^{ns}	26^{ns}	32^{ns}
ARE*SPED		44^{ns}	48^{ns}	24**	80^{ns}
OIS*FEED		22**	90^{ns}	24^{ns}	35^{ns}
OIS*SPED		67**	.19**	65**	.68**
EED*SPED		00^{ns}	63**	97^{ns}	.26**
ARE*MOIS*FEED		30^{ns}	73^{ns}	60^{ns}	55^{ns}
ARE*MOIS*SPED		33^{ns}	14^{ns}	52**	85^{ns}
OIS*FEED*SPED		63**	78^{ns}	16^{ns}	39^{ns}
ARE*MOIS*FEED*SPED		03^{ns}	02^{ns}	37^{ns}	98^{ns}

RROR	;				
OTAL	l				

ns = not significant, * = significant (α = 5%)l, ** = Highly significant (α = 1%), S_V = Source of Variation, D_F = Degree of Freedom, MOIS= Moisture Content, FEED= Feed Rate, VARE = Variety, SPED= Cylinder Speed.

Table 3: DMRT for significant and highly significant parameter of main factors

ariables	evels	ε	ε	'	;
ed Rates	; kg hr^{-1}			33b	66a
	l kg hr^{-1}			).09a	34b
ariety	ard Red winter	l.75b		54b	72a
	ard White	;.55a		).88a	27b
ylinder Speeds	)0 rpm		l.00b	98b	25c
	)0 rpm		l.36a	).15a	18b
	)0 rpm		l.92a	).01a	44a

Different letters in same column of Variables are statistically not equivalent

For variety, the threshing efficiency with F value of 5.17 was highly significant (at 1% level of confidence). This means that the thresher does not thresh the varieties with equal efficiency. Table 3 shows that the Hard White variety has high threshing efficiency of 95.55% and the Hard Red Winter wheat variety was threshed with the lower means efficiency of 94.8%. However, the Sorghum thresher was able to thresh the two varieties of wheat to an efficiency of about 95%. The result of Table 2 also reveals that the scatter loss from the thresher was highly significant to the variety of wheat. Table 3 shows that the loss of Hard Red winter variety is lower with the mean value of 8.54% as compared with 10.9% scatter loss for Hard White variety. For throughput capacity on variety, the F-value on Table 2 is 6.89 kg hr^{-1} and significant. Table 3 reveals that the mean Throughput Capacity of 7.72 kg hr^{-1} is obtained for Hard Red winter wheat; this is higher than the Throughput Capacity of 7.27 kg hr^{-1} obtained for Red Winter Wheat.

From Table 2, only threshing efficiency was not significant to the cylinder Speed; cleaning efficiency and Throughput are highly significant to Cylinder Speed. Scatter loss is significant to Cylinder Speed. From Table 3, cleaning Efficiency, Scatter Loss and Throughput Capacity statically varies with Cylinder Speed. For Cleaning Efficiency and Scatter Loss, the Cylinder Speed of 700 rpm gives the highest values for each of the parameters. But for the means values of these parameters, the Cylinder Speed of 800 rpm were not statistically differ from those of 700 rpm. However, the mean values of the parameter at 600 rpm are statically different from those of 700 rpm and 800 rpm, which are statistically equal. For throughput Capacity, Table 3 shows that each Cylinder Speed was in its own class statistically and increased with Cylinder Speed.

From Table 2, the interaction of Variety with any of the 3 other variables are not significant for Threshing Efficiency and Cleaning Efficiency. Furthermore, the interaction of Variety and Feed Rate are not significant for Scatter Loss and Throughput Capacity, while the interaction of Variety and Feed Rate is significant to Scatter Loss and highly significant to Throughput Capacity. For Varieties and Cylinder Speed, only Scatter Loss is highly significant with the F-value of 7.27. For the interaction of Moisture Content and Feed Rate, only Threshing Efficiency with F-value of 4.22 is highly significant, while for all the dependent parameters evaluated, the interaction of Moisture Content and Cylinder Speed are highly significant. This implies that the combination of moisture Content and Cylinder Speed is very strong factor to the performance of the thresher as the combination affects all the evaluated indicators. In the interaction of 3 independent factors, only Scatter Loss and Threshing Efficient are significant for the interaction of Variety, Moisture Content and Cylinder Speed and the interaction of Variety, cylinder Speed and cylinder Speed respectively. Kamble *et al.* (2003) and Afolabi (2015) had very similar results to those this study for the different pearl millet threshers evaluated by them in India and Nigeria respectively.

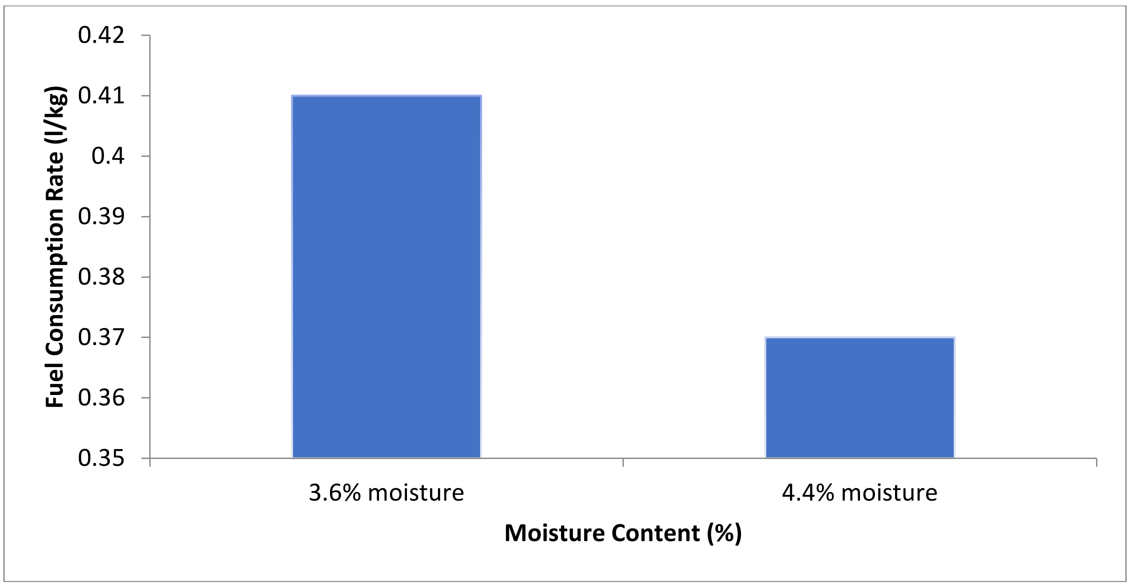

Figure 1: Effect of Moisture Contents of Hard Red Winter Wheat on Fuel Consumption Rate

Figure 1 shows the effect of Moisture Contents of Hard Red Winter Wheat on fuel consumption rate. It shows that 0.37 l kg^{-1} of fuel was consumed at the higher crop Moisture Content of 4.4% and 0.41 l kg^{-1} of fuel at the lower crop Moisture Content of 3.6%. It is expected that the fuel consumption rate decreases as the moisture content of the crop decreases. But while fixing the breakdown experienced during the experiment at 3.6% lower moisture content, the machine consumed more quantity of fuel at lower moisture content level.

Figure 2 shows the fuel consumption rate for Hard White Wheat at indicated Moisture Contents. The Hard-White Wheat consumed 0.48 l kg^{-1} of diesel having threshed the crop at the higher moisture content of 4.7% and 0.40 l kg^{-1} of fuel at the lower moisture content of 4.0%. The result is in line with the expectation based on reasoning

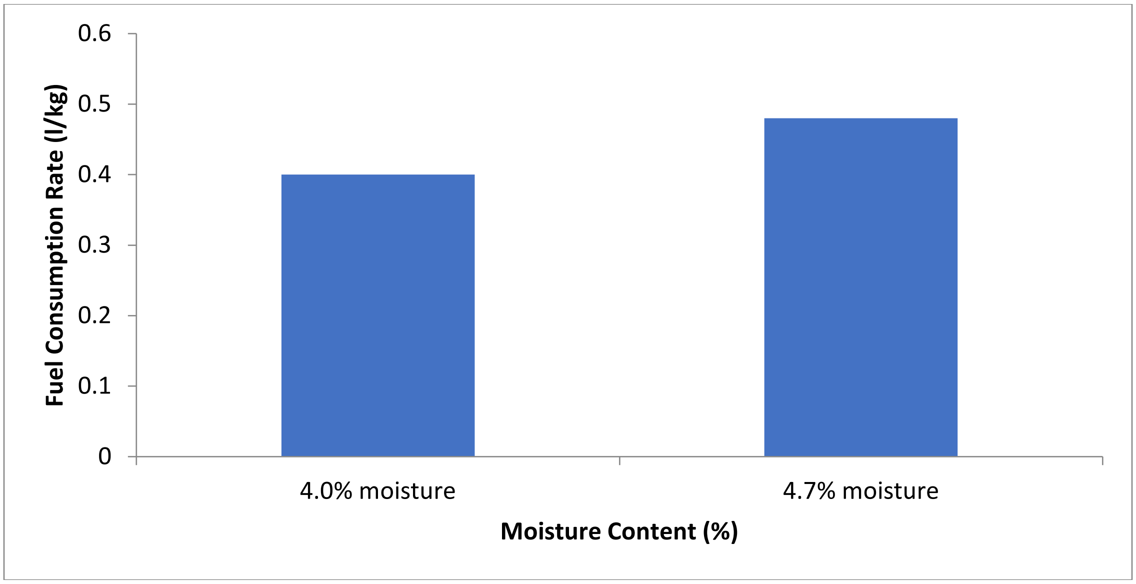

Figure 2: Effect of Moisture Contents of Hard White Wheat on Fuel Consumption Rate

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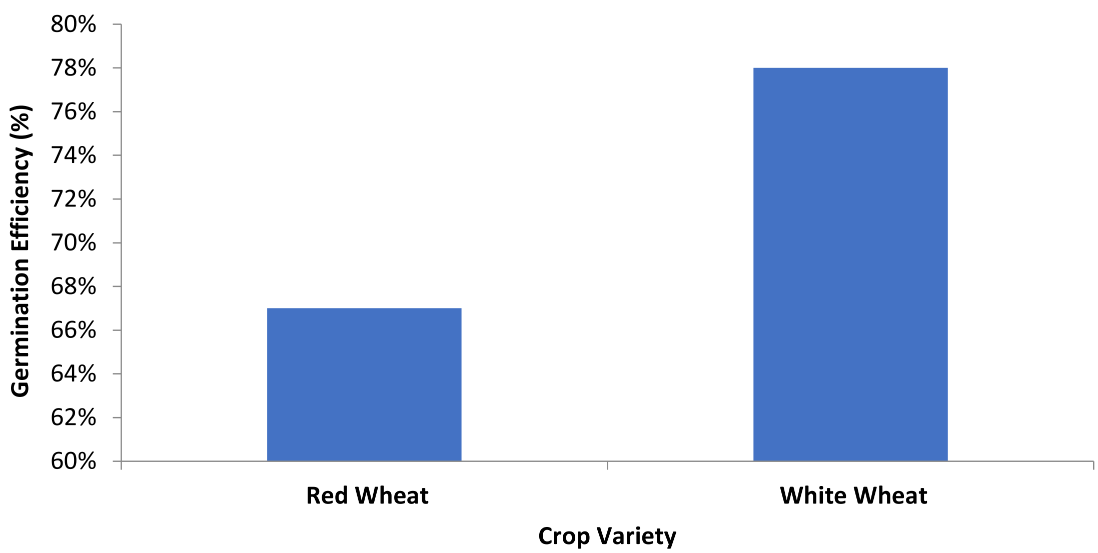

Figure 3: Result of Viability for each variety of wheat

Figure 3 shows the germination efficiency of both varieties of the crop used for the experiment. It indicates that Hard Red Winter Wheat has germination efficiency of 67% while Hard White Wheat has germination efficiency of 78% which shows that White Wheat is more viable in terms of germination compared to Hard Red Winter Wheat. However, the low variability result cannot be blamed on the thresher; as hand-threshed samples of the varieties gave similar result of viability test. This is because the wheat varieties were not meant to be sold as commercial seeds.

4. Conclusion

The IAR-Sorghum thresher was able to thresh wheat to about 95% threshing efficiency, 82% cleaning efficiency; however, the performance of the thresher for wheat can be improved by reducing the size of the perforation in the cylinder through which the threshed kernel fall before being cleaned. Also the chute inlet for the feeding in of unthreshed crop should be redesigned to allow for more quantity of wheat to be fed in per time. This would increase the output capacity (kg hr^{-1}) which is presently limited due to rate of feed input of unthreshed crop, whereas the other units of the thresher have the capacity to process more much mass than can be fed in. After this recommendation, an on-field evaluation should be carried out in order to ascertain the maximum processing capability of the thresher for wheat.

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AN OVERVIEW OF FACTORS THAT AFFECT THE PERFORMANCE OF GRAIN THRESHER

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Abstract

Threshing can only be achieved by the impact and impulsive acceleration occurring when a cylinder bar strikes the grain. This impact action is based on differences in the co-efficient of restitution of the kernel and stalk by a combination of stripping, rubbing and impact action. Threshing is the act of removing grains from the stalk without much loss or damage with the help of a thresher. A thresher is a machine that separate grains from the harvested crops. A good thresher has components like threshing unit, blower, frame, inlet, oscillating unit and outlet unit. The main factors that a thresher depends on in order to function properly were critically reviewed. The factors were crop factors (moisture content, shape, size and density), machine factors (concave clearance, angle of inclination of the hopper) and operational factors (speed, feeding rate, methods of feeding and operators experience) were thoroughly examined. All these factors affect the threshing, cleaning and separation efficiency. The rate of grain breakage, drum loss, cleaning loss, un-threshed grain loss also depended on the stated factors. It was observed that higher moisture content (MC) affect the threshing efficiency, so from the information gathered, the best moisture content as it pertains to grain threshing should be between 12 – 20 % wb. Rate of feeding also affect the threshing, cleaning and separation efficiency. Even the percentage of grain damage, drum loss, separation loss, and cleaning loss also depend on the rate of feeding. High rate of feeding increases the percentage of un-threshed grain loss. Speed also affects the performance of a thresher. Extreme speed increased threshing efficiency, output capacity and percentage of breakage. The optimum speed for threshing most grain is between 600-800 rpm. Concave clearance affects the performance of a thresher. Higher concave clearance increased the rate of un-threshed grain loss, with decreased rate of grain breakage and decreased output capacity. Smaller concave clearance increased the percentage of grain breakage. Most of the concave clearance of a thresher ranges from 12-18 mm.

Keywords: Threshing, Efficiency, Speed, Concave and Clearance.

1. Introduction

Cereal crops are essential crops in the world today because its usage/consumption has no limitation Cereal crops production ranges from land preparation, planting, weeding, harvesting, threshing, processing and packaging. Threshing is one of the critical post-harvest operations that has to be carried once they are harvested. This operation is time dependent. It is carried once the physiologically matured cereals are harvested, it need to be threshed, in order to avoid undue losses.

Threshing can be carried out manually, mechanically, or with the help of draught animals. Based on the fact that human population has exploded, the best option left for human beings as it concerns food production is to embrace full agricultural mechanization, thus the mechanical method of threshing cereals is being considered in this case. Threshing is the detachment of kernel from ear or pods, accomplished by a rotating cylinder and concave grate. As the cylinder rotates, the foliage or stalk is forced through the gap between the concave and the cylinder and is subjected to impact or rubbing action that cause grains to be detached. Threshing involves separation of grains from stalk, husks, chaff, sieving, winnowing and sorting the grains for packaging. It is obvious that the quality and quantity of cereals in the global market is a function of the threshing process (Osueke, 2013). Ndirika and Onwualu (2016), stated that threshing can only be achieved by the impact and impulsive acceleration occurring when a cylinder bar strikes the grain. This impact action is based on differences in the co-efficient of restitution of the kernel and stalk by a combination of stripping, rubbing and impact action. This action involves the application of tensile, compressive, bending and twisting forces, and their combination on ahead of grain. The threshing process can be divided into three successive and separate events:

- The detachment of the grains from the stalk by the threshing action of the threshing drum and concave grate.
- The migration of grains through the straw mat starting from a given crop layer to the outermost layer of the mat.
- The passage of grains through the opening of the concave grate after the grains reached the concave surface.

A thresher is a machine or device that separates grains from its stalks or stems. A typical thresher consists of the following components: frame, discharge outlet, straw outlet, power source, threshing unit, sieve unit, cleaning unit and transmission unit. All these components have their respective roles they play in making a thresher to work effectively. For a thresher to work efficiently, they are some factors that deserve due consideration during the design of a thresher and they include: physical properties of crops, concave length, crop feed rate, threshing speed, concave clearance, cylinder capacity, power requirement and materials of construction (Xianfei *et al*., 2018; Hongz *et al.,*2009).

Jun *et al*., 2018, described the threshing principles on four kinds. They stated that threshing is accomplished by either of the following contact methods/model, which include impact, rubbing, pre-cut combing and grinding (Kamanian *et al* 2007 and Gregory, 1998). Each contact model has its own special features, advantages and disadvantages associated with it. The importance of thresher in ensuring quality of cereals produced cannot be over emphasized. This has prompted the urgent need to brainstorm on the factors that affect the efficiency of cereal threshers. Over the years many researchers have delved into the investigation of different parameters or factors that hinder the efficiency of threshers. Osueke (2013) classified the factors affecting threshers' efficiency into three groups and they are:

- Crop factors: crop factors include variety of crop, moisture content of crop, physical and mechanical properties of crops.
- Machine factors: these factors include feeding chute angle (angle of repose), cylinder type, cylinder diameter, spike's shape, size and number, concave clearance.
- Operational factors: the operational factors are the factors attributed to the machine operator and these factors are cylinder speed, feed rate, method of feeding and machine adjustment (Ndirika and Onwualu, 2016).

These factors/parameters are essential in evaluating a thresher, thus have made many researchers to pay great attention by trying to obtain optimal parameters values by varying these parameters at different levels/conditions (Maertens and Baerde, 2003). Maerten and Baerde (2003), investigated the effect of different feed rate on grains separation. Kutsbach (2003) also investigated the effect of crop properties on the separation of cereal crops and concluded that crop properties have great influence on the separation efficiency of a threshing machine. According to Strivastava *et al* (1990), variation in the physical properties of grains, straw and chaff always have significant effect on the grain separation from the straw and chaff. The properties of grains like angle of repose, spherecity, moisture content, shape, size, specific gravity and bulk density play a major role in designing and operating of a threshing machine. They assist in selecting the optimum speed, adjusting the concave clearance, the nature of spike shape and chute angle determination. El-Behary *et al.,* (2000) evaluated a thresher with El-Sham rice thresher. They varied the speeds of drum, rate of feeding, length of conveyor chain tension at four different levels of capsule moisture content. They observed that best performance was recorded at a drum speed of 31.43 m/s, feed rate of 24 kg/min and length of conveyor tension of 48 mm at 18.45 % moisture content of grain. In their experiment the grain damage was minimal at a value of 1.78%. Chandrakanthappa *et al* (2001), evaluated a multi crop thresher with a rasp bar to thresh a finger millet. The threshing efficiency of 79.61% and mechanical damage of 2.95 % were recorded at 4 mm concave clearance at 1000 rpm (1200m/min) drum speed and 10 % grain moisture content (wet basis). Also Desta and Mishra (1990) developed and evaluated a sorghum thresher. They varied the feed rate (6, 8, and 10 kg/min), cylinder concave clearance at two levels (7 and 11 mm) and cylinder speed at three levels (300, 400 and 400 rpm) were investigated. From their results, they concluded threshing efficiency increased with an increase in cylinder speed for all feed rate and cylinder concave clearance. The threshing efficiency was found in the range of 98.3 to 99.9 %.

Osueke, 2013 from his own research work observed that there was a positive correlation between cylinder speed, threshing efficiency and separation efficiency. He attributed the directly proportional relationship between these three parameters to the fact that at higher velocity, thinning of the crop materials occurs and this gives greater opportunities for threshed materials to penetrate the straw mat. It was also observed that general level of losses decreased with increased cylinder velocity. At a moisture content of 17%, the threshing efficiency decreased as the feed rate increased. This result is based on the principle that as the feed rate increased, the threshing rate becomes slow and the kernels residence time to travel through the mat increased.

Wuttiphol and Somchai (2018) investigated the effect of moisture content, rotor speed, and feed rate on performance of a short-axial-flow soybean threshing unit and concluded that feed rates had a significant effect on threshing efficiency and grain breakage at the reliability level of 99% (0.99), but it did not have effect on un-threshed loss, separating loss and total loss. They stated that moisture content affected threshing efficiency, un-threshed loss, separating loss, total loss and grain breakage at the reliability of 99%, significantly. This is because high moisture content results in great friction between grain and non-grain materials. High moisture content increased the adherence force between grains and pods, thus leading to higher impact on threshing and more difficulty in removal of non-grain materials in the threshing unit than for grain with low moisture content. Chuadom and Chinsuwam (2015) maintained that increased grain moisture content necessitated increased separation loss owing to the fact the pods and stems have high moisture content. Srison *et al* (2016), affirmed that high moisture content of rice grain and straw affect un-threshed loss especially for the rice cultivar that is by nature difficult to thresh. The speed of a threshing drum increases separating loss, especially when the grain moisture is lower than 24 %wb. This result was based on the fact that at higher speed, there was increased violence and centrifugal force of threshing which can break the stem and pods when the moisture content lower than 24% wb. It is certain to state that the level of thresher's performance depends wholly on crop factors and operational factors so the concept and principle of designing and developing cereal threshers should strictly integrate the three factors (crop factors, machine factors and operational factors) into the main stream involved in the development and evaluation of a thresher. As a result of undue damages, separation loss, cleaning loss, drum loss encountered with the use of mechanical threshers, it is necessary to review most of the factors that affect the threshing performance with the hope of suggesting the best way/condition to improve the efficiency of a thresher.

2. Components of a Thresher

All the components of a thresher are essential for effective functioning and performance of a thresher. Some of the components are threshing unit, transmission unit, hopper, chaff outlet, grain outlet, blower and frame. Figures 1a, 1b, 1c and 1d showed a manual threshing method, a pedal operated thresher, an axial flow thresher and a threshing unit. Figure 2 illustrates a thresher and its component parts.

Figure 1 (a): Manual method of thresshing

Figure 1(b): A pedal operated thresher

Figure 1(c): An axial flow thresher

Figure 1(d): Inner side of a threshing chamber

Figure 2: A thresher and its components part.

2.1 *Threshing Unit*

Threshing unit is made up of the threshing cylinder (drum) and concave. The threshing cylinder can be of rasp bar, spike tooth, wire loop or angular bar. The wire loop mechanism is only effective for threshing rice (Ndirika and Onwualu, 2016). The peg type is suitable for threshing beans only. The rasp-bar and wire concave mechanism can be used for almost all crops, provided that clearance stators-to-beaters is correct and that beater speed is correct for the crop being threshed.

It has been categorically stated that the principal parameters of the threshing cylinder are the cylinder length, the cylinder diameter, number of beaters on the cylinder and the cylinder speed.

2.2 *Transmission unit*

The transmission unit comprises basically the shaft, pulley, belt, gears, and bearing. Shaft is a rotating machine element which is used to transmit power or motion from one place to another (Khurmi and Gupta, 2008).

2.3 *Hopper*

The hopper form the feeding chute through which the crop stalk are fed into the threshing unit. The shape and angle of inclination of the hopper depends on the mechanical and physical properties of the crops. The hopper rear wall angle must be steep enough to permit material flow and the hoppers front wall should be slightly less than the flow rate on the back wall. FMC technologies (2013) recommended $55^0 \pm 2^0$.

2.4 *Blower (Aspirator)*

The commonly used blower in a thresher is the centrifugal blower. A centrifugal blower has a moving impeller that consists of a central shaft with a positioned set of blade (vanes). The performance of a centrifugal blower depends on the configuration of the blower housing, the size of the inlet opening relative to the impeller, the location and shape of the cut off, the shape and dimension of the housing and the shape of the outlet into the outlet into the air system.

3. Indicating Parameter of a Thresher

Some of the indicating parameters of a thresher are threshing efficiency, un-threshed loss, separating loss, total loss, cleaning loss, drum loss, and grain breakage.

3.1 *Un-threshed Grain Loss (UL)*

It means the amount of grain in pods discharged at the straw outlet (gram) compared to the total amount in percentage by weight. Un-threshed grain loss can be expressed mathematically, as follows:

$$UL = \frac{W_1}{T} \times 100\% \qquad \textbf{1}$$

Where: UL was the un-threshed loss, W_1 was the amount of grain in pods discharged at the straw outlet (g), and T was the total feed amount (Wuttiphol and Somchai, 2018).

3.2 *Separating Loss (SL)*

It is the amount of fallen grain and broken grain discharged through the straw outlet (gram), compared to the total feed amount (T) expressed in percentage. The equation stated below can be used to estimate separation loss.

$$SL = \frac{W_2 + D_1}{T} \times 100\% \qquad \textbf{2}$$

Where: SL is the separation loss, W_2 is the amount of fallen grain and broken grain discharged through the straw outlet and T is the total amount.

3.3 *Grain Damage (GD)*

It means the amount of broken grains discharged through the grain outlet compared to the total feed amount.

$$GB = \frac{D_2}{T} \times 100\% \qquad \textbf{3}$$

Where: GB is the grain damage, D_2 is the amount of broken grains, and T was the total feed amount.

3.4 *Cleaning Loss (CL)*

This is can be determined by using the equation stated below courtesy of Simoyan and Yiljep (2008)

$$CL = \frac{G_i}{G_w} \times 100\% \qquad \textbf{4}$$

Where: Cl is the cleaning loss, Gi is the weight of the grain at the chaff outlet, and Gw is the weight of grain at input.

3.5 *Drum Loss (DL)*

This is the total amount of unstrapped and un-threshed grain compared to the total weight of grain at input (gram).

$$DL = \frac{W_{unthreshe} + W_{unstripped}}{W_t} \times 100\% \qquad \mathbf{5}$$

Where: DL is the drum loss, $W_{unstripped}$ and $W_{unthreshed}$ were the weight of un-threshed and un-stripped grain respectively.

3.6 *Total Grain Loss (TL)*

Total grain loss can be expressed mathematically using the stated expression below.

$$TL = \frac{D_L + S_L + C_L}{W_t} \times 100\% \qquad \mathbf{6}$$

Where: TL is the total grain loss, DL is the drum loss, SL is the separating loss and CL is the cleaning loss (Thongsri *et al., 2015*).

4. Performance Evaluation of a Thresher

The essence of evaluating a thresher is to ascertain its efficiency. The efficiency of a thresher can be investigated by determining the stripping efficiency (S_tE), the threshing efficiency (TE), cleaning efficiency (CE) and separation efficiency (S_pE).

4.1 *Threshing efficiency*

This is the ratio of grain threshed (by weight) during initial threshing to the total expressed as percentage. TE can be obtained by the expression given by Ndirika and Onwualu, 2016 as stated below:

$$TE = \frac{weight\ of\ threshed\ grain}{total\ weight\ of\ grain} \times 100\% \qquad \mathbf{7}$$

Where: TE is the threshing efficiency

4.2 *Cleaning Efficiency*

Cleaning efficiency is expressed as the weight of chaff collected at the chaff outlet to the total weight of chaff expressed as percentage.

$$CE = \frac{G_o}{G_o + C_{cg}} \times 100\% \qquad \mathbf{8}$$

Where: Go is the weight of pure grain at outlet, CE is the cleaning efficiency, Ccg is the weight of contaminant in cleaned grain.

4.3 *Separation Efficiency*

This is expressed as the weight of grain from outlet (g) and weight of grain from the straw outlet to the total weight of grain (g). It can be estimated using equation 9.

$$SPE = \frac{S_1+S_2}{S} \times 100\% \quad \textbf{9}$$

Where: S_1 is the weight of grain from the grain outlet, S_2 is the weight of the grain from the chaff outlet (g) and S is the total weight of grain (g) and S_pE is the separation efficiency.

5. Types of Power Thresher

The term thresher is used generally to mean all machines involved in detaching grains or pods with or without a separating or cleaning meachanism (Kaul and Egbo, 1985). The other terms used are sheller, sheller-dehusker, decorticator, which to an extent signify the type of operation. There are different types of thresher like drummy, spike tooth, rasp bar, hammer mill, wire loop, axial flow, syndicator and pedal operated thresher.

6. Threshing Operations

The basic unit of a threshing machine is a beater which beats and rubs the crop against a stationary plate. The beater achieves detachment of the grain from the ear head either by impact **(**beating) or by the rubbing action, or by a combination of the two. The main components of threshers that enable it to work perfectly include beater, stationary plate, feeding hopper or trough, winnowing device and a set of sieves.

The crop is fed from the hopper into the threshing area and the grain and chaff fall down into the sieve area. Simultaneously, air from the blowers pass through the screen, the chaff and other debris is blown out being lighter than the grain is collected at the grain outlet (www.farmcollector.com). Threshing is accomplished based on the principle that when:

Some impact or pounding is given on crops; the grains are separated from panicles, cobs or pods. The crop mass passes through a gap between drum and concave, wearing or rubbing action takes place. This separates grains from panicles (www.agricultureinindia.net). The strength of the bond between the grain and the panicle depends on type of crop, variety of crop, ripening phase of grain and moisture content of grain.

The Right Grain Moisture Content for Post-harvest Operations

The right moisture content is necessary in handling grains. Each operation requires different moisture content for such operation to be effectively handled. The operations are threshing which could be manual or mechanical, drying, storage, harvesting and milling. Table 1 briefly present the right moisture content at which each operation can be performed on the grain.

Table 1: The right moisture content of grain for each Operations

Operation	Desired moisture content (MC)	Primary losses
Harvesting	20 -25%	Shattering of grains if grain is too dry
Threshing	20 – 25% for mechanical threshing	Incomplete threshing
	<20% for hand threshing	Grain damage and cracking/breakage
Drying	Final moisture contents 14% or lower	Spoilage, fungal damage and discolouration
Storage	<14% for grain storage	Fungal, insect and rat damage

	<13% for feed storage	Loss of vigour
	<9% for long term seed preservation	loss of vigour
Milling	14%	Grain cracking and breakage, over milling

Source: Post-harvest@irri.org, October, 2013.

7. Important Machine Setting Tips

For minimum grain loss and maximum quality, always adjust the thresher correctly. For peg-tooth drums the drum tip speed should be about 12-16 m/sec. The drum speed in revolutions per minute depends on the drum diameter as it can be seen in Table 2. Higher speeds result in higher grain damage and de-hulled grains. Lower speeds increase the amount of non-threshed grain and result in grain loss. Lower speeds also decrease the throughput of the thresher.

Table 2 indicates the relationship between the rpm, drum's diameter and tip speed. Increase in rpm necessitate increase in the diameter of the drum and tip speed.

Table 2: How the revolution per minute (RPM) of a threshing drum determines its diameter and speed

RPM	Tip speed (m/s) for drum diameter of		
	30 cm	40cm	50 cm
400	6.3	8.4	10.42
450	7.07	9.4	11.78
500	7.85	10.5	13.09
550	8.64	11.5	14.4
600	9.42	12.6	15.7
650	10.21	13.6	17.02
700	11	14.7	18.3
750	11.8	15.7	19.67
800	12.6	16.8	21
850	13.4	17.8	22.25
900	14.14	18.85	23.6

Source: Post-harvest@irri.org, October, 2013.

Figure 3: Setting the clearance peg-teeth and concave.

Clearances between peg-teeth and concave should be about 25mm. Smaller clearance increases grain damage and might lead to clogging of straw. Larger concave clearances reduce threshing efficiency.

8. The Outcome of General Effects of Factors That Affect the Efficiency of a Threshing Machine

Many research works have been carried out on the various factors that affect the efficiency of a thresher. Some researchers have suggested one condition or the other for the best performance of a thresher, but it all depends on the condition at which the investigation was based on. Naik *et al*., (2013) conducted a study on the effect of crop and machine parameters on performance of paddy thresher that was powered by 5 hp electric motor. They observed that at a moisture content of 12.3 to 15.6% and at a feed rate of 8.56 q/hr, the output capacity of the thresher was found to be 3.57 q/hr at peripheral speed of 13.6 m/s. The grain damage decreased with increase in moisture content. The concave clearance size of the threshing unit was 9mm and it gave the best threshing efficiency of 99.02 % and acceptable cleaning efficiency of 94.83%. Olaoye *et* al (2016) evaluated the effect of threshing drum speed and crop weight on paddy grain quality in axial flow thresher. The four different speeds are (600, 800, 1000 and 1200 rpm) and the threshing capacity obtained from 600 rpm and 1200 rpm were 1326 kg/hr and 2013 kg/hr respectively. It was observed that threshing capacity increased as the threshing speed increased. It was stated threshing capacity depends on crop conditions and machines operational parameters as well as the feeding rate of materials into the threshing chambers (Miah, 1994). In their study, it was observed that at a speed of 1200 rpm recorded the highest significant ($P<0.05$) cleaning efficiency of 96.79% while the least significant value was 95.5% at 600 rpm. At a speed of 1200 rpm the highest percentage of damage (16.45 %), whereas 600 rpm and 800 rpm recorded the same value (2.63%). Askari and Abbaspour (2008) reported similar result when they evaluated a thresher using paddy and found that damaged grain increased with increase in threshing speed, but decreased with increase in concave clearance. Their result showed that grain damage ranged from 1.6 to 2.6 % and the threshing efficiency was 90 to 93.1%. El-desoukey *et al*., (2007) maintained that concave clearance affect the total kernel damage and went further to say that there was no significant difference in threshing efficiency.

The effect of throughput (weight of crops) on threshing capacities and fuel consumption at crop weights of 40, 50 and 60 kg were 1472, 1795 and 2096 kg/hr and 0.80, 0.72 and 0.70 l/kg respectively. The higher the throughput, the higher the threshing capacity (2096 kg/hr), 40 kg throughput resulted in threshing capacity of 1472 kg. As the throughput increased, the cleaning efficiency, seed damage and seed loss increased as well. The following throughput 40kg, 50kg and 60 kg resulted in the following results as it concerns cleaning efficiency, seed damage and seed loss (95.77%, 7.76%, 2.52%), (96.28 %, 7.90%, 2.38%) and (97.00%, 7.99% and 2.45%) respectively. It was observed from the study that seed loss decreased as the throughput increased. Olaoye *et al* (2016) result was in agreement with Gbado *et al* (2013) in their statement that threshing and cleaning efficiencies of millet thresher increased with increase in machine speed and that rice is best threshed at machine speed of 600 – 800 rpm.

Abich *et al.,*(2017) evaluated the effect of drum diameter and peripheral speed on the performance of a sorghum threshers, where by three speed levels (8m/s, 10m/s and 12 m/s) and three different threshing drums of diameter (200mm, 300mm and 400mm) at a fixed concave clearance of 18 mm were used to evaluate the thresher. From their results, it can be deduced that increase in threshing drum diameter from 200mm to 400mm increased threshing efficiency from 96.78 % to 96.97%, from 97.15% to 97.27% and from 97.63% to 97.48% at drum speeds of 8 m/s, 10 m/s and 12 m/s respectively. The threshing speed of 12 m/s gave the highest threshing efficiency of 97.48% with 400 mm diameter threshing drum. At 200 mm diameter with 8.0 m/s peripheral speed gave the least threshing efficiency of 96.78%. At probability level of 5% ($P<0.05$), the effect of drum diameter and peripheral speed were all significant on threshing efficiency. The interaction between speed and diameter was also found to be significant on threshing efficiency. Abich *et al.,* (2017) observed that increased drum peripheral speed from 8 m/s to 12 m/s led to increased threshing efficiency for all levels of drum diameter.

Chinsuwan *et al* (1997) investigated the effect of moisture content (MC) and rotor speed (RS) on threshing efficiency at the feed rates of 100, 150, and 200 kg/hr. They stated that high moisture content lowers threshing and cleaning efficiency. Pholpo *et al.,*(2017), Vejasit and Salokha (2004) and Wuttiphol and

Somchai (2018) agreed that high threshing speed results in high threshing efficiency and also the best range of speeds that yields higher threshing efficiency is between 10.7 m/s – 14.7 m/s for soybeans. They also observed that increased feed rate lowers the threshing efficiency because of the increase in the threshing chamber, leading to breakage of grain and blockage of materials beaten on the mesh.

The effect of operating factors on threshed grain loss was carried out by Wutttiphol and Somchai (2018), Gummert *et al* (1992), Saeng-Ong *et al* (2015) and they reported that at the moisture lower than 24% wb, low rotor speed leads to higher un-threshed grain loss. At moisture content greater than 24% wb, the un-threshed loss becomes higher when the rotor speed is lower because the increase of rotor speed raises threshing strength and hence reduced un-threshed loss.

Wuttiphol and Somchai (2018) investigated the correlation between (MC) and rotor speed (RS) on grain breakage percentage (GB) at the feed rate of 100, 150 and 200 kg/hr. it was observed that grains moisture content of 16 % wb, rotor speed variation does not affect the percentage of breakage, but as the moisture content increased above 16 % wb, increased rotor speed increases the percentage of grain breakage. This honoured the result reported by Chisuwan (2003) which showed that rice axial flow threshing unit operated with increased rotor speed will increase the percentage of grain breakage.

Shouyin and Haitao (2012) performed a study on the performance of a vertically axial flow soybean combine harvester in order to find the effect on threshing, separating and cleaning based on four (4) parameters (linear speed of rotor, concave clearance CC, feed rate FR and grain moisture content. Their experiment showed that the most appropriate moisture content of 14 – 20 % wb, rotor linear speed of 6.5 – 8.3 m/s, concave clearance of 15 mm and feed rate of 144 kg/hr which yielded 1.0% of grain breakage, 0.5 % contaminants, 2.0% of un-threshed grain, 0.7 % grain in pods, with no grain fall and left over. Also Ruoxi and Haitao (2016) also investigated the parameters that militate against the efficient performance of an axial flow thresher and concluded that the best moisture content is 17.5% wb, linear speed of 1.52m/s, feed rate of 126 – 144 kg/hr and concave clearance of 12 – 18 mm. The output of these parameters resulted in 0.3% contamination, 0.15 % grain breakage, 1.15% separation loss, 0.35 % un-threshed loss, 0.25 % cleaning loss. These particular results and parameters agreed with the efficiency index of the Chinese soybean thresher Model NY/T1014-2006.

Zaalouk (2009) carried out a study on a rice thresher made in Thailand for the possibility of threshing dry peas and chose the moderate operation condition. He concluded that the thresher can comfortably thresh peas if the moisture content is 9.20%wb, threshing speed is 15.38 m/s, feed rate is 20kg/min. The result he obtained based on the aforementioned operation condition were 2.17% damaged grain, 1.48 % un-threshed grain, 98.52 % threshing efficiency when the thresher was powered using 14.70 kw of power.

9. Conclusions and Recommendations

9.1 *Conclusions*

Threshing is a critical operation that is always carried out on grains/cereals once they are harvested. In this work, the three major factors that affect mechanical thresher were duly given holistic attention. The factors were crop factors (moisture content, shape, size, density and sperecity), machine factors (angle of inclination of hopper, concave clearance, the type of beater) and operational factors (machine speed, feed rate, methods of feeding and machine adjustment). It was observed that the suitable range of moisture content of grain should be between 12 – 20% (wb). High moisture content lowers the threshing efficiency of a thresher.

High rate of feeding affect the efficiency of a thresher. Optimum speed and appropriate concave clearance enhances the threshing efficiency of a thresher, reduces the rate of damage and loss. The best speed at which rice can be threshed is 600 – 800rpm, for sorghum the right speed is 12 m/s.

High moisture content and high rotor speed increased the rate of breakage. Most of the concave clearance ranges from 12 – 18 mm. The diameter of a threshers' drum had a significant effect on the threshing efficiency.

9.2 *Recommendations*

More should be done on the effect of speeds and moisture content on the threshing efficiency, seed loss, cleaning efficiency and rate grain damage.

The effect of diameter of a drum and speed on the total performance of a thresher should be investigated.

The effect of variation on the number of beaters on the threshing drum should be studied in order to know its relationship with thresher's performance.

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ANTHROPOMETRY OF PROCESSORS FOR ERGONOMICALLY DESIGNED IMPROVED DEWATERED CASSAVA MASH (DCM) SIEVING MACHINE

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Abstract

Traditional dewatered cassava mash sieving device developed by local craftsmen in Nigeria exposes users to work-related musculoskeletal discomfort (WMSD), among other drawbacks such as low throughput capacity, high energy, and time input. This research seeks to develop an improved manual DCM machine which alleviates this exposure as well as enhance productivity. Anthropometric parameters of 150 cassava processors from three senatorial districts of Rivers state were collected and analyzed. From the data of body parts of processors measured, an improved manual DCM machine was developed. The result of the measurement analyzed using t-test and analysis of variance (ANOVA) revealed that there was no statistically significant difference between the male and female parameters measured within a zone and between the three zones investigated. The measured parameters yielded the following mean values for the 5th, 50th and 95th percentile of the generated data: elbow height sitting (D) of 15.00, 19.23 and 22.67; lower leg length (E) of 38.80, 44.03 and 48.87, elbow to fingertip (F) of 38.27, 48.23 and 52.43; thigh clearance (H) of 9.83, 13.17 and 18.00; hip breadth (J) of 28.33, 32.83 and 42, respectively in centimeters for the three zones. Also, the ergonomic dimensions for a more comfortable posture for the machine were recommended: 72cm for machine height, 53 cm for machine width, 68cm for machine length, and a sitting range of 36-50 cm.

Keywords: Cassava mash, sieve, anthropometry, cassava processors, ergonomic

1. Introduction

Sieving, a necessary unit operation in the conversion of cassava tuber into gari, is currently executed by gari producers manually with the traditional sieves. In the traditional setting, the operators, especially women and children, sits beside a traditional sieve made of raffia, load a lump of cassava mash on to the sieve, shatters it, and then bends back and forth to shear the mash against the sieve. During the operation, the operator suffers waist pain resulting from the sitting posture, which involves bending and stretching, irritating sensation resulting from friction of rubbing the palm against the sieve with broken lumps of cassava mash (Ahiakwo *et al*., 2015; Ogunsina *et al*., 2008). The process adjudged as energy and time consuming takes two hours thirty minutes to sieve 60kg of dewatered cassava mash on a traditional sieve of 3mm aperture, with energy spent at the rate of 3.17 to 3.52KJ/min during the sieving process (Asiru *et al*., 2010; Ahiakwo *et al*., 2019a or b?).

Attempts at breaking through the drudgery involved in traditional sieving process employing motorized sieving machines have not been fully achieved. Over 92% of garri producers still use the traditional raffia sieve for pulverizing and sifting operation (Ahiakwo *et al* ., 2019, Ogunsina *et al*., 2008), with a negligible percentage of motorized sieving machine under trial (Davies *et al.,* 2008, Adekanya *et al*., 2013; Ahiakwo *et al.,* 2019a or b?).

Moreover, there has not been empirical data to back up the developmental process of the traditional sieve construction. However, the effect traditional sieves have on the users' comfort level as well as their level of exposure to musculoskeletal discomfort during sieving process was evaluated. It was revealed that traditional sieve users are at a high risk of developing musculoskeletal disorders on the long run as they were exposed to a discomfort level of 66% based on a quick ergonomic checklist rating (Ahiakwo *et al*., 2019a or b?). This justifies the need for ergonomic evaluation of processors, processing devices, and the environment using anthropometric data of user groups.

Del Prado (2007) defined anthropometry as "the science of measurement and the art of application that establishes the physical geometry, mass properties, and strength capabilities of the human body". Simply, anthropometry is the study which deals with body dimensions i.e., body size, shape, strength, and working capacity (Dawal *et al.,*2012) for design purposes and body composition (Majumder, 2014). Ergonomics make use of anthropometry to evaluate the fitness of a machine to the human operator. It involves the measurement of the human body parts to evaluate variation in user groups and to accommodate identified variation for a comfortable design. The result, when factored into a design, ensures the fitness and human comfort during operation (Dawal *et al.,* 2012). Anthropometry has three major principles, which are followed in designing various products depending on the type of product. The first principle is "design for extreme individual," which can be either design for the maximum population commonly referred to as 95th percentile male or design for the minimum population value as commonly referred to as 5th percentile female (Khaspuri et al., 2007). The second principle is "designing for an adjustable range," which put consideration of both 5th female and 95th male to accommodate 90% of the population. Anthropometric data for use in engineering design situations are best presented in percentiles (Ismail and Darshak*l*., 2016). Percentile is a value in the range of a set of data that separates the range into groups.

Ergonomics and anthropometry have recently been used to evaluate most agro-machinery and processing machines. Such evaluation using ergonomic analysis tools have revealed a misfit between human and the machine leading to severe musculoskeletal discomfort and production loss as is in the case of the sieving process. This has been noted in gari frying operation where a call for intervention and modification of the system has been made (McNeil, 2005, Bukola *et al.,* 2015; Samuel *et al*., 2016).

Ergonomics involves the application of objective data obtained from the user group to assist in improving or modifying the design of the equipment for the benefit of the user groups. The ergonomics approach encourages the evaluation of designs regarding their compatibility with user groups (Anas *et al*., 2012). Meeting ergonomic design goals can only be accomplished by considering the potential human user, and this involves their body dimensions (Guillermo *et al*., 2014).

However, no work has been reportedly done to evaluate sieving process with respect to ergonomic and anthropometry. According to Samuel *et al.,* (2016) and McNeill (2005), because there has been little published work that has focused explicitly upon occupational disorders or ergonomics hazards in agro-processing, technology initiatives that address such problems often fail because they do not engage the target users.

It is essential to include anthropometry and ergonomic in the design of agro-processing machine early enough considering the observation of Neville et *al*. (2005), that many musculoskeletal injuries begin with the worker experiencing discomfort which is usually ignored, until the risk factors responsible for the discomfort eventually leads to an increase in the severity of symptoms, and what began as mild discomfort will gradually progress from aches and pain to actual musculoskeletal injury, such as tendonitis, tenosynovitis, or serious nerve-compression injury like carpal tunnel syndrome (Surabbi and Renu, 2010). Dewatered cassava mash processors have acknowledged the feeling of sensations of discomfort during the sieving process, and this has been recognized as the body's early warning signs that some attribute of the processors' sieving operation should be changed (Alan, 2005).

It is, therefore, the objective of this research to determine the anthropometry of cassava processors using the traditional sieve in the three senatorial districts of Rivers State, find out if there is a statistically significant difference in the measured parts of the processor within and between the three zones and to factor-in the anthropometric data into a conceptualized improved DCM sieving machine to initiate a sustainable transformation in the field of cassava processing which will alleviate discomfort and enhance economic gain in cassava farming and processing.

2. Materials and Methods

2.1 *Study Area*

The research project was done in Rivers State of Nigeria. Rivers state has 23 Local Government Areas with three senatorial district, divided into: Rivers east (Zone A), Rivers west senatorial district (Zone B) and Rivers south-east district (Zone C) shown in Figure 1, having a population above 7 million people (NPC, 2015 not listed under ref) and covering an area of 11,077km^2.

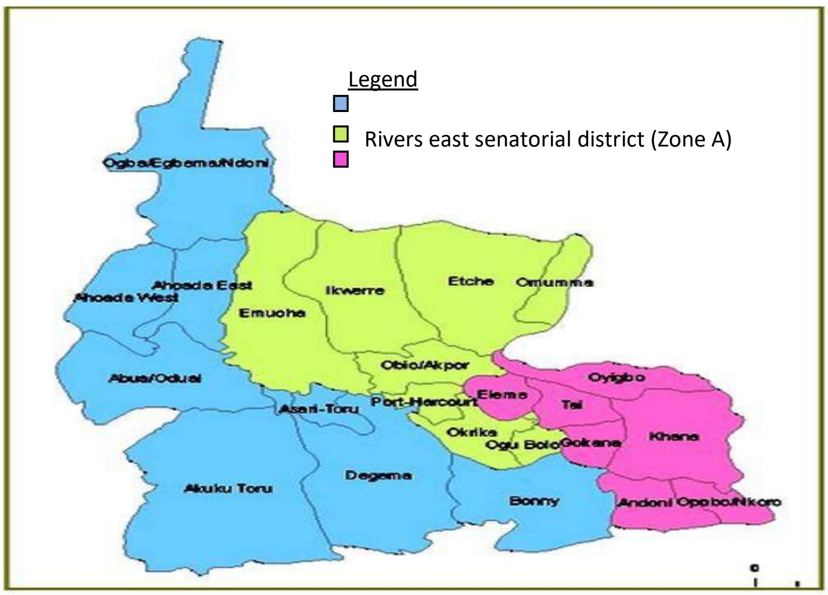


Figure 1: The three senatorial districts of Rivers state under consideration

The population for this study consisted of dewatered cassava mash (DCM) processing centres in Rivers state.

2.2 *Sampling Method*

A sample of 150 processors were randomly selected, fifty (50) from each of the three senatorial zones of Rivers state, Zone A, representing Rivers West, Zone B, Rivers South-East and Zone C, Rivers East with 30 females and 20 males.

The sample size was obtained using the formula given by Susan *et al,* (2015):

$$n = \frac{z^2pq}{e^2} \qquad 1.0$$

where n = sample size,

z = level of confidence according to the standard normal distribution (95%)

p = population having the characteristics sought,

q = 1 – p and

e = degree of precision.

The sampling procedure adopted was the random technique of sampling that permits members in the population to have equal opportunity of being selected from the three senatorial districts making up Rivers state.

The processors' measured data was used to develop an improved DCM sieve that would reduce the level of discomfort in the sieving process as well as enhance productivity. The following materials were used for the measurement of the body parts of cassava processors in the study area: measuring tape, weighing scale, wooden stool, the user group. The parts relating to the sieving machine measured in centimeter (Samuel *et al.,* 2016) were:

C - Shoulder height (sitting)

D - Elbow height (sitting),

E - Lower leg length (popliteal height),

F - Elbow to fingertip,

G - Buttock popliteal length,

H - Thigh clearance,

J - Hip breadth (sitting),

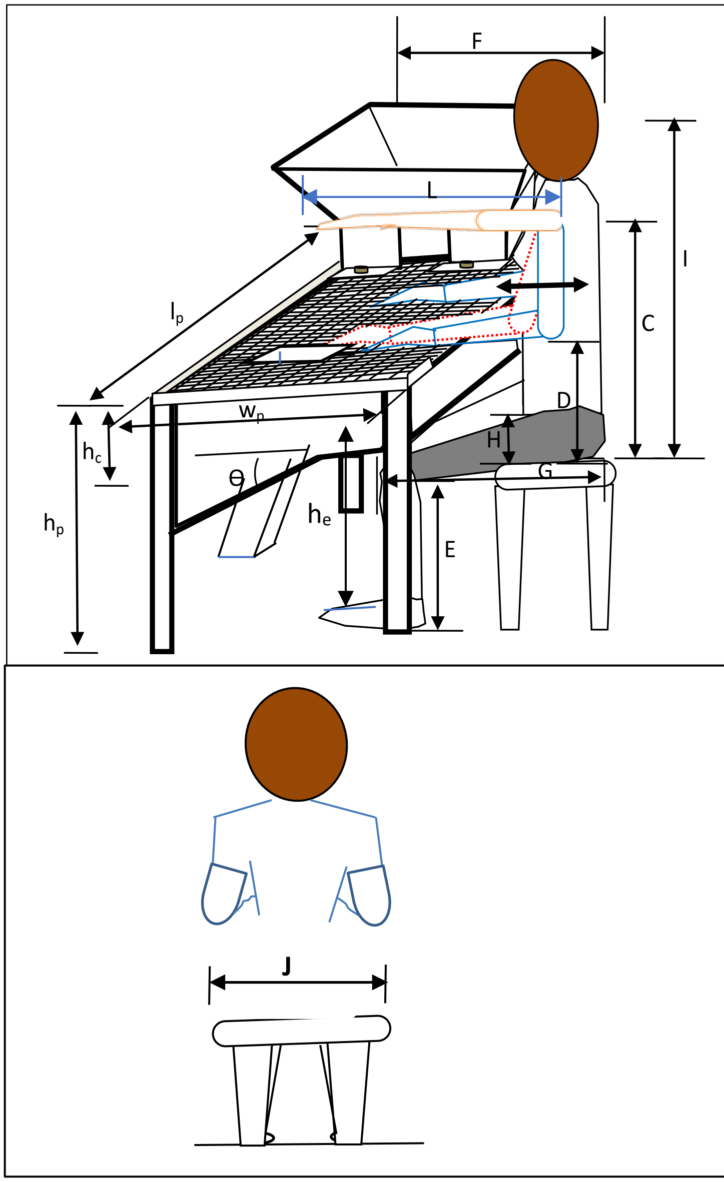
K - Knee height (sitting),

L - Forward grip reach.

These parts were identified from the processors (Figure 2) during the sieving process which highlights the prevalent posture of processors during traditional sieving process.

Figure 2: Current postures of a processors using traditional sieve

The measured parts of the processors were adjusted and used for the design of the conceptualized DCM sieving machine shown in Figure 3.



Target body parts for measurement

Legends

C – Shoulder height (sitting)

D – Elbow height (sitting)

E – Lower leg length (popliteal height)

F – Elbow to fingertip

G – Buttock-popliteal length

H – Thigh clearance

I – Eye height sitting

J- Hip breadth(sitting)

K- Knee height(sitting)Not labelled

L- Forward reach

Figure 3: The adjusted posture of a processor in a conceptualized improved manual DCM sieve

Figure 3 shows a modification of current postures of processors using traditional sieve through adjustments to their head/neck, shoulder/arm, lower leg/knee/buttock popliteal length and sitting height from an awkward posture to a standard or neutral posture (Sandip and Manish*.,* 2014), made to limit misfit, initiation, exposure, and sustenance of discomfort (Ahiakwo *et al.,* 2019a or b?).

2.3 *Design Consideration*

The following design considerations were made based on the concept in Figure 3:

1. The user's back/neck was designed to remain at a neutral position (90^o position) while performing the sieving task instead of being in the bent posture observed in the traditional sieving process to prevent induced stress.

2. Shoulder and arm was designed to be at the neutral position, as the arm rests at an angle of 90^o on the sieving platform thus keeping the back at an upright or normal position (Sandip and Manish, 2014).

3. The hopper is on the platform for easy access to DCM to avoid bending at the end of each sieving cycle.

4. The coarse particle exit is also on the platform for easy discharge of coarse particles at the end of each sieving cycle.

5. The dimension for building the machine was established based on the anthropometry of the user groups to ensure portability, prudent use of material and economy.
6. The height of the machine (hp) was established from the measured value of lower leg length (E) of processors and elbow height sitting (D),
   $$hp = E + D \qquad 2.0$$
7. The width of the machine (Wp) was established from the measured value of processor's elbow to fingertip (F),
   $$Wp = F \qquad 2.1$$
8. The length of the machine (Lp) was established from the measured value of women processor's hip breadth sitting (J) multiplied by 2,
   $$Lp = 2J \qquad 2.2$$
9. The leg recess (entrance) of the machine (Lr) was established from the measured value of processor's lower leg length (E) and processors' thigh clearance H ,
   $$h_e = E + H \qquad 2.3$$
10. The depth collector chamber of the machine (h_c) was established from the measured value of elbow height (D) minus thigh clearance (H),
   $$hc = D - H \qquad 2.4$$
11. Processors' sitting height (h_s) was established from the range of the lower leg length (E)
12. The slope of the undersize exit chamber - angle of repose (θ) was established using expression:
   $$\theta = \frac{2h}{D}, \qquad 2.5$$

   The angle of repose θ was obtained by filling a sample of DCM into a cylindrical and inverting the container, allowing the sample from the inverted container to fall by gravity slowly. After four replications, average height of the conical shape of the DCM measured using a metre rule was 8.50cm and the average diameter was 19cm, using equation 2.5 yielded the angle of repose.

13. The sieve was designed to use perforated round hole squared pitch pattern with diameter 5mm and between hole spacing of 1mm (Ahiakwo, *et al.,* 2019a or b?)
14. Materials for the machine stand and frame was of mild steel while the sieve was of galvanized steel developed with focus on portability, durability, affordability and resistance to rust.

3. Results and Discussion

The anthropometric data of 150 cassava processors collected from the three research zones and analyzed for the purpose of developing the design dimension for developing the improved manual DCM sieve are presented in Table 1 to Table 4.

3.1 *Anthropometry of cassava processors in zone A*

Table 1, shows the result of measurement of the body parts of twenty (20) male and thirty (30) female cassava processors in Zone A of the three zones under investigation carried out for the purpose of generating data for the design and development of improved manual sieving machine. The parameters measured are shown in column 1 of the table. The last two columns show the average minimum and maximum values for each parameter measured. For the lower leg length designated "E" in the conceptualized DCM sieving machine for the thirty female processors measured and shown in Table 1, the data range obtained was 37 to 48.7cm inclusive. The column under min/max in the table shows the average minimum value for the female processors to be 37 whereas the maximum is 48.7.

Table 1: Statistical analysis of body parts measurement (Zone A)

Parameters		Men (n= 20)			Women (n=30)				
Length (cm)	Tag	5th	50th	95th	5th	50th	95th	Min	Max
Age	R	18.5	37.5	56.5	21	40	58	18.5	58
Elbow height sitting	D	18	20.7	24	19	22	25	18	25
Lower leg length	E	39	45.1	48.7	37	42	47	37	48.7
Elbow to finger tip	F	41.8	47.7	51.3	42	47	52	41.8	52
Buttock popliteal length	**G**	45.3	54.8	63	45	54	63	45	63
Thigh clearance	**H**	10	12.5	16	11	14	17	10	17
Hip breadth	J	31	35.5	46	30	34	45	30	46
Knee height sitting	K	49	53.1	57	48	51	52	48	57
Forward grip reach	L	69	79.5	82.5	68	77	82	68	82.5

The 3rd to 8th columns of the table shows the record of computed 5th, 50th and 95th percentile for both the male and female processors. For the male processors, the data under parameter E are 39, 45.1 and 48.7 whereas for the female processors these are: 37, 42 and 47 for the reference percentiles respectively. The results of data from the measurement of the rest of the parameters in the table were similarly computed and recorded.

From Table 1, it was observed that the data obtained under the measured parameters for the males were different from those obtained for the female processors. The data were therefore analyzed using excel t-test to ascertain if the difference observed were statistically significant with results obtained showing a t-stat values of 0.0079, 0.067 and 0.048 at 16 degree of freedom, 5% significant level with a t-critical value of 2.12 for the 5th, 50th, 95th percentile respectively. It was found from this result that there was no statistical significant difference between the measured parameters for males and for female processors in Zone A, suggesting that either of the data could be used for developing the sieving machine, with a comfortable fitting for both genders. The age range in this zone were 18 to 58 years.

3.2 *Anthropometry of cassava processors in zone B*

Table 2, shows the result of measurement of twenty (20) men and thirty (30) women cassava processors in Zone B and the statistical analysis of the mean value of the measured data in percentile as well as minimum and maximum dimensions. The age range in this zone were 19 to 59.5 years.

Table 2: Statistical analysis of body parts measurement (Zone B)

		Men (n= 20)			Women (n=30)				
Parameter (cm)	Tag	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	Min	Max
Age	R	20.5	40	59.5	19	37	55	19	59.5
Elbow height sitting	D	13	18	22	12	17	21	12	22
Lower leg length	E	35.4	40	48.9	36	41	50	35.5	50
Elbow to finger tip	F	36	48	52	38	49	53	36	53
Buttock popliteal length	**G**	42	48	54	40	46	52	40	54
Thigh clearance	**H**	10.5	14	21	11	15	22	10.5	22
Hip breadth	J	26	29	39	27	30	40	26	40
Knee height sitting	K	44	49	53	45	50	54	44	54
Forward grip reach	L	62	68	73	60	66	71	60	73

The dimensions sought, for developing the improved sieving machine under the designations: D, E, F , G, H, J , K in the conceptualized dimension are clearly shown in table 2. The calculated values of the data in terms of 5^{th}, 50^{th}, and 95^{th}, percentile for men processors was compared to that of the women processors through excel statistical t-test with the following results: t-stat = 0.020, 0.043 and 0.062 for 5^{th}, 50^{th}, and 95^{th} percentile respectively with a t- critical of 2.12 at 5% significance level. The result showed that there was no significant difference in the measured values for men and that of the women processors, suggesting that either of the values can be used to develop a fitting machine for both genders.

3.3 *Anthropometry of cassava processors in zone C*

Table 3, shows the result of measurement of body dimension of twenty (20) men and thirty (30) women cassava processors in Zone C and the statistical analysis of the mean value of the measured data in percentile as well as the minimum and maximum dimensions. The age range in this zone was 20 to 55 years.

Table 3: Statistical analysis of body parts measurement (Zone C)

		Men (n= 20)			Women (n=30)				
Parameter	Tag	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	Min	Max
Age	R	22	38.5	55.2	20	36	54	20	55
Elbow height sitting	D	14	19	22	13	17	20	13	22
Lower leg length	E	42	47	49	40	45	47	40	49
Elbow to finger tip	F	37	49	54	35	47	53	35	54
Buttock popliteal length	**G**	41	49	57	40	48	56	40	57
Thigh clearance	**H**	9	13	17	9	13	16	9	17
Hip breadth	J	28	34	41	27	32	40	27	41
Knee height sitting	K	45	52	58	43	50	56	43	58
Forward grip reach	L	61	67	71	59	67	70	59	71

The dimensions sought, for developing the improved sieving machine under the designations: D, E, F, G, H, J , K and L in the conceptualized dimension are clearly shown in the table. The calculated values of the data in terms of 5^{th}, 50^{th}, and 95^{th}, percentile for men processors was compared to that of the women processors through excel statistical t-test with the following results: t-stat = 0.189, 0.187 and 0.163 for 5^{th}, 50^{th}, and 95^{th} percentile respectively with a t- critical of 2.12 at 5% significance level. The result also showed that there was no significant difference in the measured values for men and that of the women processors, suggesting that either of the values could be used to build a fitting machine for both genders.

From Tables 1 to 3, it was observed that the data obtained under the measured parameters from zones A, B and C differs from each other. The data from the three zones were therefore analyzed using analysis of variance ANOVA to ascertain if the difference were statistically significant with respect to the 5^{th} 50^{th} and 95^{th} percentile male and female processors across the three zones. The F values for the analysis of variance were: 0.103, 0.092 and 0.053 for data on 5^{th}, 50^{th} and 95^{th} percentile male processor respectively whereas the F values for female processors were: 0.15, 0.99 and 0.082 with F_{crit} of 3.40 for the 5^{th} , 50^{th} and 95^{th} percentile respectively. It was found from this analysis that there is no statistical significant difference in the anthropometry of processors across the three zones.

These findings show that data from any of the three zones can be used to construct befitting sieving machines that can accommodate both male and female processor in the three Zones.

3.4 *Establishing the design dimension*

The established designed dimensions for developing the improved sieving machine are shown in Table 4. The table shows how the data from the measured part of the processors were used singly or combined to establish the designed dimension of the improved manual sieving machine. The first column of the table shows the parts of the improved machine that required dimensioning while the second column shows the measured part that provided data for the dimensions singly or combined. The 3rd column shows a corresponding dimension for the machine parts while the 4th column shows how the established dimensions were sourced.

Table 4: Recommended dimension for development of improved DCM sieve

Machine parts to be dimensioned	**Processor's parts singly or combined measured**	**Designed dimension (cm) established**	**Dimension source**
Sitting height	Lower leg length E	An adjustable seat of height range (35 – 50)	5th percentile men– 95th percentile women zone B
Task height h_p	Lower leg length + Elbow height sitting (E + D)	72	95th percentile E (women) + 95th percentile D (men) zone B
Machine width W_p	Elbow to fingertip (F)	53	95th percentile F (women) Zone C
Machine length L_p	Hip breadth J x 2	68	50th percentile Jx2, women zone B
Leg entrance h_e	E+ H	64	50th percentile E and 95th H (men) Zone C.
Collector chamber h_c	hc = D – H	16	95th percentile D (Female) zone A – 5th percentile H (male) Zone C

3.4.1 *Sitting height*

From the table, an adjustable seating height range of 35 to 50cm is recommended to accommodate variation of users in the study group and enable their part to be oriented to make the processors comfortable while using the machine.

3.4.2 *Task height h_p (machine height)*

Since the task height is not to be adjustable, the 95th percentile E of women in zone B which is 50cm and 95th percentile D men in zone B which is 22cm will give a task height of 72cm to accommodate the users group.

3.4.3 *Machine width (Wp)*

F is the maximum extent the wrist/arm would move during the sieving process. The machine width is set at 95th percentile of F in zone C which is 54 or 53?cm.

3.4.4 ***Machine length Lp***

For the machine to be of portable length, consideration was given to the space that can be accommodated by hip breadth of the user. Multiplying the 50^{th} percentile hip breadth (J) of women in zone A by 2 will give a comfortable economic length of 68cm.

3.4.5 ***Leg entrance (hp)***

The leg entrance is the distance between the ground level and the machine under floor. This was drawn from 95^{th} percentile E and H of zone A which is 47 and 17 given a dimension of 64.

The anthropometric data obtained from the three senatorial zones in Rivers state is closely related to those obtained by Samuel *et al.(* 2016) and Jonathan and Shehu(2012). Samuel *et al.* (2016) carried out anthropometric studies for designing to fit gari-frying workers in the western states of Nigeria namely: Ogun, Ondo, Ekiti and Lagos state whereas Jonathan and Shehu (2012) carried out anthropometry in the design of cassava grating machine installation in Niger state of Nigeria. The minimum and maximum, 50^{th} and 95^{th} percentile with respect to hip breadth, forward grip reach, lower leg length (Popliteal height), knee height sitting (cm), buttock popliteal length, elbow height sitting and thigh clearance were closely related to the result of this research. The implication of this result is that the conceptualized improved manual sieving machine developed in this research with its dimensions can be used to develop a real manual sieving machine that can be applied in these areas as well.

4. Conclusions and Recommendations

4.1 ***Conclusions***

An improved DCM sieve can be developed using the anthropometric parameters of the users group. There was no statistical significant ($p<0.05$ or 0.01?) difference in the measured parameters for male and female processors within and between the zones considered showing that data from either of the zones can be used to develop the improved machine. A proper reorientation of the following measured parameters in the sieving process: lower leg length range, elbow to fingertip, elbow height sitting, thigh clearance and hip bread in consideration of ergonomic, can yield design dimensions for a more comfortable sieving posture for dewatered cassava mash (DCM) sieving machine.

4.2 ***Recommendations***

It is therefore recommended that the following design dimensions in centimeter: processors sitting height range of 35 – 50; sieving task height of 72; Machine width W_p of 53; Machine length of 68 obtained from the anthropometry and reorientation of the processors body parts and incorporating a modified sieve of 5mm aperture be encouraged as this will initiate a sustainable transformation from the hitherto discomfort prone, slow and energy consuming traditional sieving to an improved method which will enhance the economic viability of cassava farming and processing for the local farmers and product availability for the consumers.

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ANTHROPOMETRIC MEASUREMENTS FOR ERGONOMIC DESIGN OF PEDAL OPERATED MILLET THRESHER IN ADAMAWA STATE, NIGERIA

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Abstract

A study was undertaken to collect anthropometric dimensions of farmers in Adamawa State, Nigeria to obtain details of operators for ergonomic design of thresher. Eighty two (82) operators (61 male and 21 female) were randomly selected in three local government areas (Gombi, Hong and Song). The anthropometric measurements of the operators were carried out. Ten body segments (Stature, eye height, shoulder height, hand length, fingertip height, sitting height, sitting eye height, elbow rest height, knee and lower leg lengths) were directly measured with a measuring tape. The mean, standard deviation, difference between 5th and 95th percentile of the operators were computed. The mean age, stature and mass of male operators were found to be 35.2 ± 2.4 years, 169.82 ± 9.81cm and 63.4 ± 4.71 kg, respectively while the corresponding parameters for female operators were 26 ± 3.6 years, 158.92 ± 5.05 cm and 51.6 ± 4.43 kg. The values obtained for male operators were thus for 5th (153.7cm) and 95th (185.4cm) percentile stature respectively while the corresponding parameters for female operators were 5th (150cm) and 95th (165.9cm) percentile. In general the male operators were heavier in terms of weight (63.4kg) as against female operators with a value of 51.6kg.The mean lean body mass of male operators was also higher than female operators. The anthropometric data determined was used in the design of operator's seat adjustment and adjustable frame of the thresher to minimised drudgery of operation and increase operators comfort.

Keywords: Anthropometry, Millet Thresher, Design, Dimensions, Ergonomics.

1. Introduction

Anthropometry is the study and measurement of various physical traits like size, mobility and strength. It is the best tool to be applied for design of equipment, machines, workplace and clothing to enhance the system efficiency, safety and comfort of the farm worker. The use anthropometric data would assist in the appropriate design of equipment and machines for improved efficiency, safety and human comfort (Yadav *et al*., 2000). With the advent of technology, disregard for the human factor is no longer possible and a knowledge of man's size and its variability has become progressively more critical in designing farm equipment and workplaces (Woodson and Conover, 1985).

Jha and Tiwari (2014) conducted an anthropometric study on 100 female farm workers within the range of 20 to 45 years the data obtained from the measurements were statistically analysed and compared with those obtained from male agricultural workers in Madhya Pradesh in India, and the result revealed that the mean stature of female farm worker was 1511 ± 58.67mm. Victor et al., (2002) carried out an anthropometric survey and compared with available data from other regions. The Anthropometric measurements were carried out on 5 males from each village randomly chosen from 6 districts of Chhattisgarh region. The data showed that the Indians (Chhattisgarh region) are smaller than western people (Americans, Swedish and Germans). The other body dimensions were also found to be lower than the western people except popliteal height (sitting) and buttock popliteal length in which Indians have the higher value of body dimensions.

Lilia *et al*., (2001) use data collected from 4758 boys and girls between the ages of 6 and 11 in the Mexican city of Guadalajara in an attempt to determine the anthropometric characteristics of primary school children in Mexico. They compared the results obtained with that of earlier results from Mexican studies, American and Cuban children in order to determine any ethnic differences as well as the changes with time.

2. Materials and Methods

2.1 *Materials*

The materials used to carry out various measurements in this study include measuring tape to measure different anthropometric dimensions of operators. Weighing balance to measure the weight of the operators, stethoscope to measure the heart rate of the operators, stop watch to record the threshing time, digital blood pressure monitor (Motech, cuff pressure $\pm$ 3mmHg, pulse rate $\pm$ 5% of reading) to measure blood pressure and pulse rate of the Operators.

2.2 *Study area*

The study was conducted in Adamawa state; the population group related study was obtained from Gombi, Hong and Song local government areas of the State. These areas were selected because they are areas that are into millet production. Other areas considered for study in the State include Michika, Madagali, Uba and Mubi local government areas. However, these areas were not accessible due to insurgency issue at the time of the research; since most of the famers have fled to other location.

2.3 *Preliminary Investigation*

Adamawa State is located in the North Eastern part of Nigeria. It lies between latitude 9^0 20’ North of the equator, and longitude $12^0$30’ East of the Grenwich Meridian (Adebayo and Tukur, 1999). It shares common boundaries with Taraba State in the South and the west, Gombe State in its Northwest, and Borno State to the North. Adamawa State has an international boundary with the Cameroun Republic along its eastern border. The state covers a land area of about 38741 square kilometres with a population of 2,102,053 people, according 1991 population census of Nigeria. The State is divided into 21 local government areas (Adebayo and Tukur, 1999).

2.4 *Samples Size*

The larger the sample selected, the most likely it is to be a representative of the total population. However, cost and time becomes the limiting factors. Both purposive and simple random sampling techniques were employed to select the farmers used for the study. Three (3) major millet growing local governments areas were selected. The samples selected for the study consist of 82 Volunteer operators selected from this local governments.

2.5 *Anthropometric Data*

A sample size of eighty two (82) was used for the study whose ages were within 20 - 45 years because at this range individuals attain their highest strength level (Mc Ardle *et al*., 2001). All the subjects were right handed, physically fit and were not suffering from any physical abnormalities to perform the selected activity. The measurements of different anthropometric parameters of the operators were carried out using measuring tape. The operators were asked to remove their shoes and stand erect without bending. Different measurements of the body segment or joints were taken and recorded. Measurements at the sitting posture were made with seats of adjustable heights, (Parmanand *et al.,* 2015). The arithmetic mean, standard deviation, fifth (5^{th}) and ninety-fifth (95^{th}) percentile values were computed from the data collected for each of the body dimensions. Mean value was computed by adding the individual values and dividing the sum by the sample size. It indicates where the distribution is located on the horizontal axis. The standard deviation was computed using the formula

$$SD = \sqrt{\frac{\sum\left(x - \bar{x}\right)^2}{n-1}} \qquad (2.1)$$

Where, SD = Standard deviation of the sample.

$\bar{x}$ = Mean value of the sample.

x = Individual value of sample.

n = the number of values (the sample size).

The standard deviation is an index of degree of variability in the population concerned. It indicates the width of distribution to which individual values are scattered about the mean. The 5th and 95th percentile values were computed using the relationship given below

$X_i = M + SD \times Z$ (Parmanand *et al.,* 2015) (2.2)

Where, $X_i = ith$ percentile value of the dimension.

M = Mean value of the dimension.

SD = Standard deviation of the dimension.

Z = Z – Score corresponds to the chosen confidence level. Confidence level tells us how confidence we are that if the study was repeated again and again we would get the same result. The confidence level chosen is 95% and the Z – score is ± 1.645

For 5th percentile Z = -1.645 and for 95th percentile Z = $+$ 1.645.

The range of the dimension measured was taken by noting the minimum and maximum values among the subjects.

2.6 *Data analysis*

The arithmetic mean, standard deviation, 5th and 95th percentile were computed for each body dimensions from the data collected during the survey. All dimensions are in centimeter (cm) except for age (years) and weight in kilogram (kg).

3. Results and Discussion

3.1 *Anthropometric Parameters of Agricultural Workers*

Tables 1 and 2 below present the mean, standard deviation, 5th and 95th percentile values for the anthropometric parameters of male and female operators, respectively, the details of the study is presented in appendix I and II. The mean age, stature and mass of male operators were 35.2 ± 2.4 years, 169.82 ± 9.81cm and 63.4 ± 4.71 kg, respectively while the corresponding parameters for female operators were 26 ± 3.6 years, 158.92 ± 5.05 cm and 51.6 ± 4.43 kg. The percentile values of male operators have been found for 5th (153.7cm) and 95th (185.4cm) percentile stature respectively while the corresponding parameters for female operators were 5th (150cm) and 95th (165.9cm) percentile. In general the male operators were heavier in terms of weight (63.4kg) as against female operators with a value of 51.6kg. The mean lean body mass of male operators was also higher than female operators. Earlier studies reported similar results. Parmanand *et al.,* (2015) while studying the anthropometrics of (n =10) male and female pedal millet thresher operators reported the weight, stature, standard deviation, 5th and 95th percentile of male operators as follows 54.7 ± 8kg, 168.0 ± 2.32,cm, 164.1cm and 171.8cm respectively while the corresponding result for female operators was 55 ± 5.22kg, 160.2 ±3.27cm,154.8cm and 165.6cm respectively.

Mohanty *et al*., (2012) investigated the anthropometrics of (n=12) selected subjects from both sexes in agro-climatic zones of Odisha and reported the mean stature and weight of the male subjects as follows 164.8 ± 9.62cm and 57.4±10.57 kg respectively while the corresponding parameters for females was 152 ± 7.61cm and 51.7 ± 4.91kg respectively.

Sadeghi *et al.,*(2014) made a comparison of static anthropometric characteristics among workers of three Iranian ethnic groups.The mean, standard deviation, 5th, and 95th percentile values for male were:Fars (1730 ± 70.2, 1634.9 and 1845.5) Arab(1715±70.2, 1614.8 and 1825.5) Azeri(1693 ± 60.7, 1693 and 1815.4) respectively while the corresponding parameters for females: Fars(1584 ± 70.1, 1471.5, 1691.7) Arab(1579 ± 60.1, 1484.4 and 1681.7) Azeri(1590 ± 60.1, 1503.0, 1680.0).

Table 1: Analysis of Anthropometric Data of Male Operators (n = 61) 74.4%

S/N	Dimension	Mean	SD	5th Percentile	95th Percentile
1	Age years	35.2	2.4	32	39.46
2	Weight kg	63.4	4.71	57	72
3	Stature, cm	169.82	9.81	153.7	185.4
4	Eye height, cm	160.46	9.17	145.7	174.23
5	Shoulder height, cm	138.96	5.44	131.4	147.6
6	Hand length, cm	78.42	7.15	68.35	88.44
7	Fingertip height, cm	60.2	4.70	52.49	66.35
8	Sitting height, cm	134.86	8.04	107.54	132.4
9	Sitting eye height, cm	119.34	5.79	101.3	118.7
10	Elbow rest height, cm	68.74	4.54	62.07	75.32
11	Knee height, cm	53.5	3.62	47.2	59.2
12	Lower leg length, cm	44.68	3.79	39.18	50.58

Table 2: Analysis of Anthropometric Data of Female Operators (n = 21) 25.6%

S/N	Dimension	Mean	SD	5th Percentile	95th Percentile
1	Age, years	26	3.6	22	31
2	Weight, kg	51.6	4.43	46	59
3	Stature, cm	158.92	5.05	150	165.9
4	Eye height, cm	151.22	5.75	142	1158.3
5	Shoulder height, cm	135.28	4.67	127.3	142.1
6	Hand length, cm	70.94	3.81	65.3	75.8
7	Fingertip height, cm	62.56	43.70	57.6	68.3
8	Sitting height, cm	114.98	4.49	106.4	120.2
9	Sitting eye height, cm	106.92	4.95	100.2	114.6

10	Elbow rest height, cm	60.16	4.36	53.6	68.4
11	Knee height, cm	51.98	1.65	47.3	56.3
12	Lower leg length, cm	43.36	1.73	40.6	45.9

4. Conclusion

In conclusion, the anthropometric measurements of the operators were carried out. The mean, standard deviation, difference between 5th and 95th percentile for male and female operators were computed. The mean age, stature and mass of male operators were found to be 35.2 ± 2.4 years, 169.82 ± 9.81cm and 63.4 ± 4.71 kg, respectively while the corresponding parameters for female operators were 26 ± 3.6 years, 158.92 ± 5.05 cm and 51.6 ± 4.43 kg. The percentile values of male operators have been found for 5th (153.7cm) and 95th (185.4cm) percentile stature respectively, while the corresponding parameters for female operators were 5th (150cm) and 95th (165.9cm) percentile. In general the male operators were heavier in terms of weight (63.4kg) as against female operators with a value of 51.6kg. The anthropometric data was used in the design of the operator's seat height adjustment and determination of the distance between the seat and the steering of a pedal operated millet thresher. The findings of the study are important addition to local knowledge on anthropometry and it has increased anthropometric databases of the study population. The collected data were used in the design of the pedal operated millet thresher to prevent inadequate design that could cause discomfort, inappropriate sitting posture and musculoskeletal disorders.

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PS08

PS09

DEVELOPMENT OF A CONCENTRIC DRUMS PEELING MACHINE FOR COCOYAM (*Xanthosoma sagittifolium*) CORMEL

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Abstract

Cocoyam **(*Xanthosoma sagittifolium*)** *is cultivated mainly for its edible cormels. In spite of its great potential as a cheap raw material, the processing operations are still largely performed manually. Some of the equipment already developed for mechanizing the postharvest operations require further modifications and performance optimization. This study therefore, is aimed at developing and evaluating the performance of a cocoyam cormel peeling machine with a view to reducing the drudgery involved in manual peeling. A cocoyam cormel peeling machine was developed using locally available materials. The machine consists of the main frame, hopper and outlet gates, two abrasive concentric drums (one stationary and the other rotating) and blower. Performance of the machine in terms of capacity, peeling efficiency and peel-cormel weight proportion were evaluated for soaked and unsoaked cormels . The average machine capacities were 190 and 220 kg/h for soaked and unsoaked cormels, respectively. The peeling efficiencies ranged between 57.3 and 77.7% while the peel-cormel weight proportions ranged between 13.7 and 18.7%. The peeling efficiency was higher for soaked cormels than unsoaked ones. The developed cocoyam cormel peeling machine helped in reducing the drudgery associated with its peeling operation while soaking as a form of pretreatment was recommended before peeling the cormels for better performance.*

Keywords: Cocoyam processing, Edible cormel, Peeling, Peeling machine, Abrasive drums, Peeling efficiency

1. Introduction

Cocoyam (*Xanthosoma sagittifolium*) is cultivated in Nigeria and other tropical regions of the world purposely for its edible starchy corms and cormels. Among the root and tuber crops grown, it ranks as the

third most important crop after yam and cassava. Its cultivation in Nigeria is mostly found in Southern-Western and South Eastern parts of the country owing to suitable and adaptable ecological conditions in these areas (Balami *et al*., 2012). However, its cultivation is essentially by small scale resource poor farmers with minimal agricultural input (Dimelu *et al*., 2008).
Cocoyam contributes significant portion of carbohydrate content of the diet in many regions in developing countries. Although it is often considered less important than other tropical root crops such as yam, cassava and sweet potato, it remains a major staple crop in many parts of the tropics and sub-tropics (Onyeka, 2014).

The vast distribution of cocoyam geographically has culminated in diverse utilization of the crop. Most of the plant parts (corms, cormels, petioles, leaves and inflorescence) of cocoyam are consumable. The corms and cormels are widely used as food while the plant parts are useful for animal feed and medicine. However, most traditional cooking method adopt heat by boiling, baking, roasting or frying either alone or in combination with other ingredients to obtain delicacies (Onyeka, 2014). It is also used industrially in the production of alcohol and drugs (Okwuowulu *et al.,* 2002).

Cocoyam cormel is highly perishable and its storageability is challenging due to its high moisture content in its fresh state. This adversely affects its shelf-life and culminates in serious post-harvest losses. This therefore, necessitates prompt processing of the cormels after harvesting to obtain products such as flour, chips, flakes and *fufu* with improved storability and shelf life.
Several unit operations are involved in the conversion of cocoyam cormel into some of its final products. These unit operations are often preceded by peeling and this makes it a significant operation in cocoyam processing. Peeling, as a preliminary operation, is the first operation performed after the cocoyam tubers have been freshly harvested and cleaned from debris. It entails the removal of outer skin (cortex or peel) of cocoyam cormel which is often done manually in Nigeria and some other developing nations. However, traditional or manual peeling with knives has been found to be laborious and costly. There have been several attempts by various researchers at designing peeling machines for various roots and tuber crops such as cassava, garlic, taro etc. (Egbeocha *et al*., 2016; Balami *et al*., 2016).

This study therefore, is aimed at designing, fabricating and evaluating the performance of a motorized concentric drums peeling machine for cocoyam (*Xanthosoma sagittifolium*) cormel.

2. Materials and Methods

2.1 *Design Considerations*

In the design of the cocoyam cormel peeling machine, the physical characteristics of the cormel such as mass, volume, linear dimensions and projected areas along the three mutually perpendicular axes as reported by Raji and Oyefeso (2010) were taken into consideration for an appropriate and practicable design. The machine was ergonomically designed to enhance ease of operation and fabricated using locally available materials.

2.2 *Design of Machine Components*

2.2.1 *Inlet unit*

The inlet unit for feeding in the cormels consists of a pyramid-shaped hopper with a vertical channel. The angle of inclination of the hopper walls was determined based on the knowledge of the angle of repose of cocoyam cormels on galvanized steel. A sliding gate was incorporated to control the feeding rate of the cormels.

2.2.2 *Shaft design*

The shaft diameter required for the machine having combined bending and torsional loads was determined using Equation 1 (Adeleke, 2012).

$$d^3 = \frac{16}{\pi \times s}\sqrt{(K_t M_t)^2 + (K_b M_b)^2} \quad (1)$$

Where:
d = Shaft diameter (m)
S = Allowable stress (Nm^{-2})
K_t = Combined shock and fatique factor for torsion (Nm^{-2})
K_b = Combined shock and fatique factor for bending (Nm^{-2})
M_b = Shaft Bending Moment (Nm)
M_t = Shaft Torsional Moment (Nm)

K_t and K_b were assumed to be 1.5 (Shittu and Ndirika, 2012). Therefore, the shaft diameter was calculated to be 24.1 mm although 25 mm diameter was used.

2.2.3 *Design of pulley*

With the purpose of varying the machine speed as one of the evaluation parameters, three sets of pulleys were designed for. The pulley diameters were obtained from the speed ratio as expressed in Equation 2 (Khurmi and Gupta, 2005; Oluwole and Adio, 2013).

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \quad (2)$$

Where:
d_1 = diameter of the driving pulley (m)
d_2 = diameter of the driven pulley (m)
N_1 = Speed of the driving pulley (rpm)
N_2 = Speed of the driven pulley (rpm)

The pulley diameters for the machine were determined to be 215, 165 and 95 mm to obtain operational speed levels of 430, 540 and 920 rpm, respectively.

2.2.3 *Belt design*

V-belt (A-type) was selected in transmitting motion from the prime mover to the inner abrasive drum of the peeling machine. The angle of wrap and angle of contact of the open belt were determined using Equations 3 and 4, respectively (Khurmi and Gupta, 2005; Oluwole and Adio, 2013).

$$2.3 \times log\ log\left(\frac{T_1}{T_2}\right) = \mu\theta \quad (3)$$

$$sin\ sin\ \alpha = \frac{R+r}{x} \quad (4)$$

Where:
θ = angle of wrap of an open belt (degrees)
μ = Coefficient of friction
T_1 = Tension in the tight side of the belt (N)
T_2 = Tension in the slack side of the belt (N)
$\alpha = angle\ of\ contact$ (degrees)
r = radius of smaller pulley (m)
R = radius of larger pulley (m)
x = distance between two pulleys for peeling machine (m)

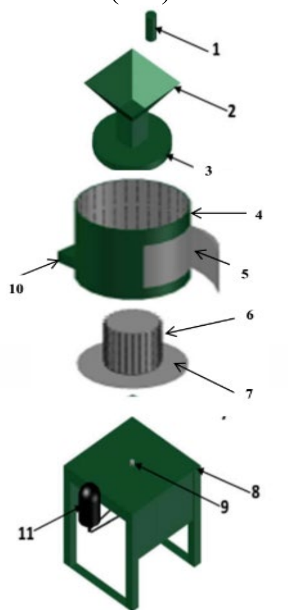
2.2.4 *Power requirement*

Total power required for effective operation of the peeling machine was obtained from Equation 5 (Khurmi and Gupta, 2005).

$$P = F \times V \quad (5)$$

Where:
P = power required to operate the machine (W)
F = Force required to power the machine (N)
V = Speed of rotation of the shaft (m/s)

S/N	PART
1	WATER INLET
2	HOPPER
3	PEELING DRUM/ CHAMBER COVER
4	PEELING DRUM
5	COCOYAM TUBER OUTLET
6	INTERNAL PEELING DRUM
7	ROTATING DISC
8	FRAME
9	PULLEY SHAFT
10	PEELS OUTLET
11	ELECTRIC MOTOR



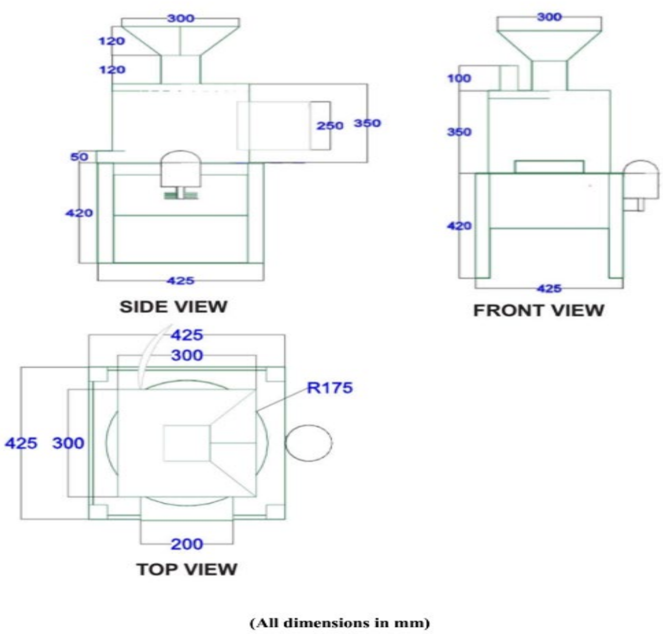


Figure 1: (a) Exploded view of the machine   (b) Orthographic projection of the machine

2.3 *Principle of Operation of the Machine*

The cocoyam cormels were fed into the peeling chamber through the trapezoidal hopper with regulated sliding gate to control the feeding rate. The peeling machine consists of two abrasive concentric drums (inner drum rotates while the outer one is stationary) which were vertically positioned and made of punched galvanized steel sheets. The peeling was achieved by abrasion caused by the movement of the cormels within the clearance between the two abrasive concentric drums. As the inner drum rotates, the cormels move against the walls of the drums and the punched surfaces rub on the cormel surfaces and peel off their skin predominantly by abrasive action. The cormels were held within the peeling chamber for specified retention time until the peeling was satisfactory. The peels escaped through the peel outlet, created by the clearance between the rotating disc and the wall of the stationary drum. The radial blower beneath the rotating disc relatively cleared the peels out through the peel outlet while the peeled cormels were collected at the main discharge unit controlled by a sliding lock.

2.4 *Performance Evaluation of the Machine*

The performance of the peeling machine was evaluated at three operational speed levels namely 430, 540 and 920 rpm using fresh, wholesome cocoyam cormels at average moisture content (wet basis) of 65%. The duration for different batches introduced were recorded. Performance indices such as peeling efficiency and peel-cormel weight proportion were determined.

2.4.1 *Capacity of the machine*

Machine peeling capacity was calculated as the ratio of batch load of the cormel to the total peeling time. It was determined according to Equation 6 (El-Ghobashy *et al.,* 2016).

$$C_p = \frac{L_b}{T_l + T_r + T_u} \times \frac{60}{1000} \qquad (6)$$

Where:
C_p = Machine peeling capacity (t/h)
L_b = batch load (kg)
T_l = Loading time (min)
T_r = Peeling resident time (min)
T_u = Unloading time (min)

2.4.2 *Machine peeling efficiency*

The peeling efficiency of the machine was determined as the ratio of weight of peel removed by the machine to the total weight of peel on the cormel. The expression is as presented in Equation 7 (Adegbehingbe, 2010).

$$\eta_p = \frac{M_{po} \times 100}{T_{wp}} \qquad (7)$$

Where:
η_p = Machine peeling efficiency (%)
M_{po} = Weight of peel collected through the peel outlet of the machine (kg)
T_{wp} = Total weight of peel on the cormel (kg), which was obtained from the sum of weight of peel removed by the machine and the peel manually removed from the partially peeled cormel.

2.4.3 *Peel-cormel weight proportion*

The peel-cormel weight proportion was determined using Equation 9 (Balami e*t al.,* 2012).

$$P_w = \frac{M_{pc} \times 100}{M_s} \qquad (9)$$

Where:
P_w = Peel-weight proportion (%)
M_{pc} = Mass of peel collected (kg)
M_s = Mass of the sample (kg)

3. Results and Discussion

A cocoyam cormel peeling machine was designed and constructed in this study using locally available materials. The machine was operated at three speed levels (426, 539 and 933 rpm) and its performance was evaluated on the basis of machine peeling efficiency and peel-cormel weight ratio. Pictures of the fabricated peeling machine are shown in Figures 2a and 2b. Soaked and unsoaked cocoyam cormels were used in evaluating the performance of the machine to determine the effect of soaking as a form of pretreatment on the peeling efficiency and peel-cormel weight ratio.

Figure 2: (a) The assembled peeling machine ***(b) Peeling machine showing internal peeling drum***

3.1 Effect of operational speed on machine performance

Variations in machine peeling efficiency at different operational speed levels for soaked and unsoaked cormels are presented in Figures 3 and 4, respectively. It was observed that the peeling efficiency increased predominantly as the operational speed increased for the soaked cormels, indicating that more peels were removed from the cormels as the speed level increased for a specified retention period. Similar trend was reported by Balami *et al*. (2016) for peeling fresh taro tubers. The highest peeling efficiency (87.5%) for soaked cormels was obtained for 60 s retention period at 539 rpm while the lowest peeling efficiency (69.4%) was obtained for 40 s retention period at 426 rpm speed level.

The peeling efficiencies of the fresh, unsoaked cormels decreased consistently as the operational speed increased for the range of retention periods considered. This is similar to the results obtained by Oluwole and Adio (2013) for peeling fresh cassava tubers. The highest peeling efficiency (72.2%) was obtained for 60 s retention period at 426 rpm while the lowest peeling efficiency (55.5%) was obtained for 40 s retention period at 917 rpm speed level.

Increase in the peeling efficiencies as the speed level increased could be attributed to the softness of the cortex of the soaked cormels which made it possible for the abrasive surfaces of the peeling drums to engage the peels and therefore, improving the efficiency at higher speeds. However, it could be observed that the outer skin of the fresh (unsoaked) cormels was quite hard and therefore, the cormels slip off the abrasive surfaces at higher operational speed levels.

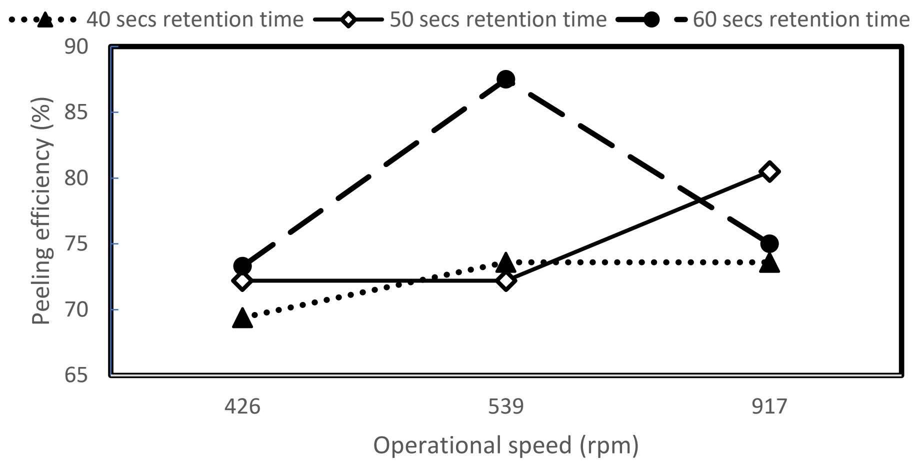


Figure 3: Peeling efficiency of soaked cormels

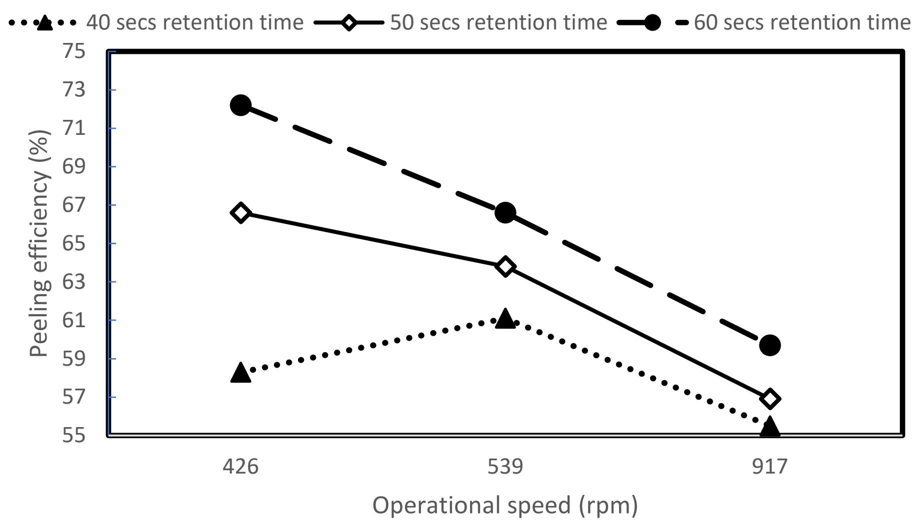


Figure 4: Peeling efficiency of unsoaked cormels

Variations in peel-cormel weight ratio at different operational speed levels for soaked and unsoaked cormels are presented in Figures 5 and 6, respectively. It was observed that the peel-cormel weight ratio increased predominantly as the operational speed increased for the soaked cormels. A similar trend was reported by Oluwole and Adio (2013) for fresh cassava tubers. The highest (22.91%) and lowest (18.38%) peel-cormel weight ratios for soaked cormels were obtained for 60 s retention period at 539 rpm and 40 s retention period at 426 rpm speed level, respectively.

The highest (19.55%) and lowest (15.27%) peel-cormel weight ratios for unsoaked cormels were obtained for 60 s retention period at 426 rpm and 40 s retention period at 917 rpm speed level, respectively. The peel-cormel weight ratio of the fresh, unsoaked cormels decreased consistently as the operational speed increased for the range of retention periods considered. This could be attributed to less contact between the cormels and abrasive surfaces of the concentric drums as the operational speed increased. The hardness of the cormel peel (without soaking) may also contribute to the reduction in the peel-cormel weight ratio of the unsoaked cormel as the operational speed increased. Soaking as a form of pre-treatment was observed to have helped in softening the cortex (outer peel) of the cocoyam cormels and this resulted in better machine performance in terms of higher peeling efficiencies and peel-cormel weight ratios.

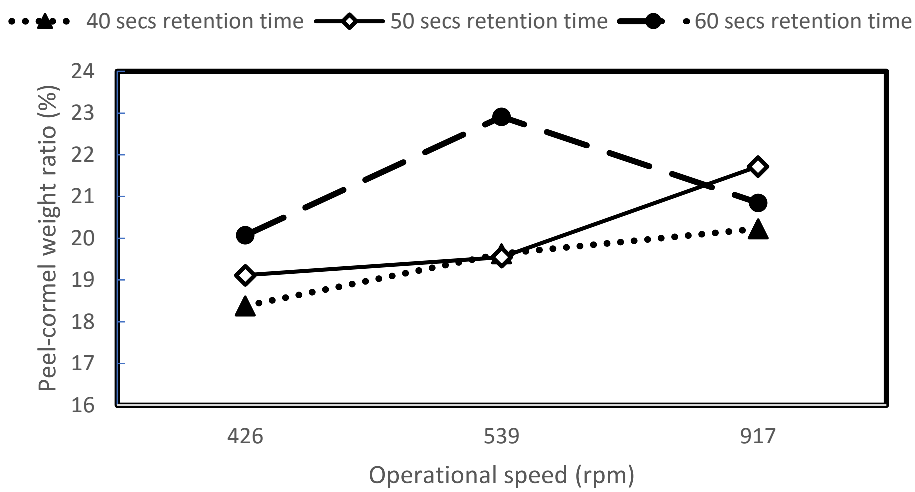


Figure 5: Peel-cormel weight proportion for soaked cormels

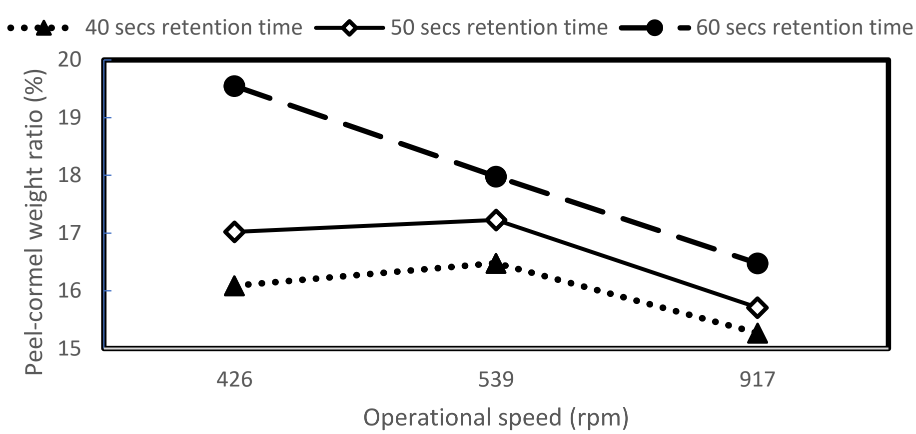


Figure 6: Peel-cormel weight proportion for unsoaked cormels

3.2 *Effect of Resident Time on Machine Performance*

Variations in peeling efficiency and peel-cormel weight ratio at different operational speed levels are presented in Figures 7 and 8, respectively. In most of the cases considered, longer retention periods resulted in higher peeling efficiencies and peel-cormel ratios for both soaked and unsoaked cormels. This implied that the longer the cormels were retained in the peeling chamber, the more the amount of peel removed by the abrasive surfaces of the concentric drums within the chamber.

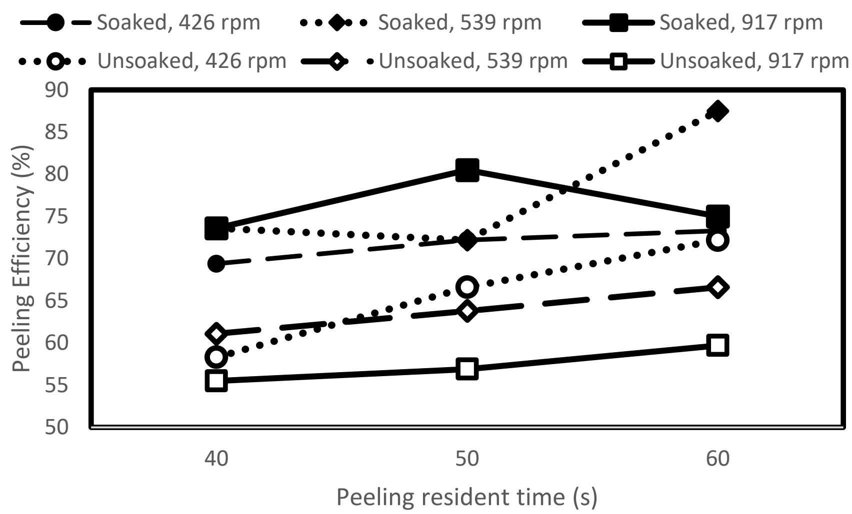


Figure 7: Effect of resident time on peeling efficiency

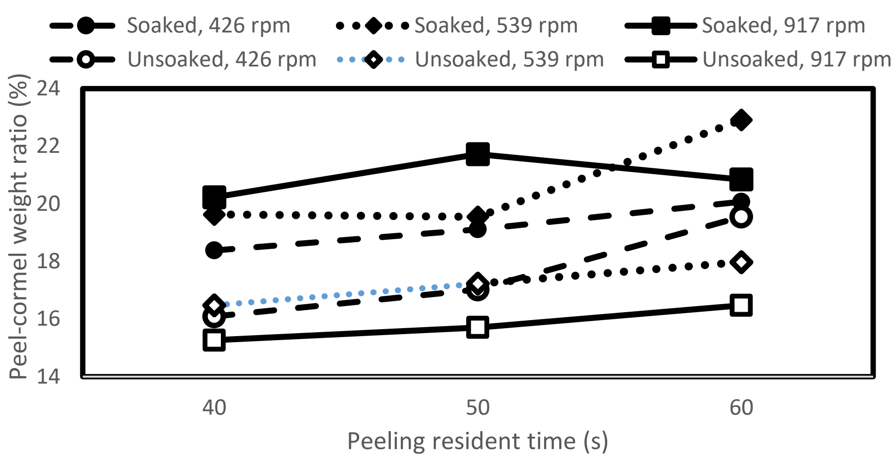


Figure 8: Effect of resident time on peel-cormel weight ratio

4. Conclusions

The cocoyam cormel peeling machine was designed, fabricated and evaluated with soaked and unsoaked cormels at three operational speed levels and three retention periods. It could be recommended that the machine should be run at a medium speed of 539 rpm which gave better performance in terms of peeling efficiency and peel-cormel weight ratio. Soaking as a form of pre-treatment is also recommended before peeling cocoyam cormels so as to soften the cortex (outer peel) of the cocoyam cormels and obtain better machine performance in terms of higher peeling efficiencies.

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PROCESS LAYOUT DESIGN FOR DEHYDRATED FRUIT AND VEGETABLES PROCESSING PLANT

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Abstract

This study was carried out to find an effective design for process layout of dehydrated fruits and vegetables processing plant. The study proffer solutions to huge losses Nigeria encounters as a result of poor postharvest handling, little to no value addition ravaging the fruit and vegetable value chain in the country. According to National Bureau of Statistics report in 2017, that agricultural sector contributed 29.15% Gross Domestic Product (GDP). Despite the huge contributions of agriculture (vegetables) to Nigeria's economic growth, postharvest losses stands at $9 million with 50% losses in fruits and vegetables as a result of their perishable nature and susceptibility of fruits and vegetables to creep, chilling injury, abrasion and stress rupture as a result of poor post handling and unfavourable weather conditions coupled with short shelf life of the fruit, leads to wastages in many fruits and vegetables producing regions of the world. Systematic layout planning (SLP) approach was used in designing of the process layout with special emphasis on tomatoes. The design was done on the basis of flow chart of the processing of dehydrated fruit and vegetables. Based on the analysis of the design data, the study proffer solutions for improved and optimal layout for dehydrated fruit and vegetables processing plant to increase value addition, reduced postharvest losses, and improved standard of living for the rural populace with an overall throughput of 10000kg per day.

Keywords: Activity relationship chart, Mass and Energy Balance, Systematic layout planning, Postharvest losses, Dehydration, fruit and vegetables

1. Introduction

The performance and efficiency of production depends on quality of machineries, employees, as well as how facilities are positioned in a plant. Poorly designed facility results in loss in production time, efficiency and wastage of raw materials. While a good designed production facility improves on the efficiency of production with fewer costs and time wastage (Tak, et al., 2012). Among the main goals of manufacturing system is to maximize productivity with regards to the complexity of the processes of manufacturing from raw materials to finished products and workstations (Carlo, et al., 2013).

Agricultural products are processed to among other things improve the shelf-life of the produce. The output of processing results in varieties of by-products. Vegetables such as onions, tomatoes and pepper are the major vegetables produced in Nigeria, vegetables play a significant role in health and nutrition due to their constituents that regulate digestion. Onions are processed to produce dehydrated onions, onion powder and puree. Despite the enormous economic potentials of onions, the processing of onions for national growth and development has little to no existence in Nigeria (Ibeawuchi, et al., 2015). According to (Aseogwu, 1989), Nigeria's vegetable processing industries need to be developed as the fruit processing industries. The establishment of these industries will boost the Nation's economy thereby creating employment, wealth, reduced rate of malnutrition and increased standards of living for the rural populace.

According to Food and Agriculture Organization (FAO) Statistics in (Muhammad, et al., 2011), the world production of onions (*Allium Cepa L.*) is estimated around 62 million metric tons of onion bulb, with an average yield per hectare at 18.5 tons. Nigeria's yield is estimated at about 15 tons per hectare. The National Bureau of Statistics in (Statistics, 2017) also reported that agricultural sector mainly crop production contributed 29.15% Gross Domestic Product (GDP) in the third quarter of 2017 which was higher than the contribution in the third quarter of 2016 and second quarter of 2017 which was at 28.68% and 22.93% respectively. Despite the huge contributions of agriculture (vegetables) to Nigeria's economic growth, postharvest losses stands at $9 million with 50% losses in fruits and vegetables as a result of their perishable nature (Elemo, 2017). The fragile nature and susceptibility of tomatoes to creep, chilling injury, abrasion and stress rupture as a result of poor post handling and unfavourable weather conditions coupled with short shelf life of the fruit, leads to wastage in many tomato producing regions of the world. (PWC, 2018). About 45% of tomatoes produced in Nigeria are wasted due to poor postharvest handling and mismanagement leading to a staggering 360 million USD loss annually (GEMS, 2016). Nigeria is the 14th largest producer to tomatoes in the world and the 13th largest importer of tomato paste, making Nigeria the 2nd largest producer in Africa and the 3rd Largest importer of processed tomato commodities (PWC, 2018; Sahel, 2017; Ugonna, et al., 2017).

From literature survey, Plant layout as described by (Jain, et al., 2013) refers to the arrangement of physical facilities such as equipment, machineries in a way to achieve the fastest flow of materials with lowest handling and costs within a factory building for efficient processing of products. (Meller, et al., 1997) describes that a facility design determines the way in which arrangements, locations and equipment with other support services in manufacturing facility are fixed to achieve robust production at shortest production time, flexibility and maximized output. (Jain, et al., 2013) also states that facility planning deals with the concept of design, layout and conglomeration of people, machines, workstations or a system within a physical environment. In a manufacturing systems there are basically four types of layouts; products, process and group layout which is further categorized into flow line, cell and centre. (Tompkins, et al., 1996) observed that the distinctions between these layouts is made based on system characteristics e.g. production volume and product variety. (Nickel S, 2005) defines facility layout problem (FLP) as the determination of the relative locations for and allocation of the available space among a given number of facilities. (E, et al., 2004) also described facility layout problem as an optimization problem that tries to make layouts more efficient by taking into consideration various relationships between facilities and material handling systems while designing layout. Systematic layout planning (SLP) is a step-by-step approach to planning procedure that allows designers to identify, visualize, classify activities, relationships and alternatives in a plant layout design (Richard Muther, 2015). SLP serves as organized way of layout planning and a tool used to arrange workstations in a plant, which offers fastest material flow in processing or products at the lowest possible handling and costs (Shubham, et al., 2016).

The aim of this study was to design an effective and efficient process layout for dehydrated fruit and vegetables processing plant with a view to helping in reduction of annual postharvest losses in Nigeria.

2. Methodology

This step involves visit to an existing Tomato Processing Plant (Savanah Integrated export processing farms) formally VEGFRU with a view to understanding the steps in processing and layout design in order to gain more familiarity with the processing sequences and effective design for dehydrated fruit and vegetables, necessary data were also recorded.

2.1 *Systematic Layout Planning Approach (Slp):*

This technique was developed by Richard Murther and Associates in 1961 (Richard Muther, 2015). The approach has three basic areas; involving Space, Relationship and Adjustments to enable designers to visualise, identify relationships and alternatives involved in layout design. SLP comprises of five elements with acronyms as P, Q, R, S, T where:

P as product (material or service): the product means goods produced by the company or area in question. Q as Quantity (Volume): this means the amount of goods or services produced, supplied or used. R as Routing (Process): It is represented by plant layout diagram, process route diagram, process flowchart. S as support services: by this means utilities, auxiliaries and related activities or areas. T as time (Timing): by timing means when, how long, how often and how soon will the layout being planned operate and products start yielding.

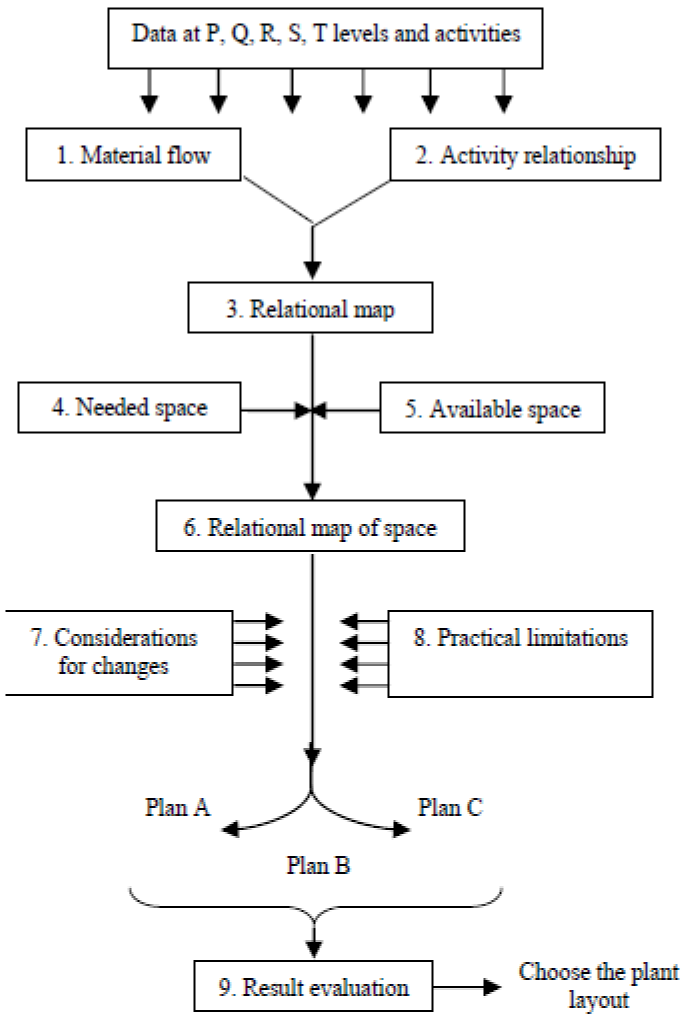

Figure 1. Systematic Layout Planning Procedure (Richard Muther, 2015).

(Woodroof, 1986) Reported that fruits and vegetables are processed to enhance the shelf life of the commodity and to refine it to the desired customer and consumer needs with outputs such as juices, dehydrated, canned and fermented fruits and vegetables. One of the oldest form of processing fruits and vegetables is through sun-drying.

(Somogyi, et al., 1986), (Woodroof, 1986), (Nuruddeen, 2019) and (Kendall, et al., 2004) classified the processes of dehydrating fruits and vegetables into pre-dehydration and post-dehydration. Pre-dehydration involves sorting, washing, and shredding/slicing then dehydration. While post-dehydration includes milling/grinding, mixture for soups, inspection and packaging.

3. Results and Discussions

3.1 *Process Flow Chart*

Process flow charts are used to represent the sequence of operations in a processing plant. This sequence is a step by step measures followed to achieve an operation. Figure 2 shows the proposed processing sequence for dehydration of fruit and vegetables plant (Nuruddeen, 2019). The Process Block Diagram (PBD) in Figure 3 showed the schematic sequence to material balances indicating the minimum losses in each step of operations (George, et al., 2002).

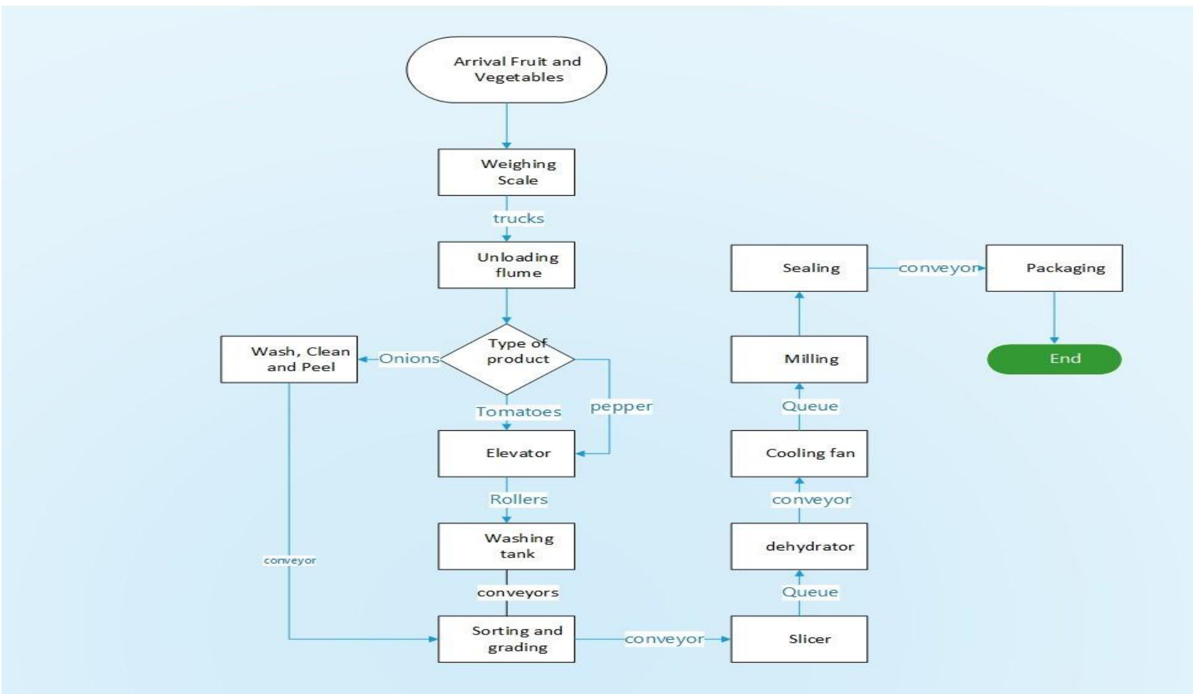

Figure 2. The Proposed Process Flow Chart for Dehydration of Fruit and Vegetables Processing Plant.

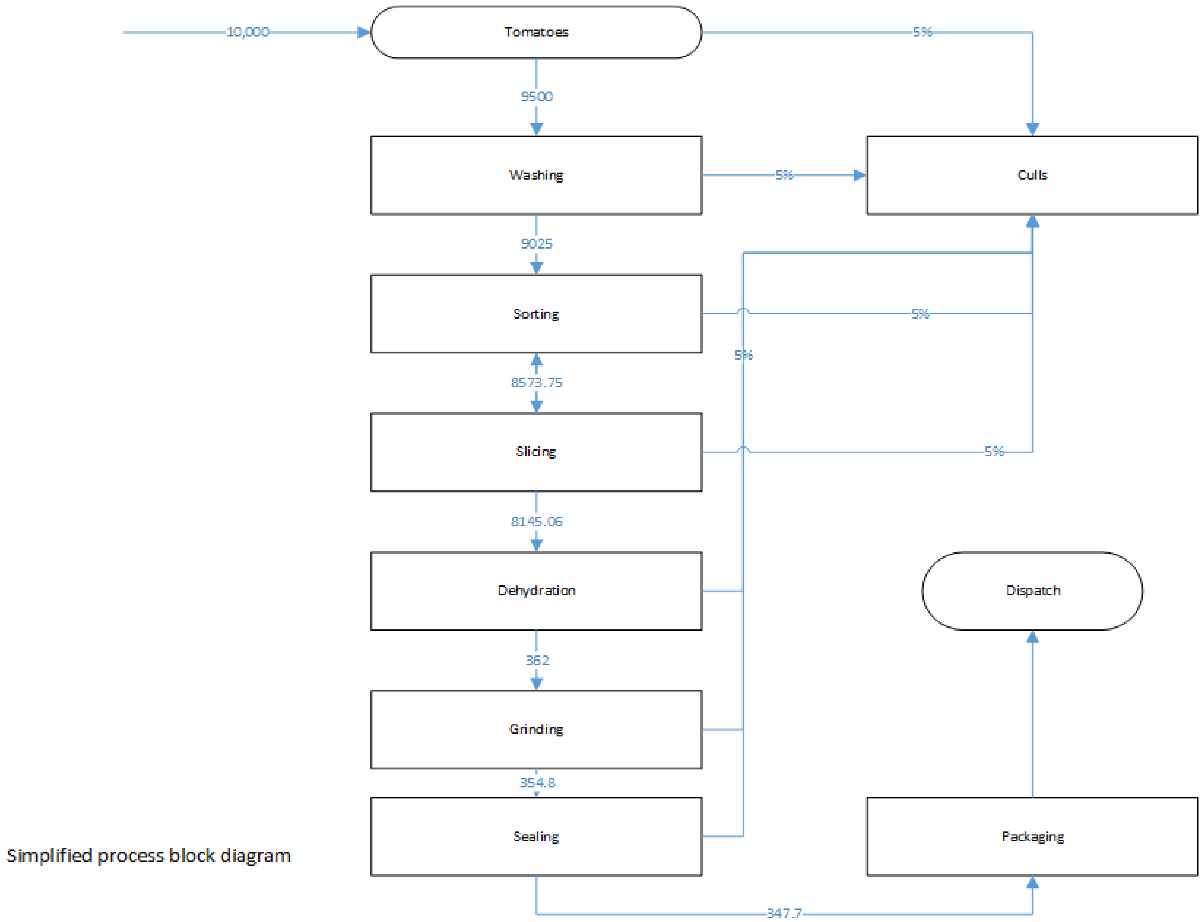

Figure 3. The Simplified Process Block Diagram (PBD) for dehydration of fruit and vegetables

3.2 *Mass Balance*

This calculation quantifies the mass in the system or process governed by the law of conservation of mass. (P.J, 1997; Fellows, 2004) reported that there are typical losses encountered in processing steps of fruits and vegetables. Washing (0-10%), sorting (5-50%), peeling (5-60%), slicing (5-10%), drying (10-20%) packaging (5-10%) and rejected packs (2-5%).

Tomatoes contains around 6% total solids and 94% moisture. From Figure 3 around 8145.06 kg goes into the dehydrator for dehydration process. The moisture content will be reduced down to 10% at the end of the process.

lass in g)	lass before ɛhydration (kg)	ɔlid mass g)	loisture ass (kg)	lass after ɛhydration g)	oisture ss (kg)	otal mass loss during ocessing (Kg)
),000	l45.06	25.80	319.26	62	781.60	638

Therefore $mass\ out + mass\ stored = 9638 + 362 = 10{,}000kg$

3.3 ***Activity Relationship Chart***

Figure 4. highlights the relationship between pairs of activities preceding in a process operation, with intersections to two dividing lines showing a letter that symbolizes the importance of their closeness between each other as shown in Table 1, this allows for an optimal sequencing with the corresponding block layout (Carlo, et al., 2013; Sutari, et al., 2014).

Table 1. showed Value, Relationship and Ratings for each letter used in drafting of the Activity Relationship Chart and Block Layout

ALUE	ELATIONSHIP	O OF RATINGS
	bsolutely important	
	specially important	
	nportant	
	loseness ok	
	nimportant	
	ot desired	

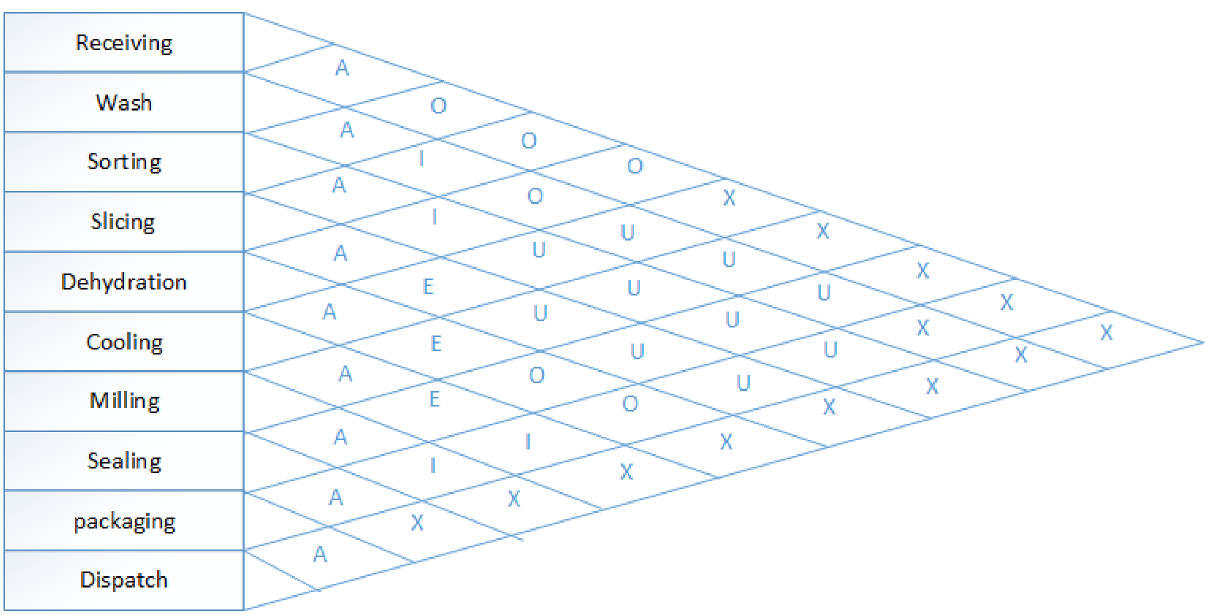

Figure 4. Activity Relationship Chart for Tomato Dehydration

3.4 *Space Requirements*

Table 2 highlighted the Space requirement for each department in relation to work equipment, space each machine occupy. The data helped in designing of an effective layout (Nuruddeen, 2019) and (Sutari, et al., 2014).

Table 2. shows the relationship between equipment size and work area

'N	EPARTMENT	QUIPMENT IZE (m^2)	O OF QUIPMENT	REA (m^2)	OTAL AREA EQUIRED (m^2)
1.	eceiving pond	20		40	).80
2.	'ashing	93		86	86
3.	eeling	2.2		40	).40
4.	orting	77		54	54
5.	.icing	16		32	32
6.	ehydration	23		l.69	5.69
7.	lilling	20		40	40
8.	ealing	30		30	30
9.	ackaging	32		33	33
				otal	5.64

3.5 *Dimensionless Block Diagram*

Dimensionless block diagrams in Figure 5 were designed from the Activity Relationship Chart, it ignores the Space requirements and building limitations. The focus behind it is that it gives a better understanding in designing an effective layout (Nuruddeen, 2019; Carlo, et al., 2013). Also, Figure 6 shows the proposed flow diagram of the processing plant, it comprises of a sketch of how the production lines will be arranged in the plant.

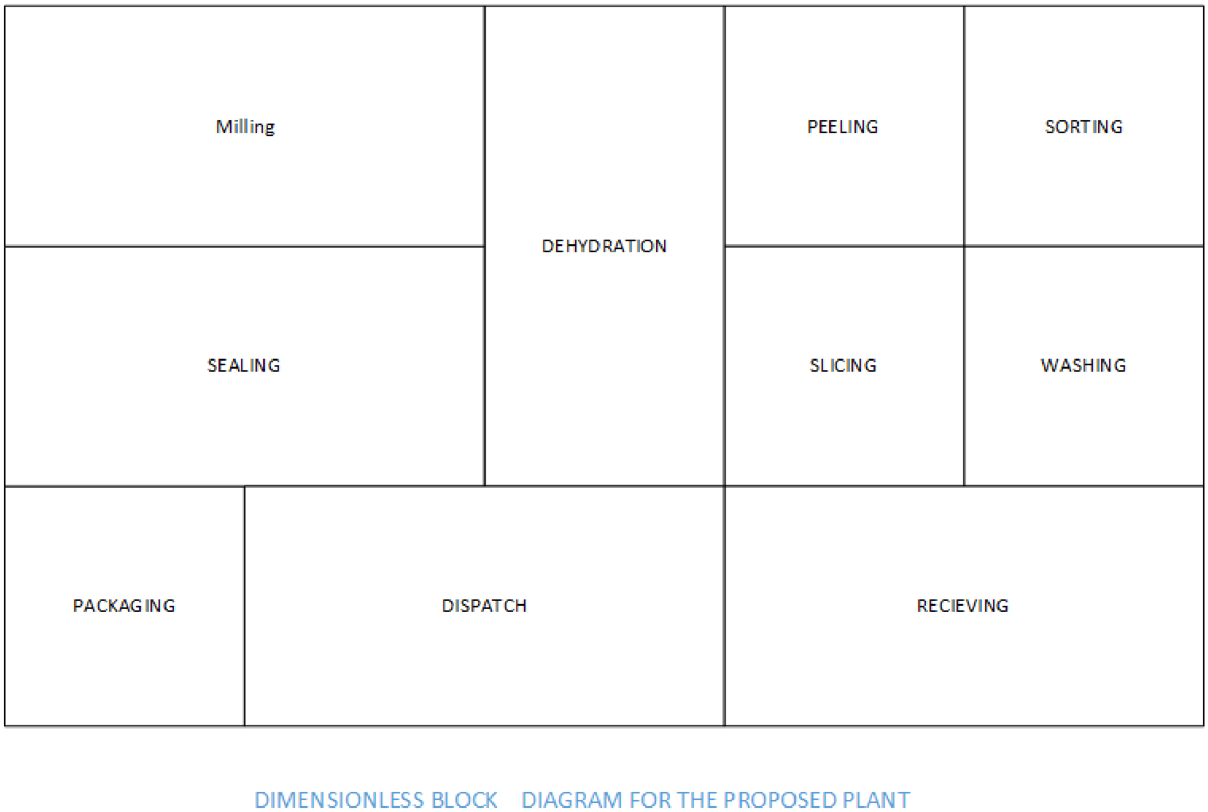

Figure 5. The Dimensionless Block Diagram for the proposed process layout for dehydration of fruit and vegetables processing plant.

3.7 *Work Study*

Work study calculations were done inorder to achieve better working conditions, perform smooth operations, help in standardization and elimination of wastes (Anil, et al., 2008).

'N	:ocessors	bserved time nin)	ormal Time nin)	llowance 0%)	:andard Time Ain)	fficiency of perator (%)
1.	'ashing	20	5	6	)5.60	3
2.	orting	20	5	6	)5.60	
3.	icing	50	20	2	32.00	
4.	ehydrator	50	38	3.8	16.80	
5.	ooling fans			4	40	
6.	lilling lachine	20	5	60	)5.60	

7.	ealing	.96	.57	76	.33

The total operation time to complete production per day is 748.93 minutes (12h 46m).

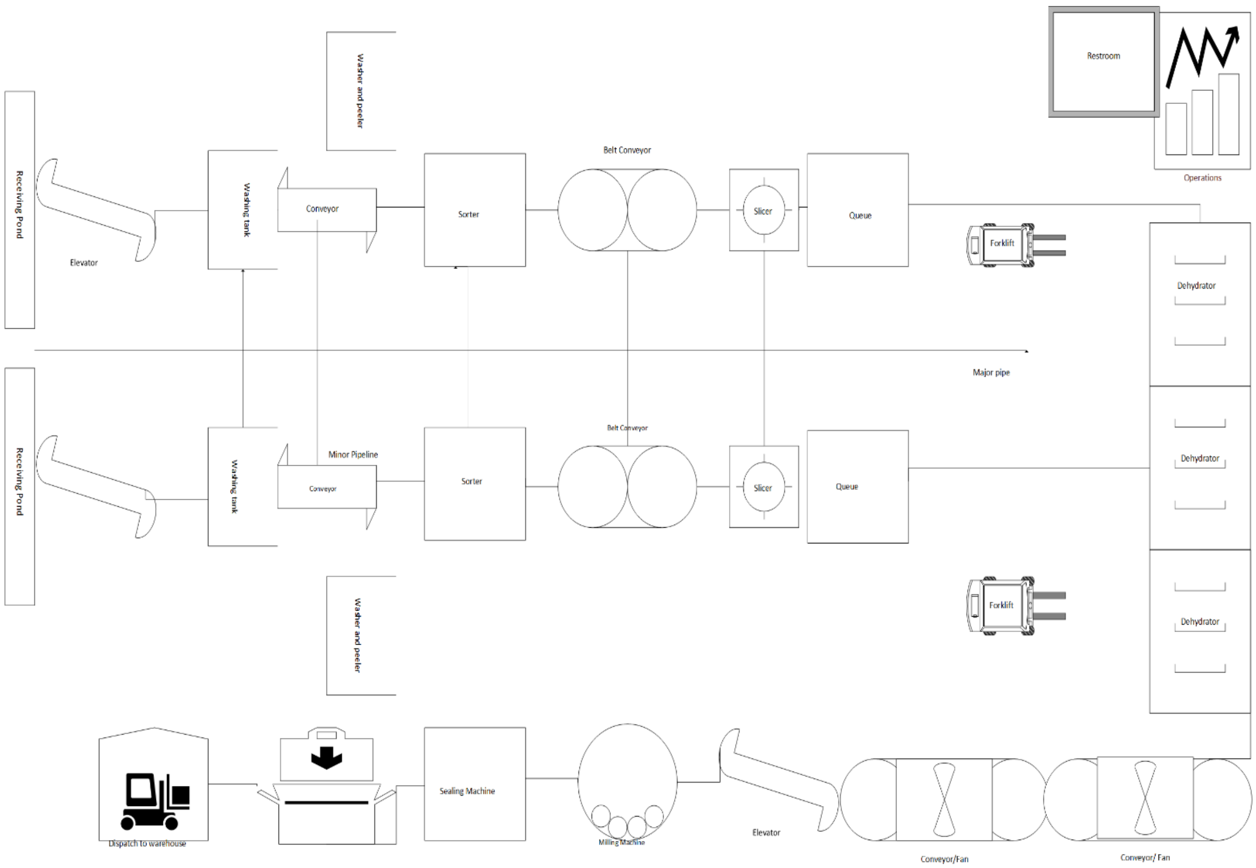

Figure 6. The floor plan for processing of dehydrated fruit and vegetables

4. Conclusions

Facilities are designed to among other things improve on the efficiency of production, reduced costs of handling, increased return on investment and effective processing sequences and design, the design uses a systematic layout planning approach (SLP) to design an effective facility. Nigeria losses about 45-50% of produced fruit and vegetables due to poor or inefficient postharvest handling and value addition. This design proffer solution to the problems encountered as a result of poor postharvest handling and value addition. This design offers a ten (10) tonnes capacity plant for processing fresh fruits and vegetables per day. The design will reduce postharvest losses through dehydration and processing of fruit and vegetables (tomatoes, onions and peppers) for increased output. Due to the flexibility and similarities in processing sequences of some fruits and vegetables, the design could also process other fruits and vegetables.

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DEVELOPMENT OF AN EFFICIENT SMALL SCALE PALM FRUIT BIOMASS-FIRED BOILER

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Abstract

A boiler that utilises palm fruit co-product as fuel was developed in this study to enhance the productivity of the processors and also address environmental challenges around the small scale mills as a result of indiscriminate dumping of the co-products. The boiler consists of furnace and shell and tube sections. The boiler was evaluated using different combinations of fuel materials i.e empty fruit bunch, fibre and shell. The study reveals that total fire tube areas of 0.101; 0.176 and 0.002 m^2 were required to raise feed water temperature from 36 °C to about 100; 130 and 150 °C, at water/steam, saturated steam and superheated steam sections, respectively. The thickness of the shell to accommodate the steam temperature and pressure of ~ 4mm, while the power rating of the boiler was calculated to be 219.9 kW. The theoretical boiler fuel consumption varies with fuel combinations, therefore fuel combination with about 80 % fiber resulted to ~ 83.2 kg of fuel consumption per hour while fuel combination with about 80 % shell will only require 68.1 kg of fuel to produce ~ 300kg of steam. With 20 % excess air margin, as much as 7.9 kg of air per kg of fuel will be required according to the design. The boiler evaluation using different fuel combination produced as much as 74.2 % efficiency.

Keywords: Biomass, Boiler blowdown, Fuel combinations, Fuel metering, Stoichiometric air, Theoretical air.

1. Introduction

The extraction efficiency and quality of oil produced by small and medium scale processors who are major key players in the Nigerian palm oil industry are very low. One of the causes of this is that palm oil extraction takes place at low temperature in most of the small and medium scale plants that use mechanical strippers (Owolarafe, 2015). This is because of the time lag in the different processing stages. Timely processing of fresh palm fruit bunch to achieve high quality palm oil production and improved extraction efficiency can only be possible with the inclusion of boiler (as used in large mills) with minimum cost into the various stages in the process line. Boilers being utilised by large scale plant (mostly imported) are usually expensive and beyond the reach of small scale processors. Indiscriminate dumping of palm fruit co-product around the mill also constitutes serious environmental hazard and therefore has to be effectively utilised by ploughing it back into the mill (Salako *et al.,*2014).

In large scale plants, boilers are usually incorporated to supply the superheated steam required to generate electricity to be used in the mill through turbine generators. The lower pressure steam from the turbine is then used for heating purposes throughout the processing stages such as sterilization, digestion, pressing and clarification and drying of oil (FAO*,* 2002).Irrespective of the scale of production, palm oil processing go through the same unit operational stages, although the level of mechanisation of each unit operation and interconnecting material transfer mechanisms (batch or continuous operation) between each unit differs.

Boiler has been identified to be the major missing gap between the small and large scale of palm fruit processing. It facilitates the introduction of steam at the various stages of production thereby enhancing the production of special palm with high oil quality and extraction efficiency. In other to bring the production quality and extraction efficiency of small scale processors up to the level of production obtainable in the large mills, a small scale boiler that can be affordable and accessible to the targeted processors has to be introduced to bridge the existing gap.

Although boiler comes in various designs, sizes, specifications with different heat source, the component parts required in the design of a boiler generally includes the furnace system; wall thickness and lagging, heat exchange mechanism, fuel systems; water systems, control valves, blowdown mechanism amongst other component parts.

In order to bridge the gap between the small scale and large scale processorsand also achieve cleaner environment around the mill, there is an urgent need for an appropriate boiler that will utilise palm fruit co-product as fuel to supply steam to various processing stages to achieve high rate of fruit recovery from fresh fruit bunch (FFB), high oil quality and improved extraction efficiency.

2. Methodology

The boiler design was based on the principle of heat and mass transfer with production capacity of 300 kg of steam per hour. This is on the basis of 500 kg/h of steam requirement for the processing of a tonne of FFB as stated by Mahlia *et al.* (2001). Since the target processors are small- scale, having the capacity of about 0.25 to 0.5 ton/hr and based on standard steam consumption rate of about 600 kg/ton of FFB/h to cater for losses, the amount of steam needed will be about 150 to 300 kg/h.

The palm fruit biomass-firedboiler has the following features to enhance optimum performance

1. Standard fuel feeding system and incorporation of fuel metering device for better performance
2. Incorporation of boiler blowdown at the water in tube section to remove dissolved solid in the feedwater, which can lead to scale formation inside the boiler, resulting in localized overheating and finally causing boiler tube failure.
3. Shell and tube heat exchange system.
4. Modification of the firetube and shell for increased capacity and more effective heat exchanging.
5. Incorporation of superheater to remove all moisture content from the steam by raising the temperature of the steam above its saturation point.
6. Ease of assembling and disassembling of the boiler to enhance moveability
7. Improved portability and high aesthetic value of the boiler.
8. Using fibre glass to improve the lagging property of the boiler.

2.1 *Boiler Design and Parts Specification*

The boiler operates on the principles of heat exchanger, and consists of basically 3 sections namely: the furnace, the fire tube section and the water and steam sections. The fundamental mechanism follows the law of thermodynamic and the parts were designed and specified based on the capacity to meet the energy requirement of a small scale palm fruit processing mill for the processing of palm fruit into oil. Design and specification of its parts are discussed in this section.

2.1.1 Furnace

The size and dimension of the furnace was based on the capacity to accommodate the fuel required to supply amount of energy needed in the boiler per time. The preparation of the palm fruit co-products to be used as fuel as well as their energy content has been established by Salako *et al.* (2009), this has formed the basis for the establishment of the energy value of the various fuel combinations that was used to estimate the modified boiler efficiency. The rate of the boiler fuel consumption was established for the various fuel combinations using the equation below.

$$FC = SP \times \frac{h_s - h_w}{BE \times LHV} \qquad 1$$

Where:

FC is the fuel consumption in kg;
SP is the steam production in kg per hour
h_s is the specific enthalpy of steam
h_w is the enthalpy of the feed water
BE is the boiler efficiency
LHV is the lowest heating value of the fuel

The stoichiometric (theoretical) and the excess air required for effective combustion of the fuel in the furnace was also established following the guidelines provided by Mahlia *et al.* (2001). This was done on the basis of the amount of oxygen required for complete combustion of the chemical substance present in the fuel materials.

2.1.2 Boiler Fire and Water Tubes

The design specification of the fire tubes and the water tubes was carried out based on the amount of steam required for the target level of palm fruit processing. The fire tubes carry the hot flue gas while the steam tubes carry the water/steam. Heat exchange takes place between these tubes which therefore changes the temperature profile of the fluids in the pipes. The temperature of the fluid in the water/steam tubes increases while the temperature of the flue gas from the furnace decreases along the fire tubes. To raise the water/steam temperature from the initial value to a target value, the dimension of the tubes in the varioussections has to be determined.

The water/steam pipe and the drum is the first section of the shell and tube arrangement and it raises the feedwater to a boiling point, such that the steam generated at this section is transfered via the riser to the saturated steam section.The following details and assumptions aided the design and part specification of the pipe and drum section:

i. The boiler was designed with a capacity of 300 kg/hr of steam (see section 2.0).
ii. Feed water temperature was at 26 ˚C
iii. The water and steam flow in the system was laminar
iv. A core temperature of 600 ºC and 260 ºC flue gas temperature for the combustion of shell, fiber and EFB were used in line with the findings of Najmi *etal.* (2008).
v. The temperature of the flue gas entering the tube sections decreases along the tube length.
vi. The feed water to be raised to about 100 ºC at the water/steam section which is the inlet temperature of the steam at the saturated steam section where it is to be raised to ~ 130 ºC, also the steam is to be heated to a superheated state at the superheated steam section to a temperature of about 150 ºC
vii. From pipe specification table as stated by Geankoplis (2003); for ease of cleaning, the diameter should be about 50 mm, using the standard pipe of dimension with 0.03340 m and 0.02664 m outside diameter and inside diameter, respectively.

The arrangement of the tube in the water/steam section is shown in Figure1. The mass flow rate of steam (ṁ) is 300 kg/hr.The rate of steam production must be equal to the feedwater flow rate to avoid shrinkage or swelling, therefore:

$$\dot{m} = \frac{300\ kg}{hr} = 0.083\ kg/s \qquad 2$$

but $Q = \dot{m} C_p \Delta T$ 3

where C_p is the heat capacity at average temperature in J/kg.K
from steam tables, C_p = 4.18 kJ/kg.K
∴ Q = 0.083 × 4.18× (100-26) = 25.67 kW
Alternatively, Q can also be evaluated as stated by Geankoplis (2003) as follows:

$$Q = \dot{m}_w (h_{w\ out} - h_{w\ in}) \qquad 4$$

Therefore, from satutared steam and water table,
$h_{w\ out}$@ $100\ ˚C =$ 419.04 kJ/kg

$h_{w\ in}@\ 26^{\circ}C = 113.00$ kJ/kg
Q = 0.083 (419.04 – 113.00) = 25.40 kW.

Assuming the temperature of the flue gas from the combustion chamber using the palm fruit biomass as fuel is 260 ºC following the guidance provided by Najmi *et al.* (2008), then the outlet temperature of the flue gas from the section can be determined using:

$$Q = UA\Delta T_{ln} = \dot{m}C_p\Delta T = \dot{m}_w(h_{w\ out} - h_{w\ in}) \quad 5$$

$$Q = \dot{m}C_p\Delta T = \dot{m}C_p(T_{out} - T_{in})$$

Then,

$T_{out} = T_{in} - Q/\dot{m}C_p$,

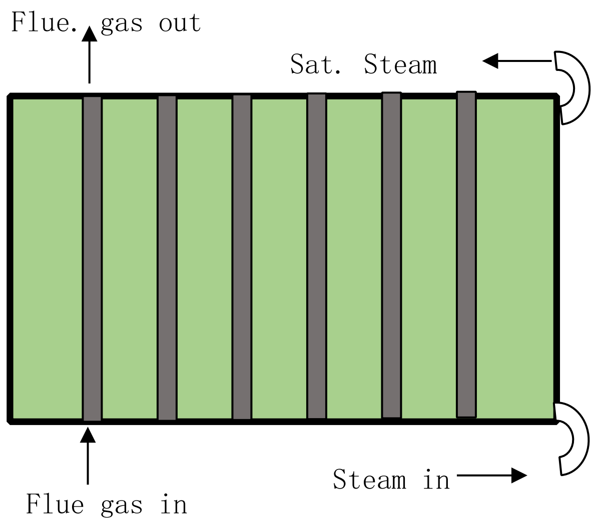


Fig. 1: Sketch of the steam/water section

Therefore assuming the mass flow rate of flue gas 0.3 kg/s and taking the C_p of air from steam tables as 1.03 kJ/kg.K,

$$T_{out} = 260 - \frac{25.67}{0.3*1.03} = 176.93 \quad 6$$

The outlet temperature from the water/steam section will therefore be 176.93 ºC as shown in Fig. 2. Geankoplis (2003), stated the approximate magnitude of heat transfer coefficient of boiling water to be in the range between 1700 to 28000 W/m^2. K, therefore choosing U to be the lowest heat transfer coefficient, i.e. 1700 W/m^2.K, also ΔT_{ln} can be expressed as follows:

$$\Delta T_{ln} = \frac{\Delta T_2 - \Delta T_1}{ln(\frac{\Delta T_2}{\Delta T_1})} \quad 7$$

$\Delta T_2 = 260 – 26 = 234\ ^{o}$ C
$\Delta T_1 = 176.93 – 100 = 76.93\ ^{o}$ C

Therefore:

$$\Delta T_{ln} = \frac{234 - 76.93}{ln(234/76.93)} = 141.20^{\circ}\ C$$

$$Q = UA\Delta T_{ln} = 25670$$

$25670 = 1700 \times A \times 141.2 \Rightarrow A = 0.101\ m^2$

Also,

$A = \pi DL \Rightarrow L = A/\pi D$ 8

From pipe selection internal diameter of pipe is 0.02664 m(Geankoplis, 2003)

Therefore L = 1.21 m.

Therefore to raise the temperature of the feedwater from $26^\circ C$ to $100^\circ C$ boiling point, 1.21 m long tube is required. The total length of the flue gas tube as shown above is 1.21 m.

Figure 3 illustrates the shell and tube arrangement at the saturated steam section where the steam temperature is expected to be raised from 100 °C to 130 °C.

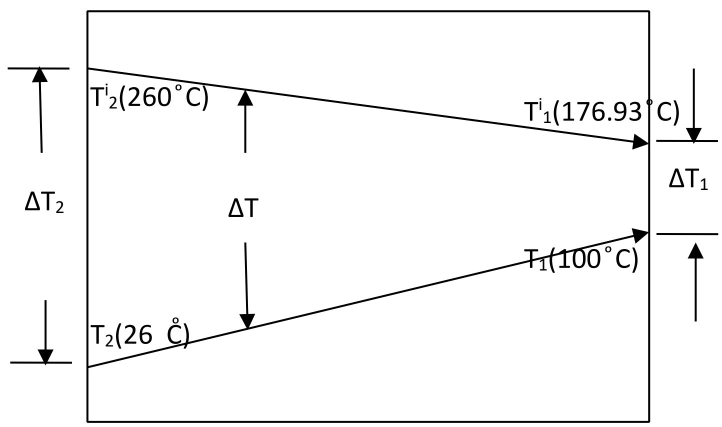


Fig. 2: Temperature profile for one-pass double-pipe heat exchangers (cocurrent / parallel flow)

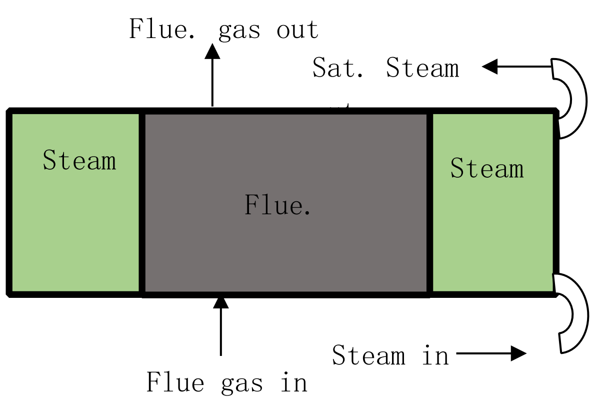


Fig. 3: Sketch of the saturated steam

Taking $\dot{m} = \frac{300\,kg}{hr} \Rightarrow 0.083\; kg/s$ as expressed earlier,

Also, $Q = \dot{m}C_p\Delta T$ 8

where C_p is the heat capacity at average temperature in J/kg.K

from steam tables, C_p = 4.27 kJ/kg.K

∴ Q = 0.083 × 4.27× (130-100)

Q = 10.63 kW

Alternatively,

$$Q = \dot{m}_w(h_{w\,out} - h_{w\,in})$$

From satutared steam and water table

$h_{w\,out}@\,100\,^{\circ}C = 419.04$ kJ/kg

$h_{w\,in}@\,130^{\circ}C = 546.31$ kJ/kg

Q = 0.083 (546.31 – 419.04) = 10.56 kW.

As earlier determined, the temperature of flue gas out of the water/steam section and entering the saturated steam tube is 176.93 °C, then the outlet temperature of the flue gas from the saturated steam section can be determined using:

$Q = UA\Delta T_{ln} = \dot{m}C_p\Delta T = \dot{m}_w(h_{w\,out} - h_{w\,in})$ 9

$$Q = \dot{m}C_p\Delta T = \dot{m}C_p(T_{out} - T_{in})$$

Then, $T_{out} = T_{in} - Q/\dot{m}C_p$,

Therefore assuming the mass flow rate of flue gas 0.3 kg/s and taking the C_p of air from steam tables as 1.03 kJ/kg.K,

$$T_{out} = 176.93 - \frac{10.63}{0.3 * 1.03} = 142.53$$

The outlet temperature from the water/steam section will therefore be 142.53 °C.as shown in Fig. 4

Then, $Q = UA\Delta T_{ln} = 10630\;W$

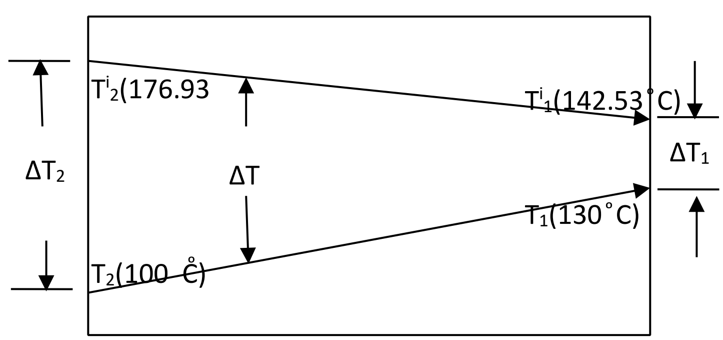


Fig. 4: Temperature profile for saturated steam section of the boiler (cocurrent / parallel flow)

$\Delta T_{ln} = \frac{\Delta T_2 - \Delta T_1}{ln(\frac{\Delta T_2}{\Delta T_1})}$ 10

ΔT_2 = 176.93 – 100 = 76.93 ° C

ΔT_1 = 142.53 – 130 = 12.53 ° C

Therefore:

$$\Delta T_{ln} = \frac{76.93 - 12.53}{ln(76.93/12.53)} = 35.48^{\circ} C$$

$$Q = UA\Delta T_{ln} = 10630$$

$10630 = 1700 \times A \times 35.48 \Rightarrow A = 0.176\ m^2$
Therefore to raise the temperature of the feedwater from $100^{\circ} C$ to $130^{\circ} C$ saturated steam, the area of the fire tube in that section will be $0.176\ m^2$.

Figure 5 illustrates the shell and tube arrangement at the superheated steam section where the steam temperature is expected to be raised from 130 °C to 150 °C.

$$Q = \dot{m} C_p \Delta T$$

$C_p = 4.27$ kJ/kg.K (from tables)
$\therefore\ Q = 0.083 \times 4.27 \times (150-130)$
Q = 7.09 kW
Alternatively,

$$Q = \dot{m}_w (h_{w\,out} - h_{w\,in})$$

From satutared steam and water table,
$h_{w\,out} @ 150\ ^{\circ}C = 632.20$ kJ/kg
$h_{w\,in} @ 130^{\circ}C = 546.31$ kJ/kg
Q = 0.083 (632.20 – 546.31) = 7.13 kW.

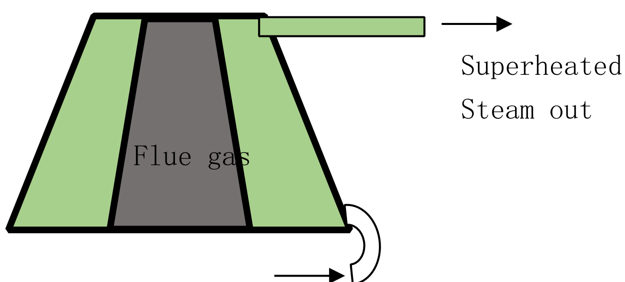


Fig. 5: Sketch of the superheated steam

As earlier determined, the temperature of flue gas out of the saturated steam section and entering the superheated steam tube is 142.53 °C, then the outlet temperature of the flue gas from the saturated steam section can be determined using:

$$Q = UA\Delta T_{ln} = \dot{m} C_p \Delta T = \dot{m}_w (h_{w\,out} - h_{w\,in}) \quad 11$$

$$Q = \dot{m} C_p \Delta T = \dot{m} C_p (T_{out} - T_{in})$$

Then,
$T_{out} = T_{in} - Q/\dot{m} C_p$,
Therefore assuming the mass flow rate of flue gas to 0.3 kg/s and taking the C_p of air from steam tables as 1.03 kJ/kg.K,

$$T_{out} = 142.53 - \frac{7.13}{0.3 * 1.03} = 119.46$$

The outlet temperature of flue gas from the boiler will therefore be 119.46 °C as shown in Fig 6.
Then, $Q = UA\Delta T_{ln} = 7130\ W$

$$\Delta T_{ln} = \frac{\Delta T_2 - \Delta T_1}{ln(\frac{\Delta T_2}{\Delta T_1})} \quad 12$$

$\Delta T_2 = 142.53 - 130 = 12.53\ ^oC$
$\Delta T_1 = 150 - 119.46 = 30.54\ ^oC$

Therefore:

$$\Delta T_{ln} = \frac{12.53 - 30.54}{ln(12.53/30.54)} = 20.21^{\circ} C$$

$$Q = UA\Delta T_{ln} = 7130\ W$$

$7130 = 1700 \times A \times 20.21 \Rightarrow A = 0.002\ m^2$
Therefore to raise the temperature of the steam from $130^{\circ}\ C$ to $150^{\circ}\ C$ saturated steam, the area of the fire tube in that section will be $0.002\ m^2$.

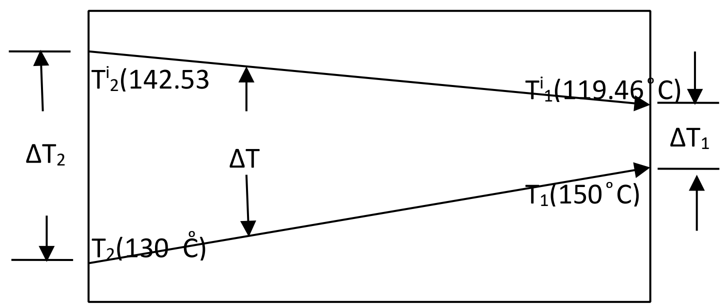


Fig. 6:Temp. profile for superheated steam section of the boiler (cocurrent / parallel flow)

2.1.3 *Design of the boiler water/steam drum for strength*

The allowable design stress for steam boiler is 94.4 N/mm^2 (Perry and Chilton, 1988). The design equation for a cylindrical shell of thickness T is given as (Babatunde, 1987; Salako, 2011)

$$T = \frac{PR}{SE \square 0.6P} \qquad 13$$

Recall that pressure in the boiler was estimated to be 4.7 bars (i.e.4.7 N/mm^2) at the temperaure of 150 ºC

The radius R of the boiler is 500 mm

$$T = \frac{0.47 \times 500}{94.4 \times 0.833 - 0.6 \times 0.47} = 3.0\ mm$$

A thickness of 4 mm will be chosen for safety reason.

2.1.4 *Boiler horse power*

The boiler horse power can be calculated by the addition of heat required to raise the temperature of the feedwater from room temperature (36 ºC) to the steam outlet temperature (150 ºC) and the heat required to evaporate at 150 º C as follows:

$P = Q_1 + Q_2$ 14

Where $Q_1 = \dot{m}C_p\Delta T$ and

$Q_2 = \dot{m}\Delta H$

Therefore, $P = \dot{m}C_p\Delta T + \dot{m}\Delta H$ 15

$\dot{m} = 300$ kg/hr
$C_{p@ (26\ ^oC)} = 4.18$ kJ/kg.K
$C_{p@ (150\ ^oC)} = 4.27$ kJ/kg.K
$C_{p.\ avg} = 4.23$ kJ/kg.K
$\Delta T = 150 - 26 = 124\ ^oC$
$H_{@\ 150\ ^oC\ (liquid)} = 632.20$ kJ/kg
$H_{@\ 150\ ^oC\ (sat.\ vap)} = 2746.5$ kJ/kg

ΔH = 2114.3
Therefore,
P = 791646 kJ/hr
P = 219.9 kW

2.2 *Heating Values of Different Fuel Combinations*

Palm fruit biomass used as fuel to fire the boiler was combined differently to establish the best possible proportion that can produce optimum boiler performance. The calorific (heating) value (CV) of EFB, fibre and shell from oil palm biomass were 13.99, 11.2 and 14.94MJ kg $^{-1}$, respectively, as obtained by Salako *et al.* (2009) and Najmi *et al.*(2008).
Representing EFB with 'X', fibre with 'Y' and shell with 'Z', therefore different possible combination of 'XYZ' and the heating value of each proportion is as presented in Table 1.

2.3 *Stoichiometric (Theoretical) Air and Excess Air*

The amount of air required per kg of shell, fiber and EFB calculated following the guidelines provided by Mahlia *et al.* (2001) are 6.66, 5.98 and 6.27 kg per kg of fuel for shell, fiber and EFB, respectively. The optimum and excess air requirement for the fuel combinations was also calculated based on the amount of air required per fuel material. Table 2 shows the optimum and 20% excess air required for the various fuel combinations. The capacity of the blower selected was 0.8771 kg of air per minute, therefore the combustion time for the fuel per kg of fuel mixture is as stated in Table 2

2.4 *Boiler Fuel Consumption (FC)*

The boiler fuel consumption was calculated as stated by JBC (2016) using equation 1 stated earlier.Salako *et al.*(2011) and Najmi *et al.* (2008) established that the calorific (heating) value (CV) of shell, fibre and EFB from oil palm biomass were13.99, 11.20 and 14.94 MJ kg $^{-1}$, therefore from the different fuel combination ratio established above, the boiler fuel consumption for the various combination of biomass is as stated in Table 3.

Table 1: Heating value of different proportion of palmfruit biomass combinations

S/No	X:Y:Z Combinations	Heating Value X(13.99)+Y(11.2)+Z(14.94) MJ kg $^{-1}$
1	0.1 : 0.1 : 0.8	14.471
2	0.1 : 0.8 : 0.1	11.853
3	0.8 : 0.1 : 0.1	13.806
4	0.1 : 0.2 : 0.7	14.097
5	0.2 : 0.7 : 0.1	12.132
6	0.7 : 0.1 : 0.2	13.901
7	0.1 : 0.7 : 0.2	12.227
8	0.2 : 0.1 : 0.7	14.376
9	0.7 : 0.2 : 0.1	13.527
10	0.1 : 0.3 : 0.6	13.723
11	0.1 : 0.6 : 0.3	12.601
12	0.3 : 0.1 : 0.6	14.281
13	0.3 : 0.6 : 0.1	12.411
14	0.6 : 0.1 : 0.3	13.996
15	0.6 : 0.3 : 0.1	13.248
16	0.1 : 0.4 : 0.5	13.349
17	0.1 : 0.5 : 0.4	12.975
18	0.4 : 0.1 : 0.5	14.186
19	0.4 : 0.5 : 0.1	12.690
20	0.5 : 0.1 : 0.4	14.091
21	0.5 : 0.4 : 0.1	12.969

22	0.2 : 0.2 : 0.6	14.002
23	0.2 : 0.6 : 0.2	12.506
24	0.6 : 0.2 : 0.2	13.622
25	0.2 : 0.3 : 0.5	13.628
26	0.2 : 0.5 : 0.3	12.880
27	0.3 : 0.2 : 0.5	13.907
28	0.3 : 0.5 : 0.2	12.785
29	0.5 : 0.2 : 0.3	13.717
30	0.5 : 0.3 : 0.2	13.343
31	0.2 : 0.4 : 0.4	13.254
32	0.4 : 0.2 : 0.4	13.812
33	0.4 : 0.4 : 0.2	13.064
34	0.3 : 0.3 : 0.4	13.533
35	0.3 : 0.4 : 0.3	13.159
36	0.4 : 0.3 : 0.3	13.438

Table 2: Optimum, 20% excess air required and combustion time for different proportion of palmfruit biomass combinations

S/No	X:Y:Z Combinations	Air required per kg of fuel	20% excess air required (kg)	Combustion time of fuel (min/kg)
1	0.1 : 0.1 : 0.8	6.553	7.863	9.616
2	0.1 : 0.8 : 0.1	6.077	7.292	8.918
3	0.8 : 0.1 : 0.1	6.280	7.536	9.216
4	0.1 : 0.2 : 0.7	6.485	7.782	9.516
5	0.2 : 0.7 : 0.1	6.106	7.327	8.960
6	0.7 : 0.1 : 0.2	6.319	7.582	9.273
7	0.1 : 0.7 : 0.2	6.145	7.374	9.017
8	0.2 : 0.1 : 0.7	6.514	7.816	9.559
9	0.7 : 0.2 : 0.1	6.251	7.501	9.173
10	0.1 : 0.3 : 0.6	6.417	7.700	9.417
11	0.1 : 0.6 : 0.3	6.213	7.455	9.117
12	0.3 : 0.1 : 0.6	6.475	7.770	9.502
13	0.3 : 0.6 : 0.1	6.135	7.362	9.003
14	0.6 : 0.1 : 0.3	6.358	7.6296	9.330
15	0.6 : 0.3 : 0.1	6.222	7.466	9.130
16	0.1 : 0.4 : 0.5	6.349	7.618	9.317
17	0.1 : 0.5 : 0.4	6.281	7.537	9.217
18	0.4 : 0.1 : 0.5	6.436	7.723	9.445
19	0.4 : 0.5 : 0.1	6.164	7.396	9.045
20	0.5 : 0.1 : 0.4	6.397	7.676	9.387
21	0.5 : 0.4 : 0.1	6.193	7.431	9.088
22	0.2 : 0.2 : 0.6	6.446	7.735	9.459
23	0.2 : 0.6 : 0.2	6.174	7.408	9.060
24	0.6 : 0.2 : 0.2	6.290	7.548	9.230
25	0.2 : 0.3 : 0.5	6.378	7.653	9.359
26	0.2 : 0.5 : 0.3	6.242	7.490	9.160

27	0.3 : 0.2 : 0.5	6.407	7.688	9.402
28	0.3 : 0.5 : 0.2	6.203	7.443	9.103
29	0.5 : 0.2 : 0.3	6.329	7.594	9.288
30	0.5 : 0.3 : 0.2	6.261	7.513	9.188
31	0.2 : 0.4 : 0.4	6.310	7.572	9.260
32	0.4 : 0.2 : 0.4	6.368	7.641	9.345
33	0.4 : 0.4 : 0.2	6.232	7.478	9.145
34	0.3 : 0.3 : 0.4	6.339	7.606	9.302
35	0.3 : 0.4 : 0.3	6.271	7.525	9.202
36	0.4 : 0.3 : 0.3	6.300	7.560	9.245

Table 3: Boiler fuel combustion based on different proportion of palmfruit biomass combinations

S/No	X:Y:Z Combinations	Fuel consumption (FC) kg/hr
1	0.1 : 0.1 : 0.8	68.1
2	0.1 : 0.8 : 0.1	83.2
3	0.8 : 0.1 : 0.1	71.4
4	0.1 : 0.2 : 0.7	69.9
5	0.2 : 0.7 : 0.1	81.2
6	0.7 : 0.1 : 0.2	70.9
7	0.1 : 0.7 : 0.2	80.6
8	0.2 : 0.1 : 0.7	68.6
9	0.7 : 0.2 : 0.1	72.9
10	0.1 : 0.3 : 0.6	71.8
11	0.1 : 0.6 : 0.3	78.2
12	0.3 : 0.1 : 0.6	69.0
13	0.3 : 0.6 : 0.1	79.4
14	0.6 : 0.1 : 0.3	70.4
15	0.6 : 0.3 : 0.1	74.4
16	0.1 : 0.4 : 0.5	73.8
17	0.1 : 0.5 : 0.4	76.0
18	0.4 : 0.1 : 0.5	69.5
19	0.4 : 0.5 : 0.1	77.7
20	0.5 : 0.1 : 0.4	70.0
21	0.5 : 0.4 : 0.1	76.0
22	0.2 : 0.2 : 0.6	70.4
23	0.2 : 0.6 : 0.2	78.8
24	0.6 : 0.2 : 0.2	72.4
25	0.2 : 0.3 : 0.5	72.3
26	0.2 : 0.5 : 0.3	76.5
27	0.3 : 0.2 : 0.5	70.9
28	0.3 : 0.5 : 0.2	77.1
29	0.5 : 0.2 : 0.3	71.9
30	0.5 : 0.3 : 0.2	73.9
31	0.2 : 0.4 : 0.4	74.4
32	0.4 : 0.2 : 0.4	71.4
33	0.4 : 0.4 : 0.2	75.5
34	0.3 : 0.3 : 0.4	72.8
35	0.3 : 0.4 : 0.3	74.9
36	0.4 : 0.3 : 0.3	73.4

4 Results and Discussion

4.1 *The Boiler*

Figures7 to 9 below show various representations of the modified boiler. The boiler operates on a mechanism of shell and tube heat exchanger where flow of fluids is continous. Tubes are arranged in parallel and hot flue gas from the combustion chamber flow through these tubes. The tubes, arranged in a bundle are enclosed in a single shell and the other fluid (water or steam) flows outside the tubes in the shell side. There were three different shell and tube sections arranged in parallel where phase change occurs from water to saturated and superheated steam along the arrangement.

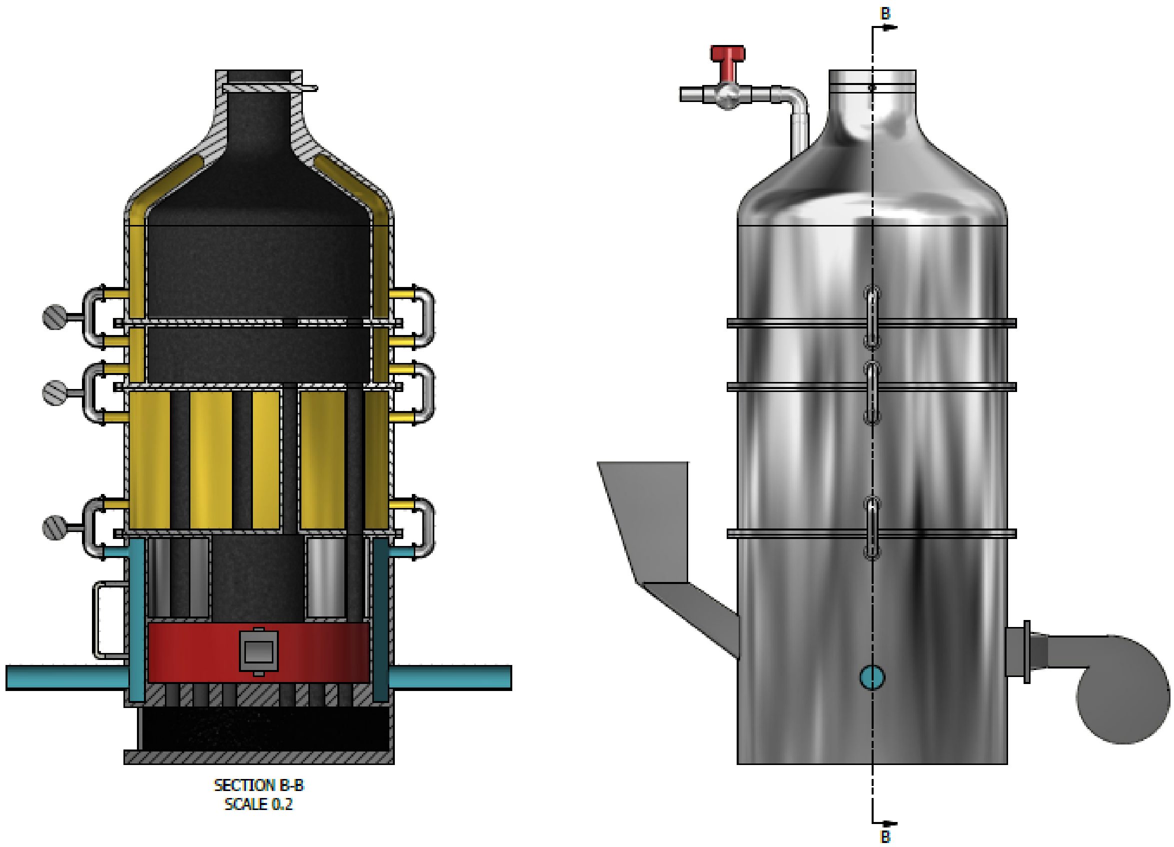


Figure 7: Sectional view of the modified biomass fired boiler

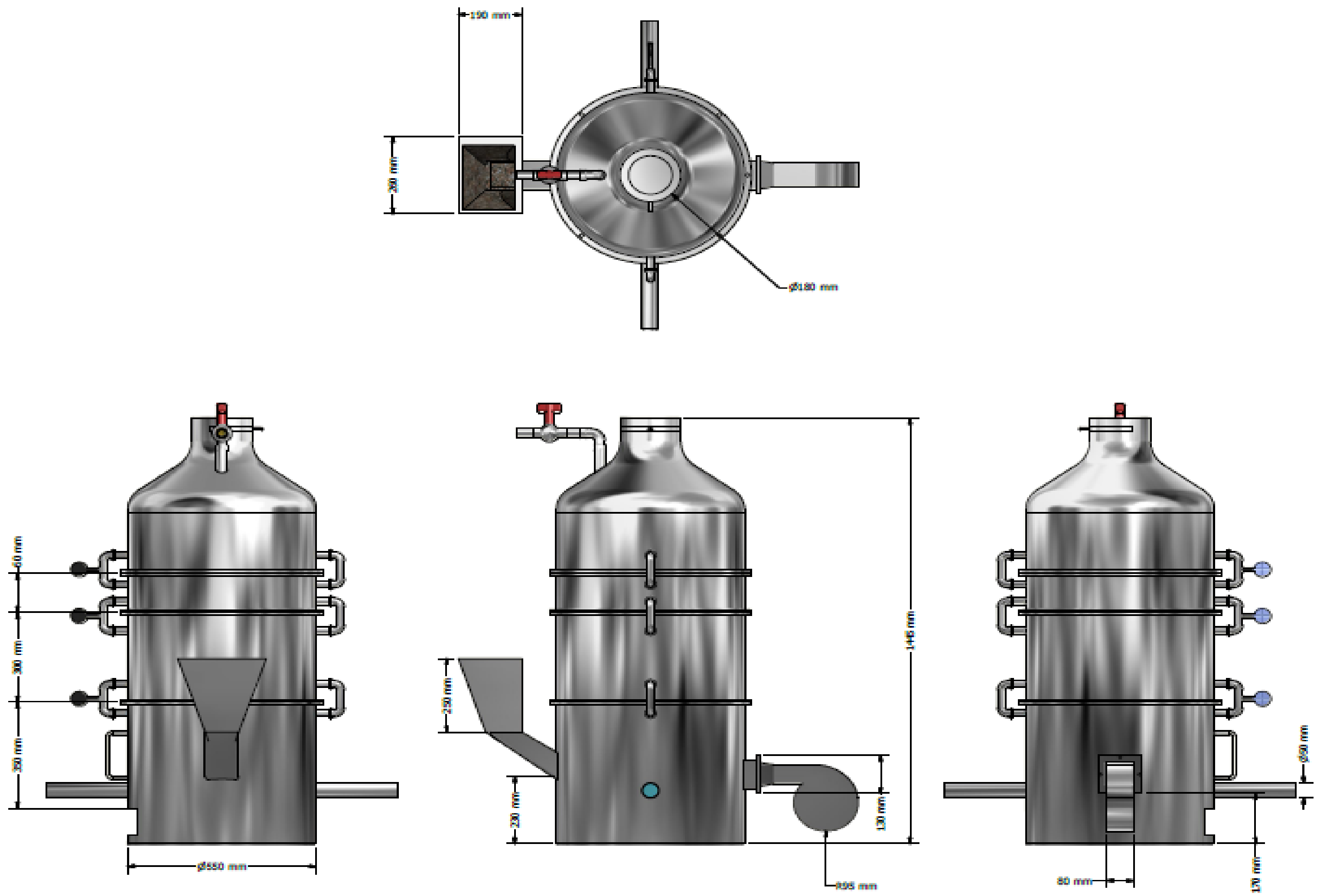
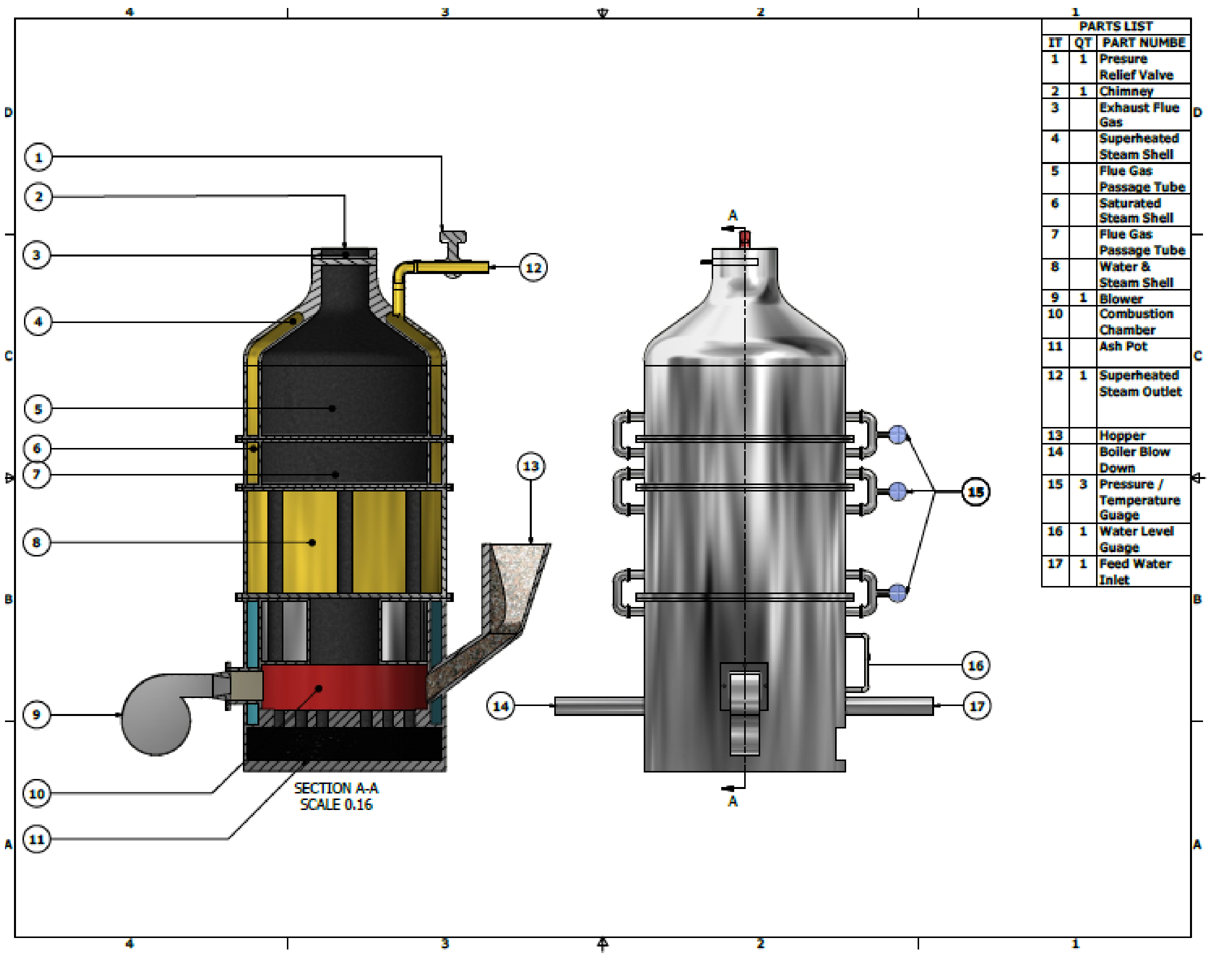


Figure 8: Orthographic view of the modified biomass fired boiler



IT	QT	PART NUMBE
1	1	Presure Relief Valve
2	1	Chimney
3		Exhaust Flue Gas
4		Superheated Steam Shell
5		Flue Gas Passage Tube
6		Saturated Steam Shell
7		Flue Gas Passage Tube
8		Water & Steam Shell
9	1	Blower
10		Combustion Chamber
11		Ash Pot
12	1	Superheated Steam Outlet
13		Hopper
14		Boiler Blow Down
15	3	Pressure / Temperature Guage
16	1	Water Level Guage
17	1	Feed Water Inlet

Figure 9: Detailed labelled view of the modified biomass fired boiler

4.2 *Effect of Fuel Combination on Rate of Boiler Efficiency*

The efficiency of the machine behaved differently when fired with the various combination of the palm fruit biomass. It was discovered that fuel combination with higher shell composition produced the best result in terms of efficiency. The highest efficiency of the boiler (74.2%) was obtained when fired with 1:2:7 fuel combination, while the least efficiency (69.4%) was obtained when fired with a fuel combination of 3:5:2. This result indicated that shell which has the highest potential in terms of alternative energy for palm fruit processing behaves better when combine with other fuel material such as fibre, because the latter releases energy and supports combustion faster. There was no much difference in the efficiencies obtained when fired with other fuel combination as shown in Fig. 10, which indicated that irrespective of the ratio of the fuel combination, palm fruit biomass has the potential to supply the energy needed in the palm oil processing industry. This fuel combinations significantly affected the boiler efficiency (at $p < 0.05$), and the result obtained followed the trend reported by Sivabalan (2013), Oladosu *et al.* (2018) and also Salako *et al.* (2014).

4.2 *Effect of Fuel Combination on the Rate of Fuel Consumption*

The rate of fuel combustion is the ratio of the total mass of fuel used in the firing process to the burning time. The different burning characteristics of the composition of the fuel material resulted to the variation in the rate of fuel consumption of the boiler. According to Figure 11 the result, fibre has the highest potential in terms of heat released but shell has the longest burning time, followed by the EFB and fibre in that order. The longer burning time of the uncrushed raw palm shells used for the experiment can be attributed to its physically hard property that requires more time for char combustion to be achieved over the entire particle, while the EFB were dried quartered bunches. This submission is corroborated by Ilmi *et al.* (2013).

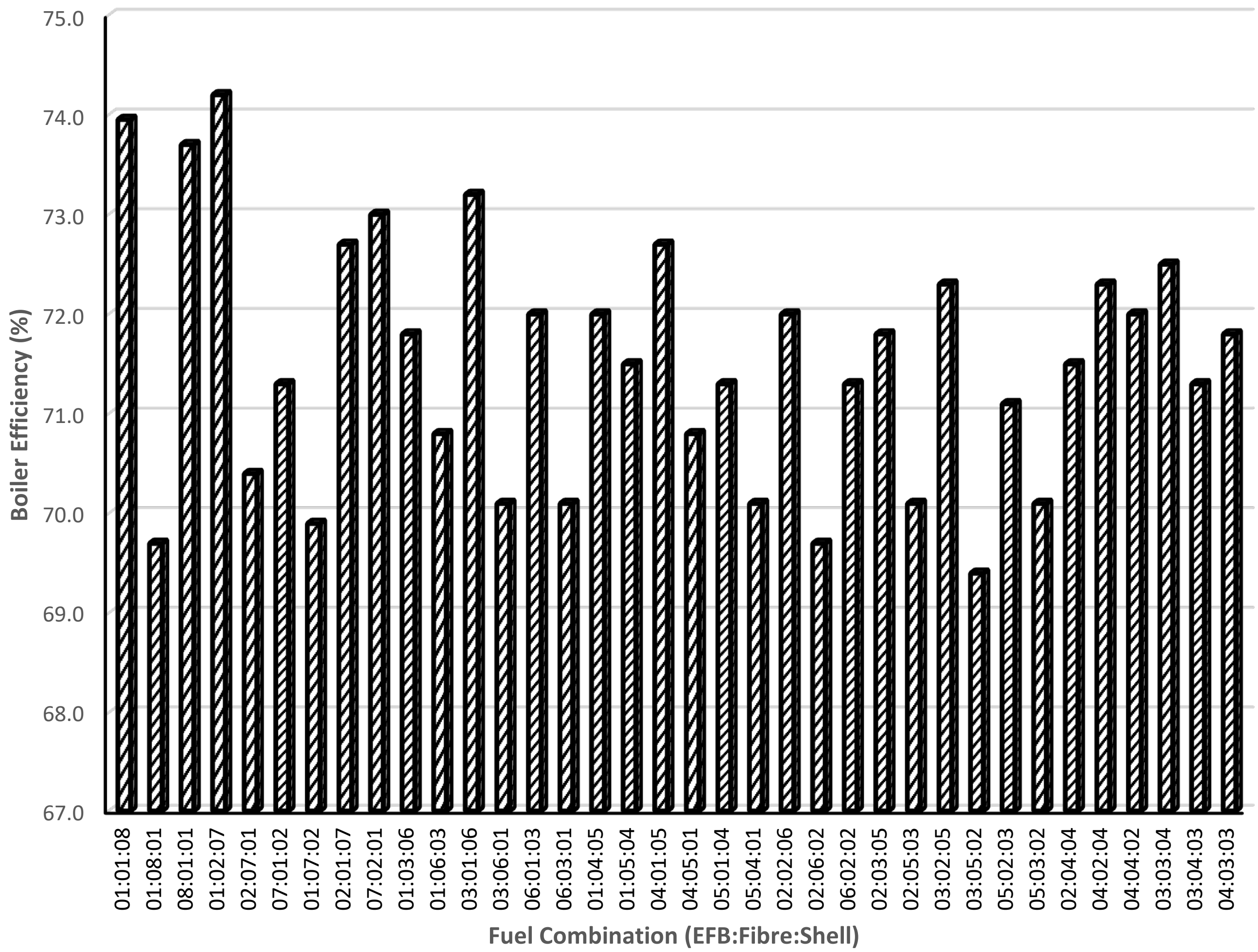


Fig. 10: Effect of fuel combination on the boiler efficiency

The burning rate of the char depends on both the chemical rate of the carbon-oxygen reaction at the surfaces and the rate of boundary layer and internal diffusion of oxygen. Fuels with higher densities typically has lower oxygen diffusion rate. This surface reaction generates primarily CO, which then reacts with free oxygen or other formed substances outside the particle to form CO_2.

As obtained in the result, fuel combination with higher composition of fibre requires larger quantity of fuel in order to maintain steady rate of combustion and heat supply to the heat exchangers. Therefore, as shown in Figure 11, as much as 21 kg of fuel was utilized when fired with a 2:7:1 and a combination of 1:1:8 only requires 12.5 kg of fuel. The result obtained is also in line the findings of Sivabalan, (2013) and Oladosu *et al.* (2018).

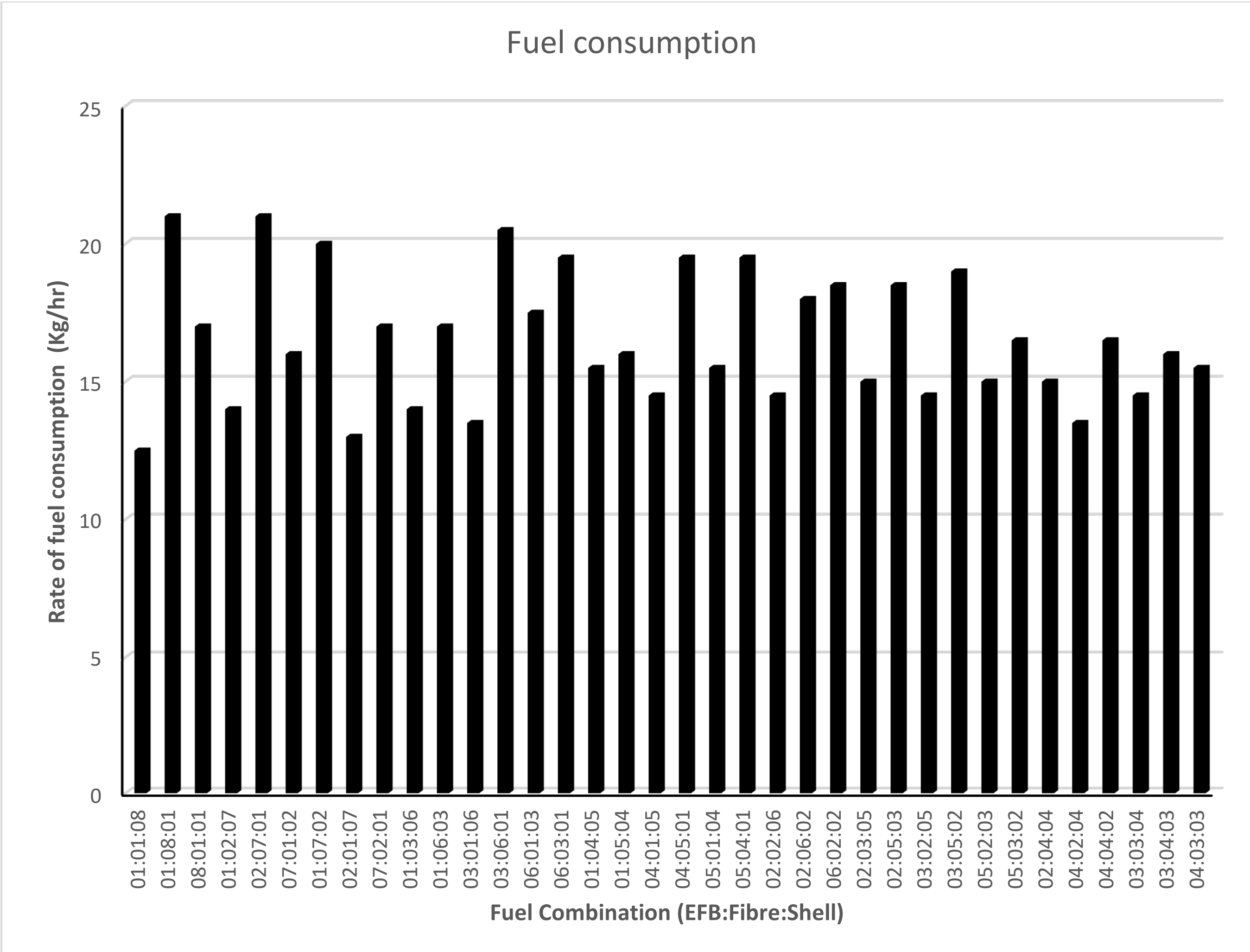


Fig. 11: Effect of fuel combination on the boiler rate of fuel consumption

5. Conclusion

A boiler for production of steam in the small scale palm fruit processing plant was developed in this study. The boiler which is 220 kW power rating with combustion air of about 7.9 kg per kilogramme of fuel will require between 68.1 to 83.2 kg of fuel (depending on the combination) to produce about 300 kg of steam at 74 % efficiency. The boiler which is capable of supplying adequate steam to the process line can therefore address the missing gap in the small palm fruit processing line. This gap has been challenging the oil quality, extraction efficiency, environmental friendliness and also production of special palm oil at this level of production.

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Notations

h_w	water / steam enthalpy in kJ/kg
$\dot{m}_w$	mass flow rate of steam or water in Kg/s
A	wall area
BE	boiler efficiency
BT	burning time
c,	specific heat capacity of the fuel; *ΔT* is the temperature change and *t*, time.
C_f	lower heating value of the biomass fuel
C_p	heat capacity at average temperature in J/kg.K
Cp	Specific heat capacity
E	efficiency
e_x	percentage excess air level
FC	fuel consumption
FS	factor of safety permitted.
GCV	gross calorific value of the fuel in kcal/kg of fuel
h_a	specific enthalpy of air
h_f	Enthalpy of feed water in kcal/kg of water
h_{fg}	specific enthalpy of furnace gas
h_s	specific enthalpy of steam
h_w	enthalpy of feedwater
k	thermal conductivity in W/m.K
LHV	lowest heating value.
m	mass of dry flue gas in kg/kg of fuel
M	percent moisture in 1kg of fuel
m,	mass of the fuel sample;
P	design internal pressure
q	Quantity of fuel used per hour in kg/hr.
R	radius of cylinder
S	maximum allowable stress
SP	steam production in kg per hour
T	temperature
TS	ultimate tensile strength of shell plates, lb/in2.
U	overrall heat transfer coefficient in $W/m^2.K$
ε	stoichiometric air/fuel volume ratio
η	Efficiency

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INFLUENCE OF SOME PROCESSING VARIABLES ON PARTICLE SIZE DISTRIBUTION AND PASTING PROPERTIES OF SPROUTED TIGERNUT (*CYPERUS ESCULENTUS L.*) FLOUR.

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Abstract

In this study, influence of some processing variables (drying temperature, drying time and post sprouting sampling time) on particle size distribution and pasting properties of tigernut flour was investigated, aimed at improving tigernut flour production process, using response surface methodology. Fresh and cleaned tigernut seeds were subjected to varied post sprouting time (PST_m), drying temperature (DT_p) and drying time (DT_m) based on the experimental design and using standard analytical methods. The result showed that increasing drying temperature from 46.59 to 63.41 C results in decrease in coarse particle size within the range of 500 – 250 µm from 25.10% to 11.30%, while that of 180 - 150µm increased from 71.70 to 84.10%. Increasing drying time from 11.32 to 14.68 hours resulted in increase in finer particles from 75.60 to 85.10% for 180 - 150µm, while decrease in coarse particle size from 12.70 to 11.40% for 250µm, respectively were observed. Also, increasing post sprouting time from 31.91 to 52.09 hours. Particle size distribution of 86.60% slightly below 200 µm and 98.2% within 250µm, were observed. The peak viscosity, trough viscosity, breakdown viscosity, final viscosity, set back, peak temperature and peak time ranges from 152.76 to 178.56 RVU, 122.47 to 143.38 RVU, 30.53 to 35.25 RVU, 176.86 to 220.42 RVU, 54.45±0.09 to 78.31±0.12, 65.73 to 66.66 C and 5.03 to 5.85 minutes, respectively, with these results able to enhance tigernut flour usage choice.

Keywords: Tigernut-flour, particle size, pasting properties, processing variables

1. Introduction

Tigernut (*Cyperus esculentus*) is a tuber crop that belongs to the family *cyperaceae*. Tigernut is an underutilized crop though cultivated throughout the world, in northern Nigeria, Niger, Mali, Senegal, Ghana and Togo where they are used primarily uncooked as side dish in Africa, Niger Republic is the major producer of tigernut, with 125 metric tons, followed by Ghana with 50 metric tons. About 36.3 metric tons is produced in Nigeria, where production is concentrated in the Northern parts of the country (Balami *et al.,* 2015).

Tigernut's composition, nutritional, health benefits and utilization have been well expatiated in literature (Ade-Omowaye *et al.,* 2008; Chinma *et al*., 2010; Elena *et al*., 2012; Gambo and Da'u, 2014; Neto *et al*., 2017; Sai'd *et al*., 2017; Komolafe *et al*., 2017; Komolafe *et al*., 2018a). The industrial processing of tigernut flour will go a long way to enhance its diversification and utilization, which will in turn lead to increase in its cultivation and production both at household and industrial levels and ultimately ensure food security (Komolafe *et al*., 2018b).The use of tigernut flour in varied food applications can be useful, not only from nutritional or food security point but from socio-economic reasons given the prohibitive cost of imported wheat flour, thus conserving the scarce foreign exchange used for wheat flour importation in developing counties like Africa and Nigeria in particular.

Particle size also known as granularity has been reported by Saravacos and Maroulis (2011), as a parameter which helps with quality control for milling flour, which is usually measured by geometric methods (microscopy or by sieving a representative amount of sample). Particle size of flour is an important physical parameter for bakeries as it plays a role in hydration capacity of flours. Hydration rate and extent are greatly dependent on the granularity of the flour used, the finer the particle size of a flour, the greater its rate and extent of water absorption while in contrast, excessively coarse flours produce low quality breads, since dough hydration is limited and takes longer to complete (Pagani, 2014).

The particle size of a given flour depends on the processing conditions at the mill and correlates directly with other quality indicators of flours, which helps milling and baking industry scientists and technicians to assess flour purity and extent of water absorption or water binding capacity flour during mixing or kneading as well as mechanical damage of starch in the flour during milling (Finnie and Atwell, 2016).

Pasting properties of flour has been reported by Andrea (2010) to be properties of flour that is used to ascertain its suitability in certain uses as it influences its granule's gelatinization, viscosity and starch solubilization, which are required in the formulation of specific products. The parameters that influence pasting properties of flour according to Sanni *et al*, (2008) include its starch content, temperature and particle size among others. Pasting temperature gives an indication of gelatinization temperature required to cook the starch food product, the pasting properties of flour is the most commonly used parameter to define quality of a particular starch-based food product (Adebayo-Oyetoro *et al*., 2016).

2. Materials and Methods

2.1 *Source of Materials*

The fresh seeds yellow variety of tigernut (*Cyperus esculentus l.*) were purchased from Sheik Abubarkar Gumi Central market Bakindogo Kaduna, Kaduna State, Nigeria.

2.2 *Experimental Design / Plan*

Response surface methodology as described by Myers and Montgomery (2009) was used. The experimental design and plan is as shown in Table 1.

2.3. *Sample Preparation*

Fresh tigernut seeds were sorted, washed, drained and set for sprouting according to the method described by Komolafe *et al*., (2018). Each portion of the seeds were spread separately on clean jute bags, covered with damp cotton cloth, then left for 31.91, 36, 42, 48 and 52.09 hours as indicated in the design plan to sprout. Water was sprinkled at 12 hours interval to facilitate the sprouting process. At the end of the post sprouting sampling, hair removed and the sprouted tigernut seeds were dried in a single layer at the varied drying temperatures in a tray dryer (LE ECHWA model LH-1300) as indicated in the design plan, using hot air at 2.0 m/s velocity. The dried sprouted tigernut seeds were milled into flour using attrition mill (Globe P. 44, China) and sieved using a 212(micron) number 70 sieve (Laboratory Endecott test sieve), cooled and packaged in air tight polyethylene bags and kept in a plastic container with cover, kept in freezer at -18□C, from where the samples were drawn for analysis.

Table1: Independent Variables and Actual Levels for Central Composite Design

Independent variable	**Variable levels**				
	-α	**-1**	**0**	**+1**	**α**
Drying temperature °C X_1	46.59	50	55	60	63.41
Drying time hour X_2	11.32	12	13	14	14.68
Post sprouting sampling Time hours X_3	31.91	36	42	48	52.09

X_1, X_2, X_3 are drying temperature, drying time and post sprouting sampling time adopted as the three most important production process variables. Levels of each variable was established based on preliminary experimentations distance a of axial point from

the centre points was ± 1.68, calculated from equation $\alpha = (2^n)^{0.25}$ where n is the number of variables.

2.4. *Analytical Methods*

Determination of Particle Size Distribution

The particle size distribution was determined by subjecting the flour to a standardized sieving test according to the method described by Ngoddy *et al*. (1986), using flour shaker with screen mesh ranging from 500 to 150µm. The experiment was carried out at Golden Penny (A commercial flour producing) Company Laboratory Oshodi , Lagos State, Nigeria. Each (100g) of the flour sample was weighed and carefully poured into the topmost sieve with 500µm screen size, the shaker was then coupled back, plugged and made to shake for about 30 minutes. The proportions of the fractions retained in each sieve were calculated as:

$$\%\, fraction\ (X) = \frac{weight\ of\ fraction\ (X)}{Total\ weight\ of\ sample} x100$$

Determination of Pasting Properties

Pasting properties of the flour samples were determined using a rapid visco analyser (RVA) (Newport Scientific Pty Ltd., Warriewood, Australia) following the method described by AACC (2000). A 2.5g of flour was weighed into a dried empty canister; then 25 ml of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed and the canister was fitted into the RVA. Each sample suspension was kept at 50°C for 1 minute and heated to 95°C at 12.2°C/ minute, then held at 95□C for 2.5 minutes, cooled to 50□C at 11.8□C/ minute and held for 2 minutes to determine the RVA profile of the sample.

3. Results and Discussions

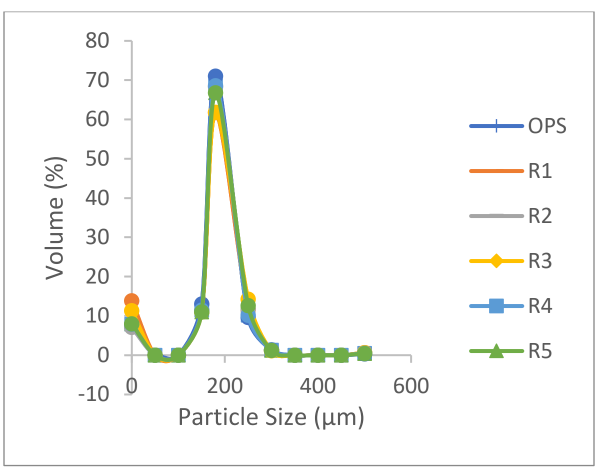
The results of the particle size distribution for the tigernut flour samples are shown in Table 2, Figures 1 and 2.

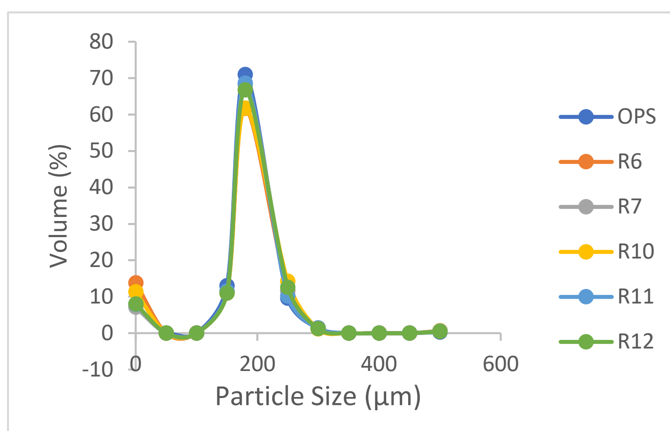
Table 2: Particle Size Distribution for Tiger nut Flour

S	500□m	300□m	250□m	180□m	150□m	Base
R1	0.60 ± 0.01	1.20 ± 0.01	11.60 ± 0.02	61.70 ± 0.01	11.10 ± 0.01	13.80 ± 0.01
R2	0.50 ± 0.01	1.20 ± 0.01	11.80 ± 0.01	68.20 ± 0.01	11.20 ± 0.01	7.10 ± 0.01
R3	0.60 ± 0.01	1.10 ± 0.01	14.20 ± 0.02	61.80 ± 0.02	11.00 ± 0.02	11.30 ± 0.02
R4	0.50 ± 0.02	1.30 ± 0.01	10.20 ± 0.01	68.60 ± 0.02	11.50 ± 0.02	7.90 ± 0.01
R5	0.40 ± 0.02	1.20 ± 0.01	12.60 ± 0.02	66.80 ± 0.01	11.00 ± 0.01	8.00 ± 0.02
R6	0.40 ± 0.02	0.20 ± 0.01	13.20 ± 0.02	66.80 ± 0.01	11.00 ± 0.01	8.40 ± 0.01
R7	0.50 ± 0.01	1.00 ± 0.02	12.20 ± 0.02	66.20 ± 0.01	11.40 ± 0.02	9.00 ± 0.02
R8	0.40 ± 0.02	1.00 ± 0.02	12.00 ± 0.01	66.40 ± 0.02	11.00 ± 0.01	9.20 ± 0.02
R9	0.80 ± 0.02	1.10 ± 0.02	14.20 ± 0.02	60.80 ± 0.01	10.90 ± 0.02	12.20 ± 0.05
R10	0.30 ± 0.01	1.60 ± 0.02	9.40 ± 0.02	71.00 ± 0.01	13.10 ± 0.02	4.60 ± 0.02
R11	0.50 ± 0.02	1.20 ± 0.01	11.80 ± 0.01	63.80 ± 0.02	11.80 ± 0.02	10.90 ± 0.01

R12	0.50 ± 0.02	1.20 ± 0.01	12.60 ± 0.02	64.50 ± 0.05	11.60 ± 0.01	9.60 ± 0.02
R13	0.50 ± 0.01	1.20 ± 0.01	10.50 ± 0.01	64.60 ± 0.02	12.00 ± 0.01	11.20 ± 0.01
R14	0.60 ± 0.01	0.20 ± 0.01	10.60 ± 0.01	66.80 ± 0.01	11.80 ± 0.02	10.00 ± 0.01
R15	0.30 ± 0.02	1.00 ± 0.02	9.70 ± 0.02	70.50 ± 0.02	12.80 ± 0.02	5.70 ± 0.02
R16	0.40 ± 0.01	1.20 ± 0.01	9.70 ± 0.02	70.40 ± 0.02	12.70 ± 0.03	5.60 ± 0.01
R17	0.40 ± 0.01	0.40 ± 0.02	9.70 ± 0.02	70.50 ± 0.02	12.70 ± 0.02	5.30 ± 0.01
R18	0.50 ± 0.02	0.40 ± 0.02	9.70 ± 0.02	70.40 ± 0.02	12.80 ± 0.02	5.20 ± 0.01
R19	0.50 ± 0.02	0.40 ± 0.02	9.70 ± 0.02	70.40 ± 0.02	12.80 ± 0.02	5.20 ± 0.01
R20	0.40 ± 0.01	0.40 ± 0.02	9.60 ± 0.01	70.40 ± 0.02	12.80 ± 0.02	5.40 ± 0.01
OPS	0.30 ± 0.01	1.40 ± 0.02	9.60 ± 0.01	71.00 ± 0.01	13.00 ± 0.01	4.70 ± 0.01

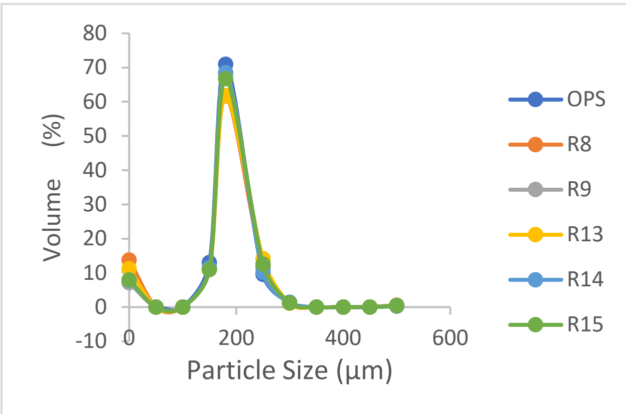
S is sample, OPS is optimized sample, □ is standard deviation of triplicate evaluation

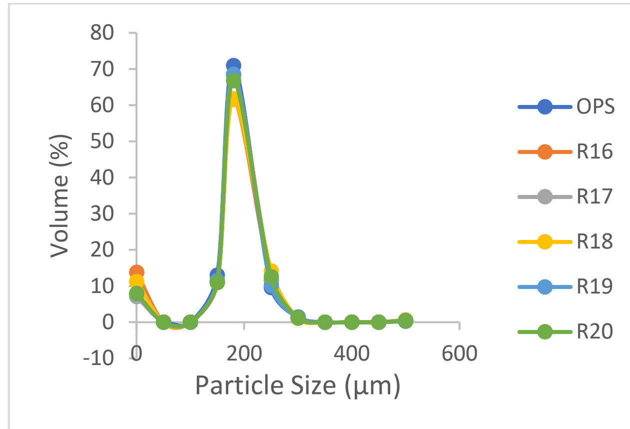




(a) (b)

Figure 1: a-b Particle Size Distribution of Tigernut Flour Samples





(a) (b)

Figure 2: a-b Particle Size Distribution of Tigernut Flour Samples

The result showed that increasing drying temperature from 46.59□C to 63.41□C results in decrease in coarse particle size within the range of 500 - 250µm from 25.10 to 11.30%, while that of 180 - 150µm increased from 71.70 to 84.10%. Increasing drying time from 11.32 to 14.68 hours resulted in increase in finer particles from 75.60 to 85.10% for 180 - 150µm, while decrease in coarse particle size from 12.70 to 11.40% for 250µm and increase in finer particles from 76.60% to 78.60% for 180 -150µm, respectively were observed for increasing post sprouting time from 31.91 to 52.09 hours. Particle size distribution of 86.60% slightly below 200µm and 98.2% within 250µm, were observed.

The results generally showed that the tigernut flour samples had 86.6% of the flour samples had 86.6% of the samples with particle size below 200□m in size, while 98.2 % were within 250□m in size. Based on this findings, particle size of 200□m was taken as the average particle size of the tigernut flour in this study. It is generally considered that powder with particle size larger than 200□m are free flowing, while fine powder are subject to cohesion and their flowability is more difficult (Shumaila *et al.*, 2015). Particle size distribution of flour is an important factor in achieving desired products qualities. It is important during mixing of dried powders. If the particle size is too small, the flour becomes too fine and reconstitution becomes a problem (Komolafe *et al.,* 2012) It has been reported by Yelmi and Ogunwole (2016) that viscosity which is often very important for quality control, particularly on products that are expected to be of a particular consistency in relation to appearance or mouth feel are parameters that depends on the particle sizes of their constituent products. Fitzpatrick *et al*. (2004a) has reported that particle and particle size distribution both play significant roles in flowability and other properties such as bulk density, compressibility of bulk solids. Fitzpatrick *et al*. (2004b) reported that reduction in particle size often tends to decrease the flowability of a given granular material due to increased surface area per unit mass. Decrease in particle size generally leads to an increase in compressibility and thus volume reduction (Ganesan *et al*.,2008). The finer the particle size and greater the range of particles, the greater the cohesive strength and the lower the flow rate. Reduction in particle size tends to increase the contact area between the particles thereby increasing the cohesive force (Ganesan *et al*., 2008). Flour particle size of 365□m and higher were more difficult to hydrate and had higher set back viscosity (Ayeh, 2013).

Particle size plays a great role in water absorption capacity of flours, as hydration are greatly dependent on granularity of the flour. Tthe smaller the particle size, the greater the rate and extent of water absorption, while excessively coarse flour produce low quality breads since dough hydration is limited (Saravacos and Maroullis 2011). Finer flours provide a homogeneous, complete and almost instantaneous hydration of the protein macromolecules vital for dough formation and development, hence wheat flour generally is of a size such that at least 98% of flour should pass through a 212 µm sieve, the US standard mesh No 70 (Pagani, 2014). Cauvain (2017) also reported particle size's role in cake – making as high-ratio flours used in cake making showed an excellent indication of how particle size of flours affect the overall texture of a product.

3.2. ***Pasting Properties of Tigernut Flour Sample***

Table 3: Result of Pasting Properties for Tigernut Flour Samples

S	Peak Viscosity	Trough viscosity	Breakdown viscosity	Final Viscosity	Set Back	Peak Temp.	Peak Time
OPS	152.76 ± 0.08	122.47±0.05	30.53± 0.15	176.86 ± 0.08	54.45 ± 0.09	65.73 ± 0.07	5.03 ± 0.01
R6	167.44 ± 0.13	134.56 ± 0.10	32.77 ± 0.04	213.55 ± 0.34	78.31 ± 0.12	66.32 ± 0.16	5.45 ± 0.06
R17	178.56 ± 0.38	143.38 ± 0.24	35.25 ± 0.13	220.42 ± 0.05	77.49 ± 0.05	66.63 ± 0.26	5.85 ± 0.01

S is sample, OPS is optimized sample, ± is standard deviation of triplicate evaluation

The pasting properties of tigernut flour is as shown in Table 3. The peak viscosity, trough viscosity, breakdown viscosity, final viscosity, set back, peak temperature, and peak time ranges from 152.76 to 178.56 RVU, 122.47 to 143.38 RVU, 30.53 and 35.25 RVU, 176.86 to 220.42 RVU, 54.45 ± 0.09 to 78.31 ± 0.12, 65.73 to 66.66 °C and 5.03 to 5.85 minutes, respectively. The result showed that the optimized tigernut flour sample sprouted for 43.53 hours and dried at 56.44 °C for 12.03 hours had better pasting properties. Similar pasting values were reported for tray- dried chestnut flour (Jasim and Hasan,2015) while a slightly higher peak viscosity and pasting temperature was reported for taro flour (Muhammet *et al*., 2016). A much higher values of peak viscosity (455.58 RVU), trough viscosity (213.17 RVU), break down viscosity (290.08 RVU) and peak temperature (78.85 °C) were reported for cassava flour (Adebayo-Oyetoro *et al.*, 2016). Optimized tigernut flour sprouted for 43.53 hours, dried at 56.44 °C for 12.02 hours had the lowest trough viscosity and breakdown viscosity values, indicating that this flour showed highest resistance against heating and shear stress applied. High trough viscosity and high breakdown viscosity indicate lower resistance of the samples to shear and temperature that causes losses in food products (Correia and Beirao-da-Costa, 2012). Trough viscosity (holding strength) represents the ability of the sample to withstand heating and shear stress applied, while final viscosity value indicates the gel forming capability of the material after heating (Sanni *et al.,* 2008). Low setback viscosity of 54.45 ± 0.09 obtained for the optimized tigernut flour indicates low retrogradation and syneresis rates (Ragaee and Abdel-Aal, 2006). Lowest peak time of 5.03 minutes was observed for the optimized tigernut flour sample, which is similar to peak ranges of 5.01 to 6.83 minutes reported by Chinma *et al* (2010). Higher peak viscosity, trough viscosity, breakdown viscosity, final viscosity, set back temperatures, with lower peak temperatures were reported for yam four and cocoyam flour (Oluwamukomi and Akinsola, 2015). Peak temperature and peak time provide an indication of the minimum temperature required and time to cook flour product. Peak time value reported in this study is in line with the peak time reported by Adebowale *et al.* (2008). Viscosity values indicates the ability of the material to withstand heat, high breakdown viscosity is usually associated with high peak viscosity, which relates to the degree of swelling of starch granules during heating (Muhammet *et al*., 2016). Pasting temperature gives an indication of the gelatinization time during processing. It is the temperature at which the first detectable increase in viscosity is measured and is an index characterized by the initial change due to the swelling of starch. Starch gelatinization involves granule melting in an aqueous medium under heating. In water, granule swelling increases with temperature and it leads to a transfer of water in the suspension to water associated with starch components, amaloyse and amylopectin. When starch temperature reaches 60 – 70 °C insoluble granules are disrupted by the energy supplied resulting in a loss of molecular organization. This process leads to increasing viscosity and starch solubilization (Andrea, 2010). Starch from roots and tubers shows some particular rheological and physical properties, such as clear gel, high viscosity and lower retrogradation, which are required in the formulation of specific products hence modified and native starches represents more than 80% of all hydrocolloids used in food systems (Wanous, 2004). The pasting properties of flour are important quality index in predicting the behavior of starch paste during and after cooking, so as to ascertain the stability of its gel (Sanni *et al*, 2006). High peak viscosity is an indication of high starch content and it is related to the water binding capacity of food starch (Adebowale *et al*, 2005). The low trough viscosity, low peak temperature and low peak time observed from the optimized tigernut flour sample indicate that tigernut flour could serve as a good thickening agent and requiring minimum cooking temperature 65.73 ± 0.07 °C and minimum time of 5 ± 0.07 minutes.

4. Conclusion

In this study, it can be concluded that sprouted tigernut at 43.53 hours post sprouting sampling time, 56.44°C drying temperature and 12.03 drying time would produce a suitable tigernut flour with particle size distribution 88.70% ≤ 180μm, 98.30% ≤ 250μm and good quality pasting peak temperature of 65.73°C and 5.03 minutes peak time, respectively, suggesting that the production of this developed quality tigernut flour should be encouraged as it will increase the economic value of the crop and provide health benefits to the consumers, both adults and children, with the application in various form such as in cakes, biscuits cookies, pasta, beverage powder, inclusion in ice- cream, soup thickner, complimentary foods production, inclusion in poultry and fish feeds along with oil and starch its derivatives.

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EFFECTS OF ALOE VERA BASED EDIBLE COATING ON SHELF LIFE AND QUALITY OF TOMATOES

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Abstract

This study investigated the feasibility of aloe vera based edible coating on the shelf life and quality parameters of unripe tomatoes. It assessed the storability and the microbiological qualities of uncoated and coated tomatoes. The control and coated samples were stored at room temperature 25°C-30°C and relative humidity of 82-84%. The microbial and fungi counts of the uncoated samples were comparably higher than those of the coated samples. For the uncoated samples, the bacterial count ranged between 10 x 10^3cfu/g and 13 x 10^3cfu/g and 4 x 10^3cfu/g and 6 x 10^3 cfu/g for fungal count, while for the coated, it ranged between 6 x 10^3cfu/g and 8 x 10^3cfu/g for bacterial count and 3 x 10^3cfu/g remains for fungal count between the 2nd and the 4th week. For the storability, it was found that the control sample began to deteriorate in quality and begin to show sign of decay from the 2nd week, on getting to the 4th week, the control was totally damaged while for the coated sample, the tomatoes remained fresh and healthy. In terms of the physiological weight loss for the uncoated, there was a percentage weight loss of 45.754% at the end of the 4th week, while for the coated, percentage weight loss was observed and determined to be 13.137% at the end of that same 4th week, finally for the chroma value, there was a significant change in the chroma value of the uncoated sample during the 4th week of storage, as it reads 44.933 which shows that there is a significant color change from the shiny red to faded red, while for the coated sample, the chroma value during the 4th week of storage was 66.581, which showed a much more bright color, as compared to the uncoated sample. Thus, the use of aloe vera based edible coating is highly recommended for storing and extending the shelf life of fresh tomatoes fruit.

Keywords: Bacterial count, edible coating, chroma value, shelf life, tomatoes, aloe vera.

1. Introduction

Tomatoes are one of the most healthy and beneficial foods in daily diets. They are extremely low in calories, rich in vitamin A and vitamin C, beta-carotene, potassium, as well as a great source of fundamental antioxidants, such as lycopene. Tomatoes are considered to be one of the most economically important crops in the world. Economically speaking, tomatoes are worth a tremendous amount of money because they give more yields (Chaudhary *et al.*, 2018).

Nigeria is one of the leading producers of tomatoes that are grown in its diverse agro-ecological zones that range from humid in the southern part of the country to sub-humid in the middle belt part of the country and semi-arid/arid in the northern part, yet the produce is lost at an increasing high and alarming rate of 30% - 50% yearly as a result of poor pre-harvest and post-harvest practices (Aworh, 2010) including storage.

Nigeria is ranked the second largest producer of tomato in Africa and the thirteenth largest in the world, producing about 1.701 million tons of tomato annually at an average of 25-30 tons per hectare (Adebisi-Adelani and Oyesola, 2014). Despite this advantageous situation, Nigeria imports processed tomato paste to the tune of about 65,809 tons valued at ₦11.7 billion ($77.167 million) annually (Ayodele *et al*., 2007) because not less than fifty per cent (50%) of the tomato produced in the country is lost due to lack of preservation facilities. According to World Food Science, about 30-50 per cent of perishable produce are lost after harvest simply as a result of poor storage system and humid weather condition exacerbated by poor marketing distribution and access to markets (Ugonna *et al*., 2015). Thus, the need to condition the tomatoes to prolong their shelf life using an edible coating.

Aloe vera is a well-known plant for its dazzling medicinal attributes. It is a tropical and subtropical plant. There are a few reviews of the antifungal activity of aloe vera gel towards numerous fungi inclusive of *Colletotrichum sp* (Nidiry *et al*., 2011). Lately, there is an accelerated interest in the usage of aloe vera gel-based edible coating for fruits and vegetable due to its anti-fungi properties.

There is an urgent need to achieve self-sufficiency in food to match all efforts at increasing crop production with equal if not greater efforts of post-harvest technology to save the crops that are produced from deterioration and wastages (Olayemi *et al*., 2010). Thus, the aim of this study is to evaluate the effect of aloe vera gel as an edible coating on the shelf-life of the tomato fruit.

2.Materials and Methods

2.1 *Collection of Tomatoes and Aloe Vera Plant*

The materials used for this study are fresh tomatoes and aloe vera. The fresh tomatoes were gotten from a small garden in Federal University of Technology, Minna, Gidan-Kwano Off-campus, and the aloe vera was gotten in Tunga Market Tunga Minna, Niger State, Nigeria.

2.2 *Sample Preparation*

Fresh aloe vera leaves collected (Figure 1) were cut and soaked in water for about 24 hours for the stains and yellow latex to drop, after that it was cleaned with a clean handkerchief. The bottom, the jagged edges and sharp points as well as one part of the leave were peeled off using the small knife, after which the gel i.e. the colorless parenchyma was extracted by scooping it out using a spoon (Figure 2). After the extraction was done, it was blended using the electric blender. After that it was filtered using a filter cloth to sieve out fibers (Figure 3).

Figure 1: Fresh Aloe Vera leaves
Figure 2: Extracted Aloe Vera Gel

Figure 3: Filtering the Aloe Vera Gel

The filtered sample aloe vera gel was put in a clean pot and heated using a hot plate (electric stove). It was pasteurized at about 100ºC for like 45 minutes in order to deactivate any form of microbial activity that may be taking place in the aloe vera gel, as might affect it preservative power. The gel was left to cool at room temperature. Upon cooling the gel becomes too watery to be used for coating. So, a thickener was needed to improve its adhesiveness so it can be able to stay on the tomato. Although most of the thickeners have one property i.e. they contain starch, so pap (local akamu) was used. The pap was prepared using the aloe vera gel to allow it to have enough thickness to be used as a coating.

After the aloe vera gel was prepared at the laboratory, the tomatoes were selected to obtain homogeneous batches based on color, absence of injuries, and of good health. Tomatoes were divided into two that is control and coated batches. The procured tomatoes were washed thoroughly with running water and surface dried before coating; else the coating would not adhere to the surface while it is still wet. The aloe vera gel was applied to the tomatoes by dipping method, given there are different methods of applying the gel, which could either be by brushing, dripping, dipping.

2.3 *Storage*

The control and coated tomato samples were stored at room or ambient temperature (25°C-30°C) and relative humidity of 82-84% throughout the duration of the study of 4 weeks.

2.4 *Determination of Physiological Weight Loss (PWL)*

Weight loss mainly occurs due to water loss by transpiration and loss of carbon reserves due to respiration (Vogler and Ernst, 1999; Prasad *et al*., 2018). The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere. The physiological weight loss was calculated according to the procedure by Workneh *et al*. (2011). Three tomatoes from each batch were taken and the mass of individual tomatoes was recorded on the day of coating, and at every 5 days interval till it attained red stage. Cumulative mass losses were calculated by using equation 1:

$$\text{Physiological weight loss (\%)} = \frac{Weight\ of\ initial - Weight\ of\ final}{Weight\ of\ initial} \times 100 \qquad 1$$

2.5 *Determination of Color*

Visual assessment is the first impression and a key feature in the choice of fruits. Color is one of the most important visual attributes of fruits. Color of the tomato was determined using Adobe Photoshop

(Photoshop CC 2019). The average value of L*, a*, b* was determined and chroma value (ΔC) was calculated using the equation 2 given below (Weatherall and Coombs, 1992).

$$\Delta C = \sqrt{(L*)^2 + (a*)^2 + (b*)^2} \quad 2$$

2.6 *Determination of Microbiological Activities (Microbial Analysis)*
Enumeration of bacteria and fungi was carried out by pour plating technique. This was done by inoculating 0.1 ml tenfold serially diluted samples onto nutrient agar (Bacterial), acidified potato Dextrose agar containing Streptomycin (1mg /100 ml) (fungal). The inoculated nutrient agar plates were incubated at 37°C for 24 hours while the potato dextrose Agar plates were incubated at room temperature for 3-5 days. Observed colonies were counted and expressed as colony forming units per gram ($cfug^{-1}$). Microbiological analysis was carried out on the 2nd week and at the end of storage period which was the 4th week by enumerating the total bacteria and fungi count which is expressed in colony forming units per gram, having a unit of cfu/g.

3. Results and Discussion
Tomatoes both from control and aloe vera coated showed mass loss throughout the storage period (Table 1). The physiological loss in weight of the control is higher than that of the coated. The physiological weight loss of control and coated during the 1st week is 8.104% and 1.125%, which shows a difference of about 6.979% between that of the control and the coated. The physiological weight loss during the 2nd week was 22.500% for the control and 7.884% for the coated, while for the 3rd week is 34.094% for the control and 10.125% for the coated while during the 4th week; the physiological weight loss for the control is 45.754% while that of the coated was 13.137%.

Table 1. Effect of Aloe Vera Based Edible Coating on the Physiological Loss in Weight (%) during storage period.

	CONTROL		COATED	
TIME	Original Weight (g)	Percentage Loss (%)	Original Weight (g)	Percentage Loss (%)
0th Week	30.196	0.000	29.413	0.000
1st Week	27.749	8.104	29.082	1.125
2nd Week	23.402	22.500	27.094	7.884
3rd Week	19.901	34.094	26.435	10.125
4th Week	16.380	45.754	25.549	13.137

Table 2. Effect of Aloe Vera Based Edible Coating on the Chroma of the Tomatoes during storage period.

	CONTROL				COATED			
TIME	L*	a*	b*	ΔC	L*	a*	b*	ΔC
0th Week	42	-7	44	61.229	45	-7	33	55.444

1st Week	38	28	34	58.172	43	3	37	56.807
2nd Week	36	32	42	63.906	43	21	46	66.378
3rd Week	31	35	37	59.624	42	34	47	71.617
4th Week	23	23	31	44.933	38	35	42	66.581

Tomatoes, both control and coated, registered some changes in L*, a* and b* values during the storage period. Table 2 shows the effect of coating on L*, a*, b* and ΔC values of tomatoes. L* means lightness (from white to black). L*values did not experience much significant change until the turning stage, indicating that there was no significant change in lightness when the green color was still predominant. The initial L* values for the control and coated tomatoes were 42 and 41 (slight difference in the initial L* value is due to coating). When red color pigments started to synthesize, there was a decline in L* value; a similar result was also reported by Carreño *et al*. (1995). Though there was a decrease in L* value in both coated and control tomatoes, coating showed a significant difference in L* value when compared to control during the 2nd Week of storage. L* value of control during its red stage in the 2nd Week was 36, whereas for the coated fruit, in the same week was 43. L* value of coated fruit decreased during its ripening. L* value of coated fruit during its red stage in the 4th week was 38. a* values change from negative (green color) to positive (red color) (Weatherall and Coombs, 1992). a* value of control during its red stage in the 2nd week was 36, whereas for the coated fruit on the same day it was 21. The increase in a* value was, however, slower for the tomatoes treated with aloe vera gel compared to control. a* value of tomato increased during its ripening, and for the coated fruit during its red stage in the 4th week, it was 35. The initial b* (blue to yellow) values for control and coated tomatoes were 44 and 33, afterwards the values gradually decreased to 42 for control tomatoes and to 46 for coated tomatoes in the 2nd week. b* value of coated tomato during its red stage in the 4th week was 42. The chroma value (ΔC) depends on a* and b* values. The chroma value indicates the colour intensity (saturation) of the sample. There was a slight increase in the chroma value from the initial value. But there were significant differences in chroma value of coated tomatoes when compared to control tomatoes. ΔC of the control was 63.906 during its ripening in the 2nd week, whereas for the coated fruit it was 66.378 on the same day. ΔC value increased during ripening of tomato. ΔC value of coated fruit during the 4th week was 66.581 and that of the control was 44.933.

Table 3. Effect of Aloe Vera Based Edible Coating on the External appearance and glossiness of The Tomatoes during storage period.

TIME	CONTROL	COATED
0th Week		
1st Week		
2nd Week		
3rd Week		
4th Week		

From table 3 above, during the 0th week of storage, there was no much difference in the appearance of the control to that of the coated, except for the glossiness and shiny surface shown by the coated tomatoes' surface due to the coating that was applied to it. During the 1st week, the control is already turning to pink/light red (30%-60% of the surface is not green), while the coated was still at the turning stage (10% to 30% of the surface is not green). In the 2nd week, the control is already at the light red/red maturity stage

(60% - 90% of the surface not green/ more than 90% of the surface is not green). In the 3rd week, the control has ripened and started shrinking and decaying, looking unhealthy, while the coated was showing a maturity stage of light red (60%-90% of the surface is not green). Finally, during the 4th week, the control sample was showing total decay, spoiled and smelling, while for the coated, although showing sign of shrinkage was still looking fresh, healthy, edible and odorless.

Table 4: Total Bacteria and Fungi count (cfu/g)

TIME	CONTROL (cfu/g)		COATED (cfu/g)	
	otal Bacterial Count	otal Fungi Count	otal Bacterial Count	otal Fungi Count
ᵈ Week	10×10^3	4×10^3	6×10^3	3×10^3
ʰ Week	13×10^3	6×10^3	8×10^3	3×10^3

From Table 4, showing the Total Bacterial and Fungi count, during the 2nd week, the Total bacterial count was $10 \times 10^3 cfu/g$ for the control and $6 \times 10^3 cfu/g$ for the coated samples respectively, while during the 4th week, the total bacterial count was $13 \times 10^3 cfu/g$ for the control and $8 \times 10^3 cfu/g$ for the coated, thus showing a significant increase in the number of bacteria count of $3 \times 10^3 cfu/g$ from the 2nd week to the 4th week for the control and the bacteria count of $2 \times 10^3 cfu/g$ for the coated, therefore the bacteria count is much at the 4th week for the control than the coated. While for the fungi count, it increases by $2 \times 10^3 cfu/g$ from the 2nd week to the 4th week, while for the coated, the fungi count remained unchanged even after the 2nd week to the 4th week.

Aloe gel based edible coating act as barrier, thereby restricting water transfer and protecting fruit skin from mechanical injuries. This positive effect in terms of reduction of moisture loss may be due to the hygroscopic properties of aloe gel that allow the formation of water barrier between the fruit and the surrounding environment, thus, preventing its external transferences (Morillon, *et al*., 2002). Interestingly, aloe vera gel mostly composed of polysaccharide (Ni *et al*., 2004) which is highly effective as a barrier against moisture loss without incorporation of lipid.
According to Ergun and Satici, (2012) aloe vera gel treatment delayed the green color loss on the fruit skin of apples stored at 2°C for 6 months.. Skin color of table grapes showed lower increases in aloe treated than in control (untreated) fruits. Table grapes are rich in anthocyanin compounds, which account for their red color. The ripening process of table grapes has been correlated to the anthocyanin content (Cantos *et al*., 2002). At the end of cold storage (1°C, 95% RH), control fruits exhibited a redder and darker color than Aloe-treated table grapes, showing the aspect of overripe fruit, which is considered to be detrimental to color quality (Tripathi and Dubey, 2004). The modified atmosphere created by the aloe vera gel coating material retarded the ethylene production rate, therefore, delaying ripening, chlorophyll degradation, anthocyanin accumulation and carotenoid synthesis thus ultimately delaying color change of fruits (Carrillo-Lopez, 2000). Color also retain in aloe gel (100%) treated papaya fruit (Brishti, 2013). Moreover, the aloe vera coating imparted an attractive natural-looking sheen to table grapes (Tripathi and Dubey, 2004), papaya (Brishti, 2013) which was correlated to lower changes in both skin color and dehydration.

3. Conclusion

This work shows that aloe vera has potent preservative capacity. Its harmless nature to both humans and the environment makes it far more advantageous than the average chemical preservative which often has dangerous side effects on health. Aloe vera gel applied as an edible coating on tomatoes has a positive effect in retarding the ripening process and microbial action on it. This method is effective as a physical barrier and thus reduces the weight loss, maintaining the firmness and enhancing the shelf life of tomatoes by preventing microbial/microbiological actions. In addition, aloe vera gel delays softening. Thus, aloe vera gel can be used as an edible coating to reduce post-harvest loss of tomatoes and increase its shelf life. It is an effective method that can be adopted in our daily life as well as our food industries.

Greater attention should be taken on edible coating, most especially the one that is based on aloe vera gel, since it has anti-microbiological properties, that is it contains certain substance that inhibits the growth of bacteria and fungi. Aloe vera based edible coating is also harmless when it comes to the health of the one consuming it, instead it contains other food vitamins and minerals which gives the human body additional nutrients. Aloe vera gel therefore can be used in preserving tomatoes thereby extending their shelf life.

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DEVELOPMENT OF MORINGA (*Moringa oleifera L.*) SEED OIL EXPELLING MACHINE

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Abstract

A Moringa (Moringa oleifera L.) seed oil expelling machine was developed after physico-mechanical properties of the seeds were determined at 6.75% moisture content. The average seed length, width and thickness were found to be 8.94, 7.84 and 6.96mm, respectively. The arithmetic mean diameter, geometric mean diameter, mean surface area, sphericity and aspect ratio were found to be 7.92 mm, 7.70 mm, 46.85 mm^2, 86.46% and 88.24, respectively. The true density, bulk density and porosity were 0.95 kg/m^3, 0.52 kg/m^3 and 45.02%, respectively. Mean angle of repose was 17.82º, coefficients of friction on mild steel surface was 0.45. Energy required to crush the seeds was found to be 147 Nm at Brinell Hardness Number below 325.32. These properties were used as input for the design of the Moringa seeds oil expelling machine using mild steel of 0.73m x 0.16m x 0.86m frame, a hopper of 0.003m^3 and an electric motor. The machine was designed, fabricated and tested to evaluate its performance in relation to manual and motorised processes. Power requirement of the machine and shaft rotational speed was 1.08 hp and 500 rpm, respectively. The machine was powered by 1.5 hp electric motor to accommodate power losses. The test was carried out in a two-step process of crushing the seeds into paste and pressing the oil out of the paste. Results obtained were mean extraction rate of 2.30 g/min (1.60 ml/min), mean throughput and yield were 1.66 kg/hr, and 35.5 ml/kg, respectively. Mean actual efficiency, weight of residual cake and unrecovered oil were 14.66%, 332.50g and 29.87%, respectively. Performance of the developed machine was compared with other machines and it was higher than that of the manual traditional process. Based on the results obtained after the test running of the machine, it was recommended that a hull removing unit, cake grater and any other additional necessary components should be added to the machine to make it multipurpose.

Keywords: Moringa, oil extraction, oil seeds.

1. Introduction

Moringa (*Moringa oleifera L.*) is a natural as well as cultivated variety of the genus *Moringa* belonging to family *Moringaceae.* It is a small size tree with approximately 5 to 10 m height and is cultivated all over the world due to its multiple utilities. It is a highly valued plant, distributed in many countries of the tropics and subtropics (Warra, 2014). It is popularly known as the "miracle tree" or "tree of life" and identified by various names, such as Drumstick tree or Horseradish plant in English and Zogale in Hausa.

Oil from Moringa seed also known as Ben oil, yields 30 to 40% by weight of sweet non-sticky, non-drying oil that resists rancidity. It has been used in human food as salads, in machines as lubricant (Stevens, 2013), it has a density of 0.9010 mg/ml (Leone *et al***.,** 2016), it is also used in soap making, cosmetics industries and as fuel in hurricane lamps (Okafor, 2010; Stevens, 2013). It has a potential for use as biodiesel (Mulugeta and Fekadu, 2014) and the cake residue results after oil extraction from the seed is used as a primary coagulant in clarification of drinking water and treatment of waste water (Garcia-Fayos *et al.,* 2010; Nwaiwu and Bello, 2011).

The oil has been studied to have a potential as an alternative feedstock for the production of biodiesel. There is a need globally of environmental friendly energy sources for domestic and industrial activities. Presently this energy is mostly provided by fossil fuel, fossil oil and coal. These sources contribute greatly in producing gases that causes some environmental hazards. The use of fossil as base oil in lubricants and as fuel in engines or domestic application build-up harmful materials that presently set the world on the brinks of environmental disaster. Oil sources that are not only producing edible oil, such as moringa seed, produce oil with less expensive materials for biodiesel production (Abdulkareem *et al.,* 2011).

Currently, Moringa oil is generated in small quantity in Nigeria. As at the year 2000, the estimated demand for oil seeds and nuts stood at 1.6 million tonnes per annum with the domestic supply estimated at 1.3 million tonnes, leaving a deficit of 0.3 million tonnes (Anyanwu *et al.,* 2011). As the demand of the seed rises, plantation of Moringa tree will increase which will imply Moringa seed production will increase. However the technology for the provision of the oil has not yet fully developed. In the near future, demand of the oil will increase which calls for a design of an affordable and accessible machine for processing of the seeds.

Despite multiple applications and uses of Moringa seed oil and its cake, the oil is expelled traditionally by squeezing a paste of grounded seed manually. This may not efficiently extract the oil from the cake, even if it does, it takes long time. In conventional large scale oil extraction, application of chemicals to extract oil from the seed is a sophisticated method that may leave a chemical residue in the final product which may affect quality of the seed cake residue. In some cases the oil being produced contains debris and sometimes mixed with hydraulic fluid or fuel being used in the machine. Such machines are expensive and may not be affordable by small scale seed oil producers.

Level of technology in Nigeria also affects efficiency of seed oil production. In developing seed oil production machines, technology involved have normally been introduced with the intention of improving traditional methods. Even though an improved method gives greater efficiency in oil yield, other problems exist. Local manufacturers tend to ignore important considerations such as the effect of friction created by the products to be processed which wears parts of the machine. In maintenance of the machines, local and unskilled mechanics had difficulty in accessing spare parts.

The scope of this work is limited to the design, construction and performance evaluation of a Moringa seed oil expelling machine using physico-mechanical properties of the seeds.

2. Materials and Methods

2.1 Determination of Physico-Mechanical Properties

2.1.1 Determination of moisture content (MC)

A bulk quantity of dehulled moringa seeds were obtained from Damaturu, Damaturu LGA, Yobe State, Nigeria. The seeds moisture content were determine using the ASAE (1983) recommended method for edible beans. This involves, oven drying of seed samples at 103 ºC for 6 hr. The seeds were allowed to cool after which the weight was recorded. Three samples were used and the average moisture content was taken. Moisture content was calculated using;

$$MC = \frac{(m_m - m_d)}{m_d} \times 100 \quad (3.1)$$

where; m_m = the mass of the moist sample
m_d = the mass of the dry sample

2.1.2 Determination of shape and size

To determine the seed size, 100 seeds were randomly selected following similar method followed by Ogunjimi *et al.* (2002). The tree principal axial dimensions; length, width and thickness were measured using a vanier caliper reading to 0.10mm. Bulk samples of the seeds were classified into large, medium and small base on their length. Mathematical relations between the mean values of the major axis was used to calculate arithmetic and geometric mean diameter d_a and d_g respectively, surface area A_s, sphericity $\emptyset$, and aspect ratio R_a.

Arithmetic mean diameter; $d_a = \frac{L + W + T}{3}$ (3.2)

Geometric mean diameter; $d_g = (LWT)^{\frac{1}{3}}$ (3.3)

Surface area; $A_s = \pi D_g^2$ (3.4)

Sphericity; $\emptyset = \frac{d_g}{L} \times 100$ (3.5)

Aspect Ratio; $R_a = \left(\frac{W}{L}\right) \times 100$ (3.6)

Where W = Width
L = Length
T = Thickness

2.1.3 Determination of true density

True density of seeds was determined by water displacement method as reported by Ogunjimi *et al.* (2002). Samples were coated with very thin layer of epoxy resin to prevent absorption of water during the experiment. Weight increase due to the adhesive was noted as negligible. The ratio of the weight of the sample to the volume recorded gives the density and it was recorded before the average true density was determined.

$$True\ Density\ (\gamma_t) = \frac{weight\ of\ the\ seeds}{volume\ of\ water\ displaced} \quad (3.7)$$

2.1.4 Determination of bulk density

Bulk density was determined by using the AOAC (1980) recommended method. This involved the filling of a 500ml cylinder with seeds from a height of 15cm and weighing the content. The ratio of the weight of the sample to the cylinder volume gives the bulk density. It was repeated five times and average recorded value was calculated to determined bulk density.

$$Bulk\ Density\ (\gamma_b) = \frac{weight\ of\ the\ sample}{volume\ occopied} \quad (3.8)$$

2.1.5 Determination of porosity

Porosity was calculated using the relationship between it, true density and bulk density. Value obtained was averaged and the porosity of the bulk sample was determined using equation given by Moshenin (1986) as;

$$P = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \qquad (3.9)$$

Where; P = porosity
ρ_b= bulk density
ρ_t = true density.

2.1.6 Determination of 1000 seed weight

One thousand seeds weight was obtained with the help of an electronic balance weight to 0.001g error. The seeds were randomly selected and weigh on the electronic balance. Value obtained was averaged and the approximate individual seed weight was obtained.

2.1.7 Determination of coefficient of friction

Surface to be tested was fixed on a tilting table and Moringa seeds were poured into a cardboard paper ring of 10cm diameter by 2cm deep until the ring was filled. Care was taken by raising the ring slightly so that it did not touch the surface. The table was then tilted slowly by a screw device until the seeds start moving down the tilt. The tilt angle was recorded and tangent of the angle gave the coefficient of friction. The coefficient of internal friction f_i of particles of a bulk material is associated with the angle of friction $\emptyset_f$ of the material by the relationship;

$$f_i = tan\ tan\ \emptyset_f \qquad (3.10)$$

2.1.8 Determination of angle of repose

Bulk material angle of repose was the angle, φ, between the slope of a freely piled materials and its horizontal base. This angle depends on the flow of material particles. It was obtained by using a specially constructed box with a removable front panel. While the box was filled with the sample, the front panel was quickly removed. This allowed the seeds to flow to their natural slope. The angle was recorded and used in hopper design.

2.1.9 Determination of mechanical properties

Modified Meyer's apparatus was used to determine mechanical properties of moringa seeds. The seed was set up for the test by subjecting it under an impact force generated by dropping a 200 g weight from a given height. The height of the drop was varied with increment of 5mm until the seed was broken. The indentation on the seed was used to measure resistance of the seed to plastic deformation. Force to break and energy to break were determined using Brinell Hardness Number (BHN).

BHN of the seed and the corresponding height of mass drop were plotted on a graph which shows a point at which the seed breaks. The rupture point is a point on the curve at which the seed specimen shows a visible breaks or cracks. The hardness was determined using the formulae below;

$$BHN = \frac{F}{\frac{\pi}{2}\left(D - \sqrt{D^2 - D_i^2}\right)} \qquad (3.11)$$

Where F = the imposed load (N)

D = diameter of seed sample (m)
D_i = diameter of indentation (m)

2.2 Design Consideration

Factors considered in designing the expelling machine includes:-

i. Material availability
ii. Lower material cost
iii. Good rigidity
iv. Easy machining properties and
v. Corrosion prevention.

This makes maintenance and cleaning of the expeller easier. Most parts on the machine were design to withstand vibration and exerted forces. The most critical part of the expeller is the screw shaft which should be able to withstand pressure exerted in expelling oil from Moringa seeds. Based on the reviewed literatures, a continuous system of strainer screw press was found suitable for oil expelling from moringa seeds.

2.3 Description of the Moringa Oil Expelling Machine

The main components of the oil expeller are frame, expeller housing, cake outlet, screw shaft, hopper, driver and driven pulleys, prime mover, barrel and cone. The components were designed using mathematical and empirical formula. The hopper into which the oil seed would be fed was located at the top of the expeller housing. The cone, located at the end of the barrel regulates the expelling pressure. The machine was powered by a prime mover via pulley arrangement connected to the driven pulley.

2.4 Materials Selection

In selecting materials for this project, functional fulfillment, reliability of equipment, economy of production, appearance and durability were considered. Physico-mechanical properties of seeds determined provide design parameters and part dimension used in the development of the expeller. The summary of material selected and the bill for engineering measurement and evaluation are shown below in Table 1 and 2 respectively.

2.5 Determination of Flow Rate

From literature, 2.6 liters of oil obtained from 11kg of seeds i.e 0.2364 liters/kg using manually oil extraction method in an hour operation. According to Jessica *et al.* (2002), mature seeds of moringa have about 40% maximum oil content by weight. This implies that;

$$\frac{mass\ of\ oil}{mass\ of\ moringa\ seed} = 0.4 \qquad (3.12)$$

Therefore $$mass\ of\ oil = mass\ of\ moringa\ seed \times 0.4$$

Table 1: Materials Selected for Expelling Machine Main Components

S/N	omponent part	[aterial
1.	[ain housing	[ild steel sheet

Legen

2.	arrel	quare mild steel bars at mild steel bars
3.	opper	lild steel sheet
4.	crew shaft	ild steel rod
5.	ılley	lild steel
6.	rame	ild steel angle iron
7.	rime Mover	A.C electric motor
8.	all bearing	o P204 series
9.	olts and nuts	ze M10
10.	– belt	-type
11.	ousing	lild steel sheet
12.	onsumables	ectrodes & filing stones,
13.	one	lild steel
14.	nish	aint, sand paper

Table 2: Bill of Engineering Measurements and Evaluation

S/N	Item	Size	nit	Unit Price (₦)	Cost (₦)
1.	lild steel sheet2mm thick	0.4	2	1,750.00	700.00
2.	ild Steel Angle Iron 25mm x25 m	6		260.00	1,560.00
3.	quare iron bar)mm x10 mm	11.5		220.00	2,530.00
4.	crew shaftØ20x300mm	1	c	3,500.00	3,500.00
5.	ollow shaft Ø50 x 500mm	1	c	2,000.00	2,000.00
6.	at bar 2 x 25mm	1.5	[	420.00	630.00

7.	olts and Nuts	14	air	50.00	700.00
8.	ime Mover 1.5 HP	1	Pc	35,000	35,000
9.	all bearing No.201	2	:s	1,000.00	2,000.00
10.	riven pulleyØ150	1	:	2,000.00	2,000.00
11.	– belt	1	:	300.00	300.00
12.	onsumables	-		5,000.00	5,000.00
13.	aint	-		3,500.00	3,500.00
	otal				59,420.00
	abour	10%			5,942.00
	rand Total				65,362.00

2.6 Calculations

2.6.1 *Packed density*

Packed density (γ_p) of the seed was calculated as;

$$\gamma_p = porosity \times bulk\ density \text{ (kg/m}^3\text{)} \qquad (3.13)$$

Where: γ_p = packed density.

= 0.2361 kg/m^3

2.6.2 *Flow rates*

Theoretically, the extracted oil in 1kg should be;

$$1 \times 0.4 = 0.4\ kg$$

Aiming at total oil expelling from the seeds, expelling rate of 1kg of seeds in a minute were used as the capacity of the machine. This gave;

Mass flow rate; $\dot{m} = \frac{1}{60}$

$= 0.017\ kg/s$

Volumetric flow rate; $\dot{V}, = \frac{\dot{m}}{\gamma_p}$ (m^3/s) (3.14)

$= \frac{0.017}{0.2361}$

$\dot{V} = 0.072\ m^3/s$

2.6.3 *Handling capacity of the expelling machine*

Volume of expression chamber at time t;

$$V_c = \dot{V}\ t \qquad (3.15)$$

$= 0.072 \times 1$sec.

$= 0.072\ m^3$

Taking length of the expression chamber L_c to be 0.57 m,

$V_c = 0.57\ A_c$

Where; A_c= cross sectional area.

Therefore; $A_c = \frac{0.072}{0.570} = 0.126\ m^2$

$V_c = 0.072\ m^3$

2.6.4 Power Requirement at the expression chamber

From the mechanical properties of the seed, it was observed that the seed breaks when impact energy reaches 0.147 Nm. This was the same as a torque required on the shaft. The minimum force to break the seed reaches 1.962 N. Taking 500 revolution per minute, the angular speed was calculated as;

$$\omega = \frac{2\pi N}{60} \quad (3.16)$$
$$= \frac{2 \times \pi\, 500}{60}$$
$$= 52.38\ radians/s$$

Total torque on the shaft would be the sum total of torque on individual seed at periphery of compression chamber

$$T = 0.147 \times \frac{L_{pc}}{maximum\ seed\ length}$$

Where L_{pc} = Perimeter of the compression chamber

$$= 2\pi\sqrt{\frac{A_c}{\pi}} \quad (3.17)$$
$$= 1.26\ \text{m}$$

$$\text{T} = 0.147 \times \frac{1.26}{0.012}$$
$$= 15.44\ \text{Nm}$$

Power require in the expression chamber = T× ω (3.18)

= 15.44 x 52.38

= 808.74 W or 1.08 hp

2.7 Determination of Throughput Capacity

Moringa seeds to be used were divided into three samples. Weight of the seeds and the time taken for the expeller to expel oil from the seed were determined and recorded. Then throughput capacity was determined using;

$$\text{Throughput } T_p = \frac{weight\ of\ moringa\ seeds\ feed\ into\ the\ machine}{total\ time\ taken\ to\ expel\ oil\ from\ the\ seed}\ \text{(kg/h)} \quad (3.40)$$

(Samaila and Chukwu2014).

2.8 Expelling Machine Efficiency

2.8.1 Theoretical expeller efficiency

Maximum efficiency was reached when helix angle reached 45°. When the screw moves through one revolution, Work output was determined as:

Useful work = $F_R \times p_{ave}$

Where p_{ave} = Average flight pitch = $\frac{L_c}{2}$ = 0.285

= 255.92 × 0.285

Work output = 72.94 Nm

Then, $efficiency = \frac{work\ output}{work\ input}$ (3.41)

$= \frac{72.94}{79.23} \times 100$

= 92.06%

2.8.2 Actual oil expelling machine efficiency

Actual efficiency were determined by measuring the oil obtained from the expelling machine against the oil content of the seed. Oil obtained from three samples were recorded and efficiency was calculated using;

$$\eta_a = \frac{quantity\ of\ oil\ obtained}{oil\ content\ of\ moringa\ seeds} \times 100 \quad (3.42)$$

2.9 Performance Evaluation

The amount of oil removed, the amount of energy required to remove the oil and the quality of oil obtained with respect to the intended application were used to evaluate the machine performance. Extraction rate and Yield of the expeller were calculated on mass and volumetric bases as follows;

$$\text{Extraction rate } R_e = \frac{\frac{weight}{quantity\ of\ oil\ expelled}}{expelling\ time} (kg/h)\ or\ (Lt/h) \quad (3.43)$$

$$\text{Yield } Y_e = \frac{quantity\ of\ oil\ obtained}{original\ weight\ of\ seeds} \times 100\ \ (\%) \quad (3.44)$$

2.10 Testing Procedure

Step 1

i. Sample was divided in to four groups of 500g each
ii. The machine was started by switching on the prime mover
iii. Two container for collecting the grounded seeds and the oil was placed under the chute and oil outlet respectively
iv. The samples were gradually poured into the hopper at the same time a stop watch was started
v. The sample was collected as a paste and the time taken was recorded.

Step 2

i. The paste was poured into the hopper
ii. About 10 ml of hot water was gradually poured onto the paste in the hopper
iii. Oil and the cake was collected and the time taken was recorded
iv. The process was repeated three times each with different sample

3. Results and Discussion

Results obtained from the determination of physico-mechanical properties and the design specifications of each part of the expelling machine were presented in this chapter. Derived data from physico-mechanical properties and standard values used in the development of the machine were shown in appendix IV. The physical properties consist of dimensional, gravimetric and frictional properties. The dimensional consist of properties related to length, width or thickness of the seed. Seed properties related to weight were gravimetric, and those with movement between seeds and a surface were frictional. The physico-mechanical properties were observed at 6.75 moisture contents.

3.1 Physical Properties

3.1.1 Dimensional properties

Major axes of moringa seeds were used to determine its dimensional properties. They were recorded in table 3 below. Mean value of length, width and thickness were found to be 8.94 ± 0.93, 7.84±0.64 and 6.96±0.75, respectively. Maximum seed length was 12.14mm which was used as the space between the flight shaft and the barrel. Values reported for moringa seed (Ajav and Fakayode, 2013a) were 8.45±0.976, 7.82±0.922 and 6.41± 1.092mm, respectively.

Table 3: Dimensional Properties of Moringa Seeds

xis	Unit	N	Max.	Min.	mean	SD	CV
ength	mm	100	12.14	7.0	8.94	0.93	0.87
/idth	mm	100	9.12	5.9	7.84	0.64	0.41
hickness	mm	100	8.62	4.42	6.96	0.75	0.56
rithmetic mean ameter, D_a	mm	100	9.45	6.27	7.92	0.62	0.39
eometric mean iameter, D_g	mm	100	9.17	6.09	7.70	0.60	0.36
ırface area, A_s	mm^2	100	65.99	29.12	46.85	7.24	52.40
phericity	%	100	97.02	68.54	86.46	5.56	30.90
spect Ratio	%	100	101.64	61.29	88.24	7.91	62.52

Based on recommendation by Olayanju, (2002), large oil barrel clearance may result in partial crushing of seeds and too small clearance, may lead to excessive choking of the discharge section during oil expression. For optimum performance of the oil expeller, the barrel clearance was minimised to 2mm, which will be sufficient enough to allow oil to move out without the cake.

The size and shape of Moringa seeds affects the handling of losses during oil expression, hence, mean arithmetic diameter, geometric diameter and surface area, were found to be 7.92mm, 7.70mm and 46.85mm^2, respectively. Mean values of sphericity and aspect ratio were 86.46% and 88.24% this shows that the seed shape is almost a sphere. The sphericity was used in designing the conveying section geometry of the barrel. Sphericity and aspect ratio has a standard deviation of 5.56% and 7.91%, respectively. This shows that the remaining 92.09% to 94.44% of the seeds has negligible deviation from the mean value.

3.1.2 Gravimetric and frictional properties

Gravimetric and frictional properties of the Moringa seeds were determined and recorded. The mean value of true and bulk densities were found to be 0.95kg/m^3±0.0115 and 0.52 kg/m^{-3}± 0.0248, respectively. Mean porosity of 45.02% was obtained which is similar to reported values by (Ajav and Fakayode 2013a) as average porosity, true and bulk densities were 68.18%, 0.971gcm^{-3} (971kgm^{-3}) and 0.662gcm^{-3} (662 kgm^{-3}), respectively.

One thousand seed weight and mean coefficient of friction on mild steel sheet surfaces were 229.51g and 0.45 similar to the value of 239.20g and 1.376 as respectively found by (Ajav and Fakayode 2013a) and 0.39 friction coefficient of beniseed on same surface of at least 5.3% moisture content was reported by Olayanju (2003). The one thousand seed weight and coefficient of friction were used in calculating various forces required to compress the seeds and the frictional force from the screw's motion.

Mean angle of repose was 17.82° ± 1.0616° unlike a finding by (Ajav and Fakayode, 2013a) of 21.44± 0.745°. Bolufawi (2004) also reported groundnut mean repose value of 35.79°. Considering standard deviation, a slightly higher value than the mean repose was used to position the hopper for consistent seeds flow. Table 4 below shows the result obtained in 5 different observations with minimum, maximum and mean values with the respective standard deviation and coefficient of variation. Raw data obtained was recorded in appendix III.

Table 4: Gravimetric and frictional properties

Physical properties	Unit	Min.	Max.	Mean	Standard deviation	Coefficient of variation
Moisture content	%	5.83	6.9	6.75	0.4800	0.24
True Density ρ_t;	Kg/m^3	0.94	0.97	0.95	0.0115	0.0001
Bulk Density ρ_b	Kg/m^3	0.49	0.55	0.52	0.0248	0.0006

Porosity ***P***	%	-	-	-	45.02	-
Coefficient of friction	Fraction	0.43	0.46	0.45	0.0128	0.0002
Angle of Repose, ***φ***	Degree	16.39	19.03	17.82	1.0616	1.1271

3.3 *Mechanical Properties*

Hardness is one of the mechanical properties of the seed determined. Maximum values of indentation created on the seed, the corresponding height of mass drop and Brinell Hadness Number were 4.86 mm, 75mm and 3366.52, respectively. Mean value of energy needed to break the seed was determined through a point when the dropping height was just about 75mm which gives energy equivalent to 0.147 Nm. Breaking force obtained of 76.83 N was similar to 58.54 N varying from 49.900 N to 67.000 N as obtained by (Ajav and Fakayode 2013b). Energy needed to rupture the seed was found to be 0.147 Nm with minimum indentation diameter of 4.86 mm. A summary of results obtained were presented in table 5 below.

Table 5: Break Energy Requirement of Moringa Seeds

Indentation diameter, D_i (mm)	Height of drop, h (mm)	Brinell Hardness Number (BHN)	Energy (Nmm)	Regression (*Y Value)
1.89	5	3366.52	9.81	2120.29
2.49	10	1885.96	19.62	1952.90
2.65	15	1647.76	29.43	1785.50
2.93	20	1316.77	39.24	1618.11
3.31	25	997.13	49.05	1450.72
3.51	30	865.84	58.86	1283.33
3.42	35	923.33	68.67	1115.94
3.87	40	679.43	78.48	948.54
4.12	45	577.60	88.29	781.15
4.16	50	561.01	98.10	613.76
4.28	55	515.93	107.91	446.37

4.58	60	417.11	117.72	278.98
4.72	65	371.71	127.53	111.58
4.86	70	325.32	137.34	-55.81
Broken	75	-	147.00	-

*Y = 2287.68 – 33.48x

Singh and Goswami (1996), quasi-statically loaded a Cumin seeds in the horizontal and vertical orientations. It was observed that force increased with increasing deformation of the seeds. Force required to initiate seed rupture decreased from 40 N to 20.3 N as seed deformation increased from 0.285 to 0.428 with increase in moisture content from 7 to 12% d.b. The energy absorbed increased with increasing moisture content and it followed a second-order polynomial regression. Maximum energy absorbed was found to be 14.8 and 20.4 mJ at the moisture content of 7% d.b.

Regression analysis was carried out with the Brinell hardness number as a dependent variable while height of drop, h as the independent variable. The result obtained shows a minimum point of -55.81 at 325.32 BHN. The negative sign indicate a change in direction at which a point will be found where the energy was just enough to break the seed. The breaking force was determined by a curves obtained after plotting Brinell hardness number against height of drop, h as shown in figure 3 below. The "r" value obtained was -0.85.

The breaking force was used in the calculation of the main forces acting on expeller screw. From the figure, it was observed that the Brinell hardness number decreases as the height of drop increases this correspond to the decrease in the hardness of the seed as the indentation force increase. Energy required to break the seed was then determined to be greater than or equal to 147 Nm. This was the same as the torque used to determine the power needed to break the seed for oil to be expelled.

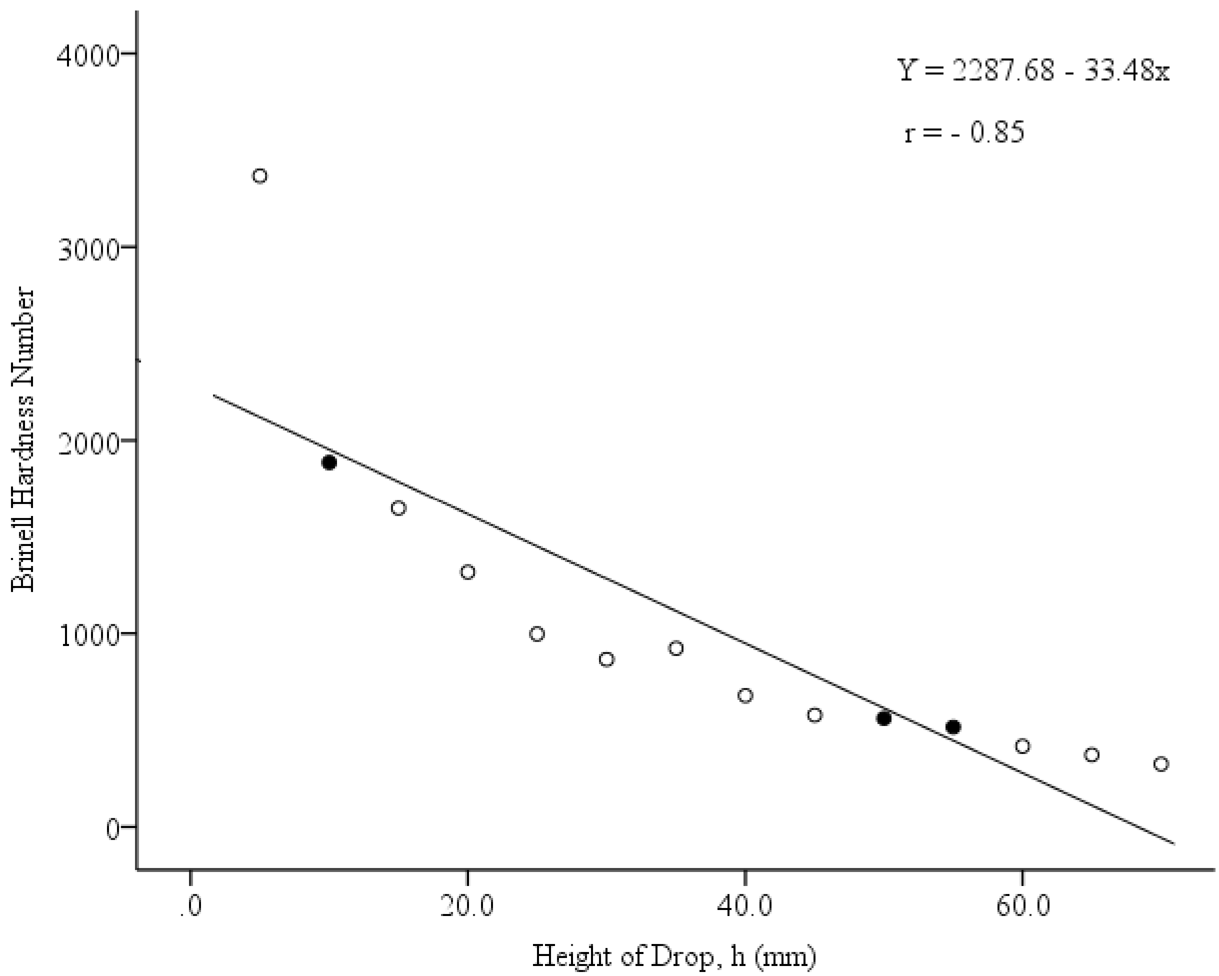

Figure 3: Regression analysis of Brinell Hadness Number and Height of Drop for Moringa Seeds

3.4 Moringa Oil Expelling Machine Output

Sample of moringa seed was divided into four, each sample weighed 500g. The operation was done by running the sample twice through the expeller. The first run grounded the seeds into paste without expelling oil. Mean time taken to ground the seed t_t was 6.92 minutes with maximum of 7.49 minutes. In the second run, 11.14 minute was recorded as the mean time t_e, that expelled the oil. Average volume of oil obtained, V_{ol} was 17.75 ml with the maximum of 26 ml. Average weight of expelled oil V_{ow} was 25.65g (29.87%) with the range of 28.09% to 30.77%.

Mean weight of the cake obtained was 332.5g (33.5%). Unrecovered oil varies from 28.09 to 30.77% which doubled the reported residual oil from seed cake of 10% - 15%. (Osamu *et al*., 1999 and Riva and Sissot, 1999). In developing Sunflower oil expeller, Bamgboye and Adejumo (2007), obtained expelling efficiency of over 70% with expelling capacity of 24.4 litres/hr of oil and throughput capacity of 502.64 kg/day. **Table 6 below recorded the output of the expelling machine with the corresponding time taken.**

Ibrahim and Onwualu (2005) in a review of technologies for extraction of oil from oil-bearing agricultural products records that most power-driven expellers are capable of extracting an average of 4.77

liter from seeds weighing between 8 and 45 kg with average as 26.5 kg of oil seeds in one hour. Depending upon the type of expeller used the volume of oil obtained can vary. Olatunde *et al.,* (2014) extracts about 1.2 liters from 4kg of groundnut oil with a fabricated expeller in one hour.

Table 6: Values Obtained after Test

ample	t_t (min)	$_{ol}$ (ml)	$_{ow}$ (g)	$_{ow}$ (%)	**ake** (g)	ake (%)	nrecovered il (%)	$_e$ (min)
A	03	7	.49	50	)0	40.00	30.50	).17
B	49	5	.4	88	50	30.00	30.12	.91
C	14	3	.16	23	30	24.00	30.77	.04
D	02	5	.55	91	)0	40.00	28.09	.44
ean	92	.75	.65	13	2.5	33.50	29.87	.14

<u>Key</u>
t_t = time taken to complete step 1 procedure
V_{ol} = volume of oil obtained in millilitres
V_{ow} = volume of oil obtained in grams
t_e = time taken to expel oil in step 2 procedure

3.5 Performance Evaluation

Performance of the expelling machine was determined when the machine was tested. The screw shaft of the expelling machine runs at 52.38 radians/s and driven by a 1.5 hp prime mover was used in testing the machine. For best performance, the expelling machine was fed continuously at 0.017 kg/s while a stop watch determined the time. The high sphericity of the Moringa seeds allows its flow into the compression chamber. Mean throughput capacity, actual efficiency, extraction rate in grams and extraction rate in millilitres of the Moringa seed oil expelling machine was 1.66 kg/hr, 14.66%, 2.30 g/min and 1.60 ml/min, respectively. Standard deviation of 0.0883 shows the throughput capacity is more consistent during the test. Deviation of 3.47% efficiency shows greater disparity between each trial.

The mean yield obtained was 35.5 ml/kg and was below the recorded oil yields of Jatropha curcas, 46.4%; Neem, 45.3%; Castor, 47.2% and Moringa seed, 40.2% (Zaku *et al*., 2012). Jessica *et al.* (2012) used a cell of 100cm^3 with flow rate of 0.66g/min with only 30 minutes duration to expel Moringa oil. Olatunde *et al.* (2014), obtained highest percentage groundnut oil yields of 41.6, % at 6% moisture content. Oil yield was similar to that obtained by Samaila and Chukwu, (2014), whose value was 30.23ml/kg obtained when 5 kg of melon seeds were fed into a motorized '*egusi'* melon seeds oil expeller with throughput capacity of 10.12 kg/hr and extraction efficiency of 60.83%.

Bamgboye and Adejumo (2007) developed a sunflower oil expeller and found the performance with the throughput capacity of 502.64 kg/day (20.94 kg/hr) and efficiency of 70% (that is 35%with respect to 50% sunflower oil content), respectively with the oil extraction rate of 24.4 l/hr (40.67 ml/min).

Olatunde *et al.,* (2014) design and fabricate a groundnut roster cun expeller with power rating of 5.5KW recorded the throughput capacity of 4kg/hr with the screw shaft rotating at 60 revolutions per minute. The highest oil yield was 41.6%, an equivalent of 92% when compared to 45% oil content of groundnut, at 100ºC, and 6% moisture content.

Amruthraj *et al.,* (2013) design and develop a twin screw oil expeller for pongamia pinnata seeds with high through put of 80 to 100 kg/hr and reported that single screw press expeller can process only 25 – 30 kg of Pongamia pinnata seeds per hour in three or more passes, with low oil yield of about 18 percent.

Table 7: Performance of the Moringa Seed Oil Expelling Machine

ample	Throughput (kg/hr)	Actual Efficiency, (%)	ɛxtraction Rate (ml/min)	(g/min)	'ield (ml/kg)
	1.74	12.85	2.21	1.67	34.0
	1.55	13.94	2.05	1.26	30.0
	1.65	12.09	1.92	1.18	26.0
	1.72	19.74	3.02	2.27	52.0
otal	6.66	58.63	9.20	6.38	142.0
lean	1.66	14.66	2.30	1.60	35.5
D	0.09	3.47	0.50	0.50	11.5

3.6 Performance of the Moringa Seed Oil Expelling Machine in Relation to other Machines

Performance of the oil expelling machine was compared to other machines based on the throughput capacity and actual efficiency. Table 8 below shows the relationship with a Ghani, strainer screw and a twin screw oil expeller. The developed oil expeller has higher actual efficiency than the Ghani oil expeller and twin screw oil expeller while its throughput was the lowest.

The Ghani oil expeller has mean value of 4 kg/hr throughput capacity with mean actual efficiency of 14.66%, strainer screw expeller has about 26.50 kg/hr with an actual efficiency of 31.50 % while twin screw expeller has a throughput capacity of 27.50 and mean actual efficiency of 18%. This shows that the developed moringa seed oil expelling machine has a better performance than the ghani oil expeller but has less performance and actual efficiency than strainer screw expeller and twin screw expeller.

Table 8: Performance of the Moringa Seed Oil Expelling Machine in Relation to other Machines

Machines	Throughput (kg/hr)	Actual Efficiency (%)
Developed Expeller	1.69	14.66
Ghani Oil Expeller	4.00	14.35

Strainer Screw Expeller	26.50	31.50
Twin Screw Expeller	27.50	18.00

3.7 *Comparative Analysis of the Machine with Manual Method*

The developed Moringa seed oil expelling machine was compared with a manual traditional method of the seed oil expelling. The oil expelling machine has a mean throughput capacity of 1.66 kg/hr, actual efficiency of 14.66%, mean extraction rate of 1.60 ml/min and a yield of 35.5 ml/kg while the manual traditional method had a throughput capacity of 0.33 kg/hr, mean actual efficiency of 14%, mean extraction rate of 1.33 and mean yield of 30.00 ml/kg. Comparing the result obtained, the performance of the moringa seed oil expelling machine was higher than that of manual traditional expelling process.

Ibrahim and Onwualu (2005), attribute the inefficiency and lower performance in manual traditional method to the use of mortar and pestle or grinding stones. This crude nature of the processing affects the quantity of oil recovered at the end of processing the oil seed.

Table 9 below shows comparison between the developed moringa seed oil expelling machine and manual traditional method. The expelling machine varies from the manual in throughput capacity, actual efficiency, extraction rate and yield with 0.93, 0.22, 0.37 and 15.13, respectively. Highest deviation was observed in yield while the lowest deviation was in the extraction rate.

Table 9: Comparative Analysis of the Machine with Manual Method

	DEM	MM	D	AR
hroughput (kg/hr)	1.69	33	9641	9294
Actual Efficiency (%)	14.66	.00	4667	2178
xtraction Rate (ml/min)	1.60	33	1909	0365
Yield (ml/kg)	35.50	.00	8891	.125

DME = Developed expelling machine
TMM =Traditional manual method
SD = Standard deviation

VAR = Variation

4. Conclusion and Recommendation

4.1 *Conclusion*

Physico-mechanical properties: moisture content, shape and size, true density, bulk density, porosity, one thousand seed weight, friction coefficient, angle of repose and breaking energy of Moringa seed determined were found to be within range as determined by Azeez *et al.* (2013), Ajav and Fakayode (2013a) and (2013b), Olayanju (2003) and Bolufawi (2004). The machine was developed using the determined properties and after testing, an average of about 95.72 ml per hour was obtained. The highest actual efficiency was 14.86% and mean throughput capacity was 1.6647 kg/hr. These results indicate that the sample seed yield oil enough to be extracted for small scale production.

The efficiency obtained was less than the 40% obtained by the traditional method and not up to 90% and 98% of oil-plate presses and solvent extraction respectively. The machine does not require pre-heating of the seeds before extraction begins like other types of oil extraction mechanisms required. With the 1.6647 kg/hr throughput, the machine can processed about 11.65 kg per day which is 0.15 kg greater than 11.5 kg average of the wooden ghani.

For normal working hours of 7 hours per day and 5 days a week for a year operation, the mean annual oil extraction rate of 2.30 g/min will produce 0.25 tonnes annually, which is to say that 100 pieces of the machine will yield about 8.3% of the reported 0.3mt deficit of annual seed oil demand in Nigeria (Anyanwu *et al*. 2011). With same operation, the mean seed cake produced by the machine was 1.8 kg/hr. This will amount to 3.276 tonnes per annum. Comparing with the report by Schwarz (June 2000), the cake produced in a year will coagulates about 32,760 litres of water as 1 kg of moringa seed cake powder will treat about 10,000 litres of water.

4.2 Recommendation

Based on the results obtained after the test running of the Moringa oil expelling machine, there is a need to improve the machine for better performance. To achieve this, the following are recommended;

a. The machine should be optimized by improving the flow rate, actual efficiency and throughput capacity.
b. A hull removing unit, cake grater and any other additional necessary components should be added to the machine to make it multipurpose.
c. The two-step process of crushing the seeds to paste and pressing the oil out of the paste should be integrated as a single process.

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EFFECT OF TEMPERATURE ON THIN-LAYER DRYING CHARACTERISTICS OF SLICED OKRA *(ABELMOSCHUS ESCULENTUS)*

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Abstract

Okra (Abelmoschus esculentu) is harvested in sufficient amount during wet season, therefore, postharvest losses increases during off-seasons because of its perishability in nature which leads to expensiveness and lost by deterioration. Drying as a method of preservation can reduce these losses. This research is to study the effect of temperature on thin-layer drying characteristics of Okra (Abelmoschus esculentu) applying convective oven dryer method at 12-deferent temperatures amongst are 60, 65, 70, 75, 80, 85, 90, 95, 100, 105, 110^{0}C, and 115^{0}C and was imputed into Page, Henderson-Parbis, and Lewis models in other to predict the drying kinetics based on linearize Fick's Second law of diffusion. The temperature dependent effective diffusivity and the related activation energy was investigated as their values ranges from 1.369x10^{-7}-7.12x10^{-8}m^2/sec and 0.1235kJ/mol.k respectively which is an indication that moisture reduction from the samples increased rather sharply at the initial stages of drying became exponentially at the later stages. It is therefore, shows that drying of the Okra (Abelmoschus esculentu) took place almost entirely in the falling rate period, characteristic of drying of biomaterials. The Page model closely followed by the Henderson-Parbis' were noticed to be the best models applicable for predicting the drying behaviour of the Okra (Abelmoschus esculentu) by a non-linear regression analysis.

Keywords: *Okra , drying kinetics, thin layer, activation energy, and effective moisture diffusivity.*

1. Introduction

Okra (Abelmoschus esculents (L) Monarch is an annually harvested vegetable crop belonging to malvaceae family. Okra is mostly sliced and dried and sometimes grinded into a powder form. Okra is consumed as snack, cooked and fresh vegetable addictive to soup, stew or salace. Okra is consumed in a large quantity in Nigeria (FAO 2014). Okra is a good source of carbohydrate, protein, dietary fibre, calcium, magnesium, potassium and vitamin A and C (Pendre *et al* 2012). Because of its sensitivity and essentiality to storage most fresh okra preserved in some way such as solar drying, hot air dryer, open sun dryer and ovum drying method. Solar dryer is a reciprocal to hot air and open sun drying methods mostly in a place where sunshine is favourable during harvest period (Pangavhane, Sawhney and Sarsavadia, 2002).

Okra freshly harvested have high systematic moisture content and respiratory activities whereas it can be best preserve at moisture level of 10% wet basis (Shivhare *et al* 2000). Due to the high level of moisture content of okra, okra is subjected to easily deterioration causing chemical, physical, and biological damage. Drying is very important in reducing the growth of microorganism and deterioration processes (Falade and Omojola 2010). Drying helps in reducing postharvest losses of fruits and vegetables, particularly those that have moisture content as high as 70% (Guan *et al* 2013). Drying lengthen the shelf life of agricultural product without addictive of any form of preservative and it assists in size reduction during packaging and reduce cost of transportation (Figiel 2010). Drying does not only reduce moisture content but also affect its organoleptic properties, enzymative activity, rheology properties, hardness and microbial spoilage.

The two most common type of drying are sun drying and hot air drying and they are different types of disadvantages that are not hygienic and not desirable for food industry (Soysal and Oztekin 2001). Oven drying method is a good alternative method. It has a space capacity, hygienic condition, time saving, precise control system, energy saving, easy setup and shutdown. It reduces drying time and stop food from being decomposing (Maskan 2000). It's applied to numbers of agricultural products such as banana (Masken 2000), Spinads (Ozkan *et al* 2007). As shown in Plate 1.1

Preservation, drying has been a method to pro-long it shelf life to prevent deterioration but improved and maintained it quality. Severally, several publication has been published on drying of biomaterials, they include egg-plant (Ertekin and Yaldiz., 2004), mud snail meat (Burubai and Bratua., 2015), Green pepper and Onion (Yaldiz and Ertekin, 2001), Soyabeans (Gely and Santalla, 2000), apple (Wang *et al*; 2006), and African nutmeg (Burubai and Etekpe, 2014). This research work is Effect of temperature on thin-layer drying characteristics of Sliced Okra *(Abelmoschus esculentus)*

Plate 1:1 Sliced Okra (Abelmoschus esculents (L) Monarch

2. Materials and Method

Okra *(Abelmoschus esculentus)* was harvested fresh from Ondewari town market Southern Ijaw local government area of Bayelsa state. The sample was taken to the food processing laboratory in Niger Delta University, Bayelsa State Department of Agricultural and Environmental Engineering in other to study their drying kinetics Okra *(Abelmoschus esculentus)* was measured with vanier caliper with equal thickness of $13\times \mathbf{10}^{-3}$m and was weigh with top digital balance which initial weight was taken as 29.85grams and was oven dried using (WTC binder oven Model WTCB 1718). The samples of equal weight and thickness were measured and oven dried at varying temperatures from 60^0C-115^0C with an increment of 5^0C. The initial moisture content of the samples was then determined by the oven method as recommended by ASAE standard (S368 41 2000). The samples were studied and experimental data and predicted data were calculated accordingly from the beginning of the drying experiment at every 5mins to when its equilibrium moisture content took place. The method of drying employed in this research was oven drying method. This method was also applied by Jittanit, (2011) for pumpkin seeds and grape seeds (Robert *et al,* 2008). The drying test was replicated thrice at each temperature levels and averages were recorded.

Thin Layer Models

Thin layer models are usually used often to betel the dehydration of kinetics from different types of permeable materials. The thin layer drying models are mainly depicted the drying of agricultural products fall mostly into three classes namely theoretical, semi-theoretical and empirical. The theoretical takes in consideration only intern resistance movement of moisture stasis while semi-theoretical and empirical models put into consideration extern movement resistance to moisture stasis between the agricultural biomaterial and the aura. (Fortes and Okos 1981).

Fick's Second Law of Moisture Diffusion

Fick's second law of moisture diffusion was used in this technical research in a permeable media and was adapted in the method of drying as reported by (Crank, 1975)

$$\frac{\delta m}{\delta t} = D\frac{\partial 2m}{\partial t2} \quad (1)$$

where m is moisture content (kg water/kg solid); t = time (s); D = diffusion coefficient for moisture in solids (m^2/s).

Moisture Ratio

The initial weight of the Okra *(Abelmoschus esculentus)* was measured to be 29.85gram and the moisture content of the sample was determined with the cited to the bone-dried according to AOAC (2000) using the equation (2)

$$MR = \frac{m_i - m_e}{m_0 - m_e} \text{ x } 100\% \text{ (wetbasis)} \quad (2)$$

where MR = dimensionless moisture ratio, M_i = instantaneous moisture content (g water/g solid) m_e = equilibrium moisture content (g water/ g solid), m_0 = Initial moisture content (g water/ g solid). Nevertheless, due to incessant undulating of relative humidity of the dehydration air in dryer, equation can be written as equation (3).

$$MR = \frac{m_i}{m_0} \quad (3)$$

Moisture Content

The initial weight of the Okra *(Abelmoschus esculentus)* was measured to be 29.85gram during drying record of the experimental data was taken at every 5mins. The moisture content of Okra *(Abelmoschus esculentus)* was calculated using equation (4) as reported by AOAC (2011)

$$MC = \frac{w_i - w_d}{w_i} \text{ x } 100\% \quad (4)$$

where MC is the moisture content, w_i is the initial wight of the sample before drying and w_d = is the mass of the sample at time t.

Calculation on Effective Moisture Diffusivity

In calculating the effective moisture diffusivity (Deff) the application Fick's second law equation of diffusion was used. However, constant moisture diffusivity infinite slab geometry and a uniform initial moisture distribution was taken into consideration in equation (5).

$$MR = \left(\frac{8}{\pi^2}\right) \sum_{n=0}^{\infty} \frac{1}{2n+1} \; exp^{\left(\frac{-(2n+1)^{\pi^2}}{4L^2}\right)Deff^{t}} \quad (5)$$

where Deff is the effective diffusivity (m^2/s) and L is the sample thickness in (m) measured to be 0.013m and t is the drying time. Equation (5) was deduced to produce equation (6)

$$MR = 0.8104 \exp\left(-\frac{\pi^2}{4l^2}\, Deff^t\right) \quad (6)$$

In other to Linear the equation (6) natural logarithm of both sides is taken thereby transforming it to produce equation (7) (Burubai, W. & Etekpe, G.W., 2014)

$$In(MR) = In\ (0.8104) \exp\left(-\frac{\pi^2}{4l^2}\, Deff^t\right) \quad (7)$$

Hence, equation (7) produces equation (8)

$$In(MR) = In\ (0.8104) - \frac{9.872}{0.000676} Deff^t \quad (8)$$

Therefore, plotting In(MR) versus drying time (t), which resulted a slope, whereby, the effective moisture diffusivity was obtained.

Further deducing of equation (8) will produce equation (9) and equation (10)

$$Slope = -14603.6Deff \quad (9)$$

$$Deff = \frac{Slope}{0.000676.} \quad (10)$$

Activation Energy

Arrhenius equation was used to calculate the activation energy as shown in equation (11)

$$Deff = D_O\ esp\left[-\frac{Ea}{R\ (T+273.15)}\right] \quad (11)$$

where D_0 is the pre-exponential factor of the Arrhenius model in m^2/s, Ea is the activation energy in kj/mol, R is the universal gas constant kj/mol k and T is the absolute air temperature.

Taking natural logarithm of both sides simplified to produce equation (12)

$$InDeff = InD_0 \left[-\frac{Ea}{8.3145\ (T+273.15)}\right] \quad (12)$$

The activation energy was calculated by plotting natural logarithm In(Deff) against inverse of the absolute temperature $\left(\frac{1}{T}\right)$

Non- linear regression equation was used to determine each constant of selected statistical model in other to obtain the best model for experimental data that described the drying curves. The best suitable and most appropriate of the selected model was examined from reduced chi-square (X^2), root mean square error (RMSE), coefficient of determination (R^2) and mean bias error (MBE). The higher the values of R^2 (proximity to one), the lower the values of (X^2) and the RMSE (proximity to zero) ascertained definitely the goodness of fit (McMinn, 2006). These evaluation criteria methods can be determined as

$$X^2 = \sum_{i=1}^{n} \frac{(MR_{pre} - MR_{exp})^2}{N-K} \quad (13)$$

MBE = $\frac{1}{N}\sum_{i=0}^{n} \quad (MR_{Pred} - MR_{exp})$ (14)

RMSE = $\frac{1}{N}\sum_{i=0}^{n} \quad (MR_{Pred} - MR_{exp})^{1/2}$ (15)

Lewis model

MR =exp(-kt) (kingly et al., (2007)) (16)

Taking natural logarithm of both sides deduced equation (17)

In(MR) = -kt (17)

A plot of In(MR) against time T and the constant k is evaluated

Henderson- Parbis Model

MR = aexp(-kt) (chinnman, (1984)) (18)

Taking natural logarithm of both sides deduced equation (19)

In(MR) = Ina- kt (19)

A graph of In(MR) against time T and the constant 'k' and coefficient 'a' is obtained from the graph.

Page Model

MR =exp(-kt^n) (karathonos and Belessiotics (2003)) (20)

Taking natural logarithm of both sides deduced equation (21)

$log\ log\ (-\ ln\ ln\ (MR)\ ) = n\ log\ log\ t\ \ +log\ log\ k$ (21)

A plot of $log\ log\ (-\ ln\ ln\ (MR)\ )$ against logt and constant K and coefficient is deduced from the graph

3. Results and Discussions

The moisture ratio of the sample was determined from the drying data (moisture ratio) collected plotted against time as shown in figure1

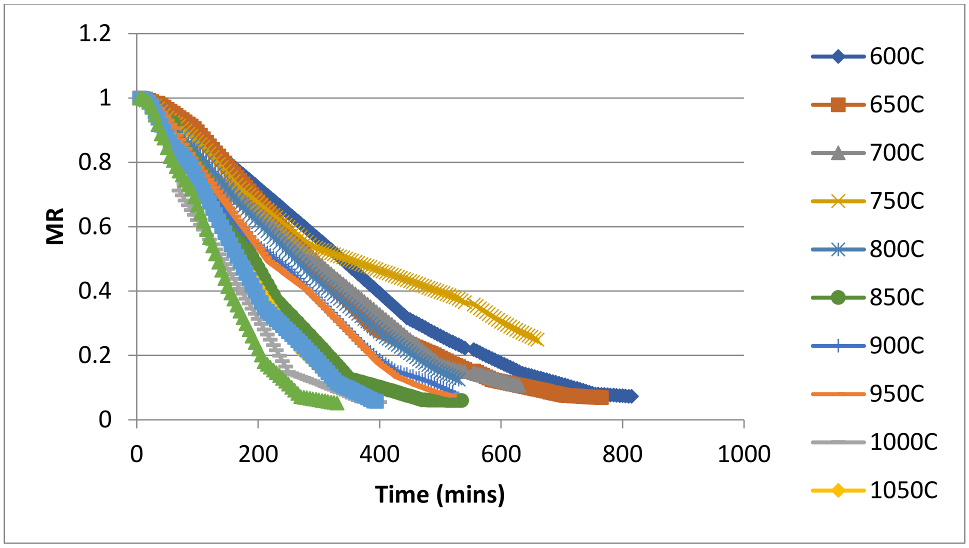

Figure 1: Moisture ratio for Okra (Abelmoschus esculentus) at different temperature

Experimentally, from figure 1 shows that the higher the temperature, the shorter the time of drying. It has proof clearly like other Agricultural biomaterials, the drying of Okra *(Abelmoschus esculentus)* falls mainly under the falling rate period. This indicated that, the drying rate of Okra *(Abelmoschus esculentus)* was basically controlled by internal diffusion. Similar results had been published by other scientists on different biomaterials and food products (Doymaz, 2004, Kilic, 2009, Burubai and Etekpe, 2014).

Fitting of Drying Curves

The statistical parameters are useful in analysing experimental results. The statistical parameters considered in this work are coefficient of determination (R^2), mean square error (MSE) reduced chi-square (X^2) mean bias error (MBE) as shown in Table 1 below.

Table 1 Statistical results of the model for Okra (Abelmoschus esculentus)

MODEL	Temp (0°C)	a	n	k	R²	MBE	X²	RMSE
	60		0.000116	0.6522	0.9984	0.00324	0.0017115	0.041113
	65		0.000098	1.5646	0.9978	0.00107	0.000158	0.012497
	70		0.00015	1.5813	0.9928	0.004041	0.001617	0.001584
	75		0.000466	1.2411	0.9866	0.00127157	0.0002135	0.0144982
Page	80		0.000391	1.3564	0.9986	0.00318957	0.0010991	0.0328386
	85		0.000264	1.5096	0.9969	0.00380728	0.0015805	0.03938278
	90		0.000294	1.4488	0.9831	0.00370566	0.0014561	0.03779004
	95		0.000196	1.5252	0.9932	0.00367881	0.0014216	0.03733583
	100		0.000146	1.7055	0.9773	0.007029	0.004054	0.06287

	105		0.000219	1.5859	0.9926	0.006028	0.002909	0.053242
	110		0.000224	1.5828	0.9924	0.00602343	0.0029407	0.00286625
	115		0.000141	1.7567	0.9845	0.008138	0.0045076	0.066114
	60	1.3867		0.0035	0.9785	0.046852	0.357864	0.59449
	65	1.3668		0.004	0.99	0.057671	0.508961	0.708675
	70	1.4718		0.0057	0.9568	0.077861	0.600422	0.766839
	75	1.0251		0.002	0.9908	0.011982	0.018954	0.13661
Henderson	80	1.2535		0.0039	0.9733	0.034978	0.132178	0.360117
	85	1.4262		0.0063	0.9821	0.109182	1.29915	1.129389
	90	1.2807		0.0047	0.971	0.049164	0.2563031	0.501372
	95	1.3795		0.0052	0.9632	0.064182	0.432696	0.651379
	100	1.384		0.0083	0.9867	0.136963	1.539193	1.225036
	105	1.4799		0.0074	0.9644	0.107364	0.922776	0.948217
	110	1.4736		0.0074	0.9639	0.108609	0.956089	0.965342
	115	1.5909		0.0104	0.97	0.209386	2.984027	1.701059
	60			0.0035	0.9785	0.418864	0.176543	0.418864
	65			0.004	0.99	0.509274	0.261089	0.509274
	70			0.0057	0.9568	0.505459	0.25815	0.505459
	75			0.002	0.9908	0.132048	0.01757	0.132048
	80			0.0039	0.9733	0.277107	0.07752	0.277107
Lewis	85			0.0063	0.9821	0.780531	0.614976	0.780531
	90			0.0047	0.971	0.381507	0.146961	0.381507
	95			0.0052	0.9632	0.459624	0.213325	0.4596624
	100			0.0083	0.9867	0.873075	0.771909	0.873075
	105			0.0074	0.9644	0.623686	0.394036	0.623686
	110			0.0074	0.9639	0.63859	0.413026	0.63859
	115			0.0104	0.97	1.04993	1.1193126	1.04993

The R^2 values according to the models were recorded in the range of 0.9775-0.9986 for page model, 0.9632-0.9908 for Henderson model and 0.9568-0.9908 for Lewis model. The MSE values ranging from 0.00158-0.0661 for page, 0.1366-1.7011 for Henderson, and 0.2771-1.0499 for Lewis model. It shows that page has the lowest MSE value and the reduced Chi-square value (X^2) closer to 0 which ranging from 0.000158-0.00109 while Henderson model ranging from 0.018954-2.984027, 0.0175-1.1193 for Lewis model. Therefore page model been the lowest MSE and (X^2)-value closest to zero is considered to be the best model predicting the drying behaviour of Okra *(Abelmoschus esculentus)*. Thus a relationship between measured and predicted moisture ratios is as shown in Fig 2 and since the moisture ratio values are banded or clustered along the straight line of the graph, it is an indication of good fitness of the page model in describing the drying characteristics of Okra *(Abelmoschus esculentus)*

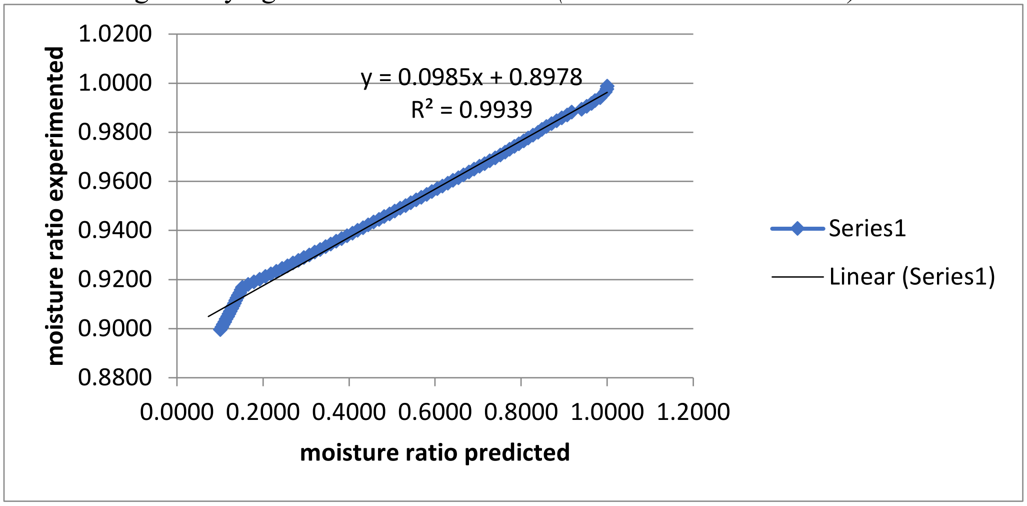

Figure. Relationship between experimental and Predicted moisture ratio

Effective Moisture Diffusivity

This was evident that moisture diffusivity increased when the drying temperature was increased and the kinetics could be as a result of higher temperatures affecting the activity of water molecules, causing higher moisture diffusivity. Similar results were reported by Sacilik (2007), Jittanik (2011), Doymaz (2004), Robert *et al* (2008). For Okra *(Abelmoschus esculentus)*, the same approach was used in determining the effective moisture diffusivity using figure 2 below and the effective moisture diffusivity varied from $1.369x10^{-7}$ -$7.12x10^{-7}m^2$/sec for respective temperature ranges from 60^0C, 65^0C, 70^0C, 75^0C, 80^0C, 85^0C, 90^0C, 95^0C, 100^0C, 105^0C, 110^0C and 115^0C. According to table 2 of the Okra *(Abelmoschus esculentus)* shows that the effective moisture diffusivity increases with an increase in temperature. This reports obtained in this work agree with the report of Burubai and Bratua (2015) and Sacilik (2017)

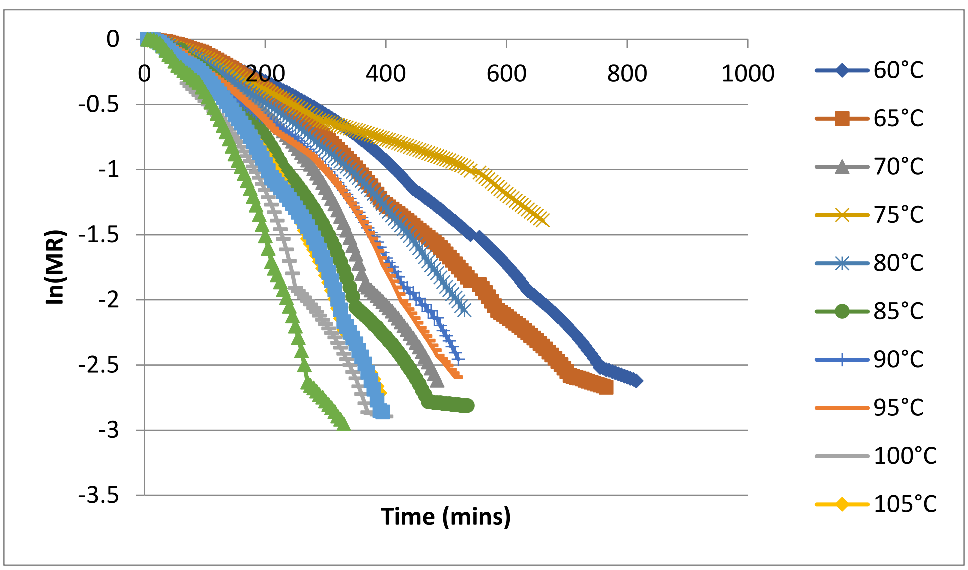

Figure 2: Estimation of Moisture Diffusivity Coefficient of Okra (Abelmoschus esculentus)

Table 2 Moisture diffusivity values of Okra (Abelmoschus esculentus)

emp (0°C)	**ffective moisture iffusivity m²/sec**
)	0000002396
5	0000002739
)	0000003902
5	0000001369
)	0.0000002670
5	0000002191
)	0000003218
5	0000003560
)0	0000005682
)5	0.0000005066
15	000000712

Activation Energy

Activation energy is the energy that is responsible for the initiation of mass transfer from a wet biomaterial during drying. The temperature dependence of moisture diffusivity is reported to obey Arrhenius Law, and the activation energy was calculated from the In Deff Versus temperature curve as shown in Figure 3 by using equation (12). The energy of activation for Okra *(Abelmoschus esculentus)* was recorded as 0.1235kJ/mol.k.

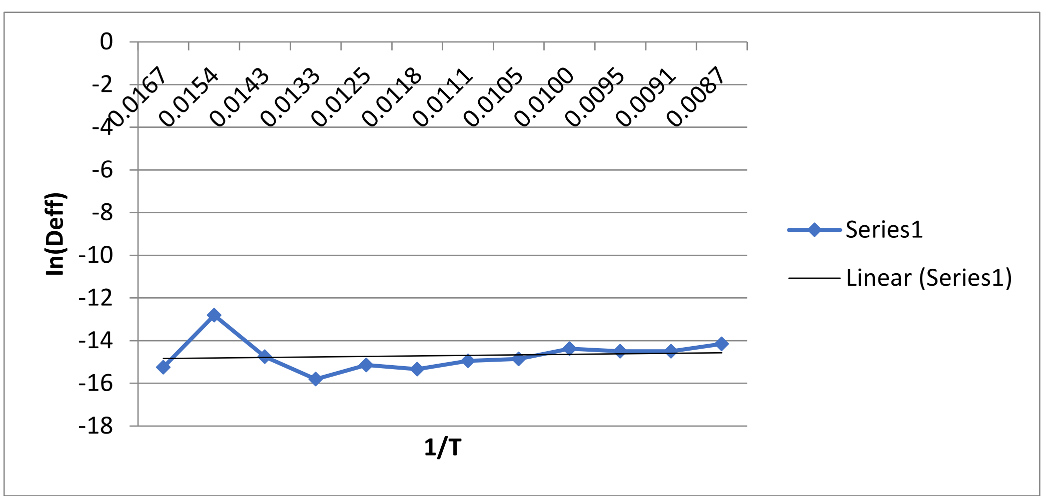

Figure 3 Estimation of Activation Energy of Okra (Abelmoschus esculentus

4. Conclusion

The drying kinetics of Okra *(Abelmoschus esculentus)* was investigated and it was evident that the drying process falls under the falling rate period like other biological materials. Out of the three thin layer models that were investigated, the best predicting model for Okra *(Abelmoschus esculentus)* are page model and Henderson model having undergo mathematical analysis of the drying parameters and for the effective moisture diffusivity, the values obtained ranges from $1.369 \times 10^{-7} - 7.12 \times 10^{-7} m^2/sec$ for the temperatures used. The activation energy value obtained was 0.1235kJ/mol.k

List of symbols

D_{eff} Effective moisture diffusivity (m^2s^{-1})
M_e Equilibrium moisture content of sample (g water/g dry solid)
M_t Initial moisture at any time (g water/g dry solid)
MR Moisture ratio
m Mass of sample (g)
N The number experiment taken
Ea Activation Energy (Wg^{-1})
R^2 Correlation coefficient
K Reactive rate
A Pre-exponential constant
L Half thickness of the sample
T Drying time
RMSE Root mean square Error
MBE Mean bias Error

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EFFECT OF FOAMING AGENT AND WHIPPING TIME ON DRYING PROCESS OF MANGO PULP UNDER DIFFERENT DRYING OPERATIVE CONDITIONS

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Abstract

*Laboratory experiments were conducted to determine the effect of foaming agent (egg albumen liquid EWL and egg albumen powder EWP) and whipping time on drying rate and quality of pulp dried under instrumented mechanical dryer. A 4^3 factorial experiment in Randomized Complete Block Design (RCBD) was used to study the effect of the three levels each of foaming agent (6, 12 and 18 % EWL and EWP) and whipping time (5,10 and 15 min) on drying rate and quality of foam-mat dried mango powder. Each trial was performed in triplicates making a total number of 675 samples that were individually tested and measured. 50g sample of the pulp were dried to a moisture content of 4.89 % (wb) for 8 hours, 7hrs and 6hrs in the mechanical dryer at temperatures of 50 ^{0}C, 60 ^{0}C and 70 ^{0}C respectively. Data obtained from the experiments were statistically analyzed using the analysis of variance (ANOVA) while the Duncan's Multiple Range Test was used to compare the means. Results showed that the highest value of drying rate was obtained to be 183.49g/hr for EAL with 18% foaming agent and dried at 60 ^{0}C. While for EAP, 113.60g/hr drying rate was achieved as the highest when dried at 70^{0}C with 18%. Increase in foaming agent, foam stabilizer and whipping time did not cause any adverse effect on vitamin C, highest at 60 ^{0}C with 18.91% and Beta carotene of the samples, highest at 50^{0}C with 5.69mg/100g. The results of the study showed that egg white both in liquid and powdered form, XG and whipping time influenced the drying rate and quality of foam mat dried mango powder.***

Keywords: foaming agent, foam-mat drying, foam stabilizer, drying rate, Mango

1. Introduction

Mango (*Mangifera Julie*) is one of the most important and choicest of all tropical fruits. It is rightly referred to as the 'King of Fruits' because of its excellent flavor, delicious taste and higher nutritional value (Eipenson and Bhowmik, 1992). Mango occupies the first position in tropics as being enjoyed by all in temperate countries and being a highly perishable crop inflict greater setback as in storage and transportation. The problem of storage facilities and poor transportation created a wide gap between total production and consumption leading to post harvest losses (Wilson *et al*., 2012).

A massive amount of fresh mango fruits are wasted every year through postharvest losses leading to reduction in its nutritional and market value. As established by Lisa and Adel (2015) the rate of postharvest losses in fresh fruit in developing countries is about 20 to 50%. For the prevention of crop from postharvest losses, deterioration and for increasing its shelf life, different ways of preservation are used. The major aim of food processing is to convert perishable and high moisture produce into shelf stable products that can be stored for extended periods thereby reducing losses and making them available at the time of shortage and off-season Santos and Silva, 2008.

Foam-mat drying is a technique that involves incorporation of foaming agent into liquids or semi-liquid with adequate whipping to form stable and stiff foam, and subsequently dehydrated by air drying (Affandi *et al*., 2017). Foam mat drying leads to increase of surface area, faster drying rate and considerable decrease in drying time and drying temperature; as well improve the sensory, nutritional and functional properties of the product. In addition, the foam mat dried products are highly stable against deteriorative microbial, chemical and biochemical reactions. The shorter drying time generated not only reduces the dryer load but also increases the dryer throughput by 32 and 22% for foamed material (Rajkumar *et al*., 2006).

2. Materials and Methods

2.1. *Experimental Equipment*

The following equipment and apparatus were used for the study: (i) an instrumented mechanical dryer as shown in Figure 1; (ii) a moisture analyser (Model: OHAUS MB 90; (iii) an electronic weighing balance; (iv) a stainless steel knife; (v) desiccators; and (vi) a foaming device.

Figure 1: Pictorial View of the Instrumented Dryer Figure 2: Moisture Analyzer (OHAUS MB 90)

Figure 3: Electronic Weighing Balance ***Figure 4: Foaming Device***

2.2. ***Experimental Design***

A 4^3 factorial experiment in a randomized complete block design was used in this study. The factors taken into consideration included 3 levels each of foaming agent, foam stabilizer, and whipping time. The range of foaming agent considered was 6, 12 and 18 % in two forms (EWL and EWP); foam stabilizer was 0.02, 0.04 and 0.06 % XG while the whipping time was 5, 10 and 15 min. Every trial was carried out in triplicate in the drying equipment.

2.3. ***Experimental Procedure***

The experiment was carried out in the Food Engineering Laboratory, National Centre for Agricultural Mechanization. The average room temperature was 21^{0}C throughout the period of experimentation. Fresh and ripe mangoes (Julie Variety) were bought from a local market in Ilorin metropolis. The weights of the mangoes were measured to ensure uniformity of samples to be used for experimentation.

2.3.1. ***Sample Preparation***

The mangoes were washed in clean water, skinned and deseeded with the use of the stainless steel knife on a stainless steel tray and then blended using foaming device to form mango concentrate. 100 ml of the concentrate was measured and foamed with 6, 12 and 18 % EWL and EWP and 0.02, 0.04 and 0.06 % XG. The mixture was then foamed for 5, 10 and 15 min whipping time with the aid of the device designed for foaming to form a foamed mixture.

2.3.2. ***Drying Procedure***

The mechanical dryer was set at temperatures 50 ^{0}C, 60 ^{0}C and 70 ^{0}C respectively. 50g of foamed samples prepared as described earlier were spread evenly on the labelled laboratory drying containers at a foam thickness of 1 mm and carefully placed inside the drying equipment for drying as shown in Figures 5 below. The weights of the samples were taken every minute and the drying operation continued until there were no more changes in the weight of the samples. The experiment was performed in triplicate in all the three drying equipment.

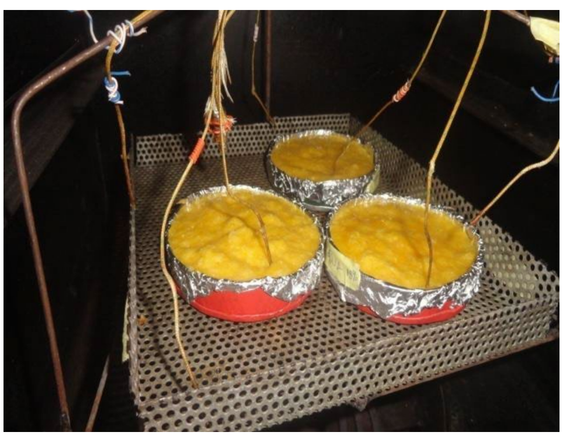

Figure 5: Foamed Samples in the Dryer

Output Parameters

2.4.1. ***Drying Kinetics***

In this study, drying rate was calculated as described by Olaniyan and Omoleyomi (2013) as the amount of moisture removed from product per unit time during a drying operation. It was determined by the equation used by which is expressed below as:

$$DR = \frac{dM}{dt} = \frac{m_i - m_f}{t} \quad (1)$$

where; DR is the drying rate in g/h; dM is change in mass of mango in g; dt change in time in h; t is the total time of drying in h; mi and mf are the initial and final mass of mango samples respectively in g.

2.4.2 ***Quality Analysis***

2.4.2.1 ***Determination of Vitamin C content (mg/100ml)***

The 2, 6-dichlorophenol indophenol titration method described by Ndawula *et al*., 2004 was used for the determination of ascorbic acid content. 2 g of sample was homogenized in a mortar containing 10 ml of 0.5% oxalic acid (extraction solution) and the content was transferred into 100 ml volumetric flask. More extraction solution was added up to the mark. The content being mixed thoroughly was filtered immediately (What man No. 4) and aliquots (10 ml) of extract was titrated against standardized 2, 6-dichlorophenol indophenol solution. An equivalent amount of the extraction solution was titrated against standard 2, 6-dichlorophenol indophenol solution as blank at the same time.

2.4.2.2. ***Beta Carotenoids Determination (mg/100ml)***

The samples were homogenized using a mortar and pestle in the presence of water bath containing squash ice. Exactly 16ml of acetone-hexane (4:6) solvent was added to 1.0 g of homogenized sample and mixed in a test-tube to extract the carotenoids, an aliquot was taken from the upper solution from the two phases formed and its optical density (OD) was measured at 663, 645, 505, and 453 nm in a UV-VIS spectrophotometer. Lycopene and β-carotene contents was calculated according to the Nagata and Yamashita equations below as reported by Sharoba (2009).

2.5. ***Experimental Analysis***

In analysis the results from the study, the IBM SPSS (25.0) computer software package was used, model equations were developed by employing essential regression analysis. The model equations were used to predict the drying rate and quality of dried product based on foaming agent, foam stabilizer and whipping time.

3. Results and Discussion

3.1 ***Effects of Drying Air Temperature, whipping time and foaming Agent on the Drying Rate***

It was observed from Table 1 that the drying air temperature had significant effect on the drying rate at 5% level. To ascertain the levels of significance of the drying air temperature that led to the significant difference in the drying rate, Duncan's Multiple Range Test was used. Table 2 showed that the results presents the level significance of drying air temperature with the mean value of the drying rate in which the lowest temperature level is 50^{0}C had the lowest drying rate, at temperature 60^{0}C, there was an increase in the mean value of the drying rate. This showed that as the temperature increases the drying rate also increases. Based on the Kinetic theory of molecular motion described by Carvalho *et al*., (2014), water molecules with high kinetic energy will escape from the liquid water surface against the cohesive forces that binds the water molecules together. The highest value of drying rate was obtained to be 183.49g/hr for EAL with 18% foaming agent and dried at 60 ^{0}C. While for EAP, 113.60g/hr drying rate was achieved as the highest when dried at 70^{0}C with 18%. This showed that whipping time, drying air temperature, foaming agent and foam stabilizing and their various interactions exhibited significant effects. The change in the drying rate might be as a result of the increase in the binding force as the drying time increases (Jabeen *et al*., 2015).

Table 1: Analysis of Variance Table (ANOVA) for Drying Rate

Source	Sum of	df	Mean	F	Sig.

		Squares		Square		
	Between Groups	1944.000	26	74.769 .	.	
A	Within Groups	.000	54	.000		
	Total	1944.000	80			
	Between Groups	.022	26	.001 .	.	
B	Within Groups	.000	54	.000		
	Total	.022	80			
	Between Groups	.000	26	.000	.000	1.000
C	Within Groups	1350.000	54	25.000		
	Total	1350.000	80			
	Between Groups	6.739	26	.259	.	.
AB	Within Groups	.000	54	.000		
	Total	6.739	80			
	Between Groups	2.160	26	.083	1.780	.037*
BC	Within Groups	2.520	54	.047		
	Total	4.680	80			
	Between Groups	673.920	26	25.920	3.306	.000*
ABC	Within Groups	423.360	54	7.840		
	Total	1097.280	80			
	Between Groups	100234.995	26	3855.192	122.388	.000*
DR	Within Groups	1700.989	54	31.500		
	Total	101935.984	80			

A = Foaming Agent; B= Stabilizing Agent; C= Whipping Time

Table 2: Duncan Multiple Range Test for the Effect of the Drying Air Temperature levels on the Drying Rate

emperature C)	ıbset of the mean values of the drying Rate (g/hr)		
	1	2	3
)	16.1700		
)		21.3333	
)			24.4400

3.2. Effects of Drying Temperature, Whipping Time and Foaming Agent on the Vitamin C and Beta Carotene Content

Table 3 showed the level of significance of the Vitamin C and Beta Carotene at 5%. From Table 4, the drying temperature, whipping time and foaming agents had effects on the Vitamin C and Beta Carotene. The highest Vitamin C of mean value 18.91% was at 60^{0}C and highest Beta Carotene of 5.69 mg was achieved at 50 ^{0}C. This indicated the effect of heat on the Mango powder. The highest whipping time and foaming agent concentration gave the highest Vitamin C, with more air incorporated into the material, more Vitamin C be achieved.

Table 3: Analysis of Variance Table (ANOVA) for Vitamin C and Beta Carotene

	Source	Sum of Squares	df	Mean Square	F	Sig.
VC	Between Groups	4956.833	26	190.647	329.843	.000
	Within Groups	31.212	54	.578		
	Total	4988.045	80			
BE	Between Groups	48.211	26	1.854	20.495	.000
	Within Groups	4.886	54	.090		
	Total	53.096	80			

Table 4: Mean Values of Vitamin C and Beta Carotene

arameters		
emperature (^{0}C)	itamin C (%)	eta Carotene (mg/100g)
)	5.63	69
)	3.91	62
)	4.74	66
'hipping Time (min)		
	5.22	30
)	5.22	33
5	7.26	34
oaming Agent (%)		
	5.42	58
2	5.89	04
3	7.97	35

4.0. Conclusion

1. Drying rate increased with increased drying air temperature and was highest at 70 ^{0}C with 24.4g/hr and lowest mean value at 50 ^{0}C
2. Vitamin C and Beta Carotene of Mango powder reduced with increase in air drying temperature and were highest at 60^{0}C with 18.91% and at 50^{0}C 5.69mg/100g.

3. Vitamin C and Beta Carotene of Mango powder increased with increased in whipping time and was17.26% when whipped for 15min. Also, increased with foaming agent concentration and was 17.97% at 18% concentration.

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MODIFICATION AND PERFORMANCE EVALUATION OF FAN UNIT OF AN EXISTING IAR MILLET THRESHER

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Abstract
Millet is a major source of food for most families in the North West and North Eastern part of Nigeria. In Africa Nigeria is the leading producer of pearl millet. Cleaning is among the most important harvest and post-harvest operation after threshing. Manual cleaning of millet put enormous strains on labour force and time consuming. The prototypemachine developed at Institute for Agricultural Research (IAR) is associated with many difficulties during operation. The problems of IAR millet thresher are poor performance such as high scatter grain loss and low cleaning efficiency. This study undertaken to modify the fan unit of the IAR millet thresher with the aim of eliminating the drudgery involved in the operation and to improve its performance. In order to increase the cleaning efficiency and to reduce the percentage scatter grain loss the fan unit as modified. The modification carried out include replacement of fan shaft with the one of higher diameter, size of the pulley were also changed and increase length of fan blade. This work evaluated the cleaning efficiency and the percentage scatter grains loss of fan unit of an existing millet thresher. This is achieved by the threshing of millet of the same variety (elusive coracana) at two levels of feed rate of (3 kg/min and 4 kg/min) with five levels of fan speed was selected from a preliminary test Viz: 17.8, 20.5, 20.9, 24.7 and 25.5 m/sec respectively. The maximum performance achieved with fan speed, federate and moisture content were 25.5 m/sec, 3 kg/min and 22.2%, respectively, while the cleaning efficiency and percentage grain loss were 89% and 1.94%, respectively. The modified prototype machine reduces drudgery associated with the traditional method of cleaning millet and therefore increase productivity of farmers.

Keywords:- IAR Millet thresher, modification and performance evaluation.

1 Introduction

The millet is group of highly variable small-seeded grasses, widely grown around the world as cereal crops or grains for both human food and fodder. They do not form taxonomic group but rather a functional agronomic one. Millets are important crop in the semi-arid region of Asia and Africa (especially in India, Nigeria and Niger) with 97% of millet production in developing countries. Nigeria is the third leading millet producing country in the world after India and Chile with production capacity of about 4 million tons, which is about 13% of total world production (FAO, 1996). The crops are favoured due to its productivity and short growing season under dry, high temperature condition. While millets are indigenous to many parts of the world, millet most likely had an evolutionary origin in tropical western African, as that is where greatest number of both wild and cultivated form exist (FAO, 1995). Millet have been important food staple in human history, particularly in Asia and Africa, and they have been in cultivation in East Asia for the last 10,000 years (Lu H; hang *et al.,* 2009).It has been reported that the air – dried grain of milletcontains approximately 12.4% water: 11.6% protein, 5% fat, 67.1% carbohydrate, 1.2% fibre and 2.7% ash (Onwueeme and Sinha, 1991)

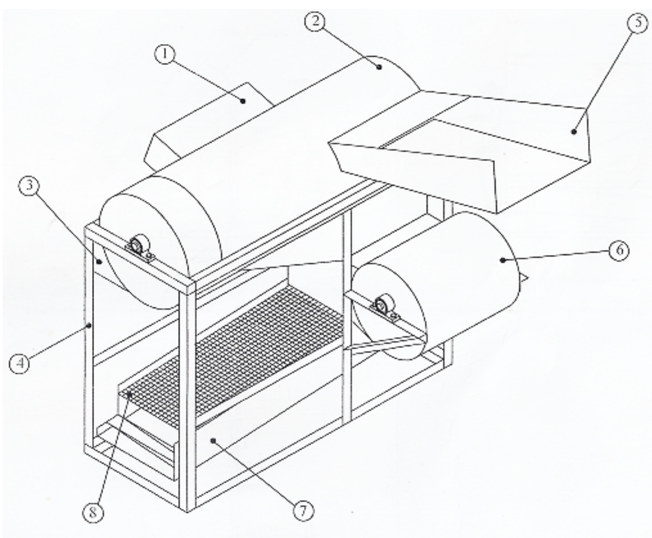
The varieties mainly grown in the savannah part of Nigeria are Ex-Borno, Zango, Maiwa and Gauva. The Ex-Borno variety constitute 90% of all millet grown, it grows at an annual rate of 2.1% (Agidi *at al.,*2013).

In Nigeria millet seeds have multi-purpose used by the rural communities most especially for making porridge (*fura*), "*Tuwo*", local cake (*waina*), local drink (*kunu*) and *pap*.In order to increase millet production, it is necessary to modernize the production techniques and optimize the processing conditions with a view to realizing some basic quality requirements such as improved flavor and increased shelf life (Ogunlowo and Adesuyi, 1999). Traditional method of cleaning process is slow and energy consuming. Often this local method of processing the crop leads to low quality product due to the presence of impurities like stones: dust and chaff (Agidi*et al.,* 2013). Threshing and cleaning of the grains from these impurities requires modern technology that can be easily maintained and required for effective utilization. Therefore, the modified thresher is aimed to evaluate the cleaning performance of the existing machine, so that it will efficiently increase the productivity.

2 Materials and Methods

2.1 *Description of the machine*

The machine consists of the hopper; shelling cylinder, bearings, bolt and nut, concave, cleaning unit, grain outlet, pulley, shaft, prime mover seat and frame.



1. Chaff outlet
2. Threshing cylinder cover
3. Straw outlet
4. Frame
5. Hopper
6. Blower
7. Shaker
8. sieve

Fig. 1: Isometric view of the machine

2.2 *Design Consideration*

The design considerations considered were: affordability; maintainability cost of material, durability, rigidity, availability of part, safety and ease of operation. The machine consists of two set of sieves. The first sieve straw sieved has holes diameter of 3 mm while the second for cleaned sieved have diameter of 2 mm respectively. The fan unit has four blades made of mild steel. The blade is supported by shaft.

2.3 *Material Selection*

The materials used for the modification of cleaning mechanism were: mild steel; metals sheet, bearing, belt, pulleys, flat bars, 12 mm mild steel rod and angle iron . The materials were selected based on strength, rigidity, availability and cost of the material was taken into consideration. The selection was based on the resistance to all possible stress may be subjected to during operation; metal sheets were selected by considering failure due to shearing and crushing Nura *et al.,* (2017). The sieve hole was chosen based on the physical properties of the millet grain as quoted by Afolabi, (2015)

2.4 *Determination of The Size Of Component*

2.4.1 *Determination of Weight of the fan blades*

The weight of the fan blades was determined based on relationship adapted by Mohammed (2009) as:

$W_f = \delta g v_m$ (1)

Where:

W_f = weight of the fan blade (N)

 = density of the galvanized steel = 7850kg/m^3(as given by Khurmi and Gupta, 2007)

g = acceleration due to gravity = 9.81 m/s^2

v_m = volume of material used for the fan construction (m^3). Four (4) blades each of volume $30 \times 12 \times 1.5$mm^{3}wereused in construction.

2.4.2 *Determination of fan air discharge rate*

According to Joshi (1981), the air discharge (Q) by a blower is given by

$Q = V \times D \times W$ (2)

Where:

Q = air discharge in m/s

V = air velocity m/s

D = depth of flow above the reference point (m)

W = width over which air is required (m)

2.4.3 *Determination of power required in fan and shaker mechanism*

$P_{f=} f \times V\ (Vf)$ (Joshi, 1981) (3)

Where;

$P_{f=}$ power required in fan (W)

f = force

V = Velocity

V_f= peripheral velocity of fan (m/s)

$V_f = \frac{\pi DN}{60}$ (4)

Where;

D = diameter of the pulley (mm)

N = speed of revolution in (m/s)

P_r = power required for shaker reciprocation (W)

2.4.4 *Determination of fan shaft torsional moment*

$M_{t_f} = \frac{px60}{2\pi N}$ (khurmi and Gupta, 2007) (5)

Where;

M_{t_f} = Shaft torsion moment (Nm)

P = Power of required for the fan (W)

N = Speed of the fan shaft (rpm)

2.4. 5 *Determination of fan shaft diameter*

The determination of the shaft diameter was obtained ASME (1948) code, equation for solid shaft having or no little axial load, the diameter of the shaft was determined using:

$d^3 = \frac{16}{\pi\sigma_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$ (6)

Where;

d = diameter of shaft (mm)

d_s = design stress (55x10^6 N/m^2)

K_b& K_t = combined shock and fatigue factor applied to bending and tensional moment respectively

(K_b = 1.0 & K_t = 1.5)
M_t = tensional moment (N_m)

2.5 *Determination of Pulley Size Dimension*

The criteria for the selection of pulley sizes were based on speed ratio to drive the fan and the cylinder at designed speed and frequencies. The efficiency and availability of the belt were also considered.
The size of pulley and speed relationship is given by: Hannah and Stephen (1979).

$N_1D_1 = N_2D_2$ (7)

Where;
N_1 = speed of driving shaft (rpm)
D_1 = diameter of driving pulley (rpm)
N_2 = speed of driven shaft (rpm)
D_2 = diameter of driven pulley (mm)

$$(\omega) = \frac{2\pi N_1}{60}$$ (khurmi and Gupta, 2007) (8)

Where;
(ω)= Angular velocity (red/s)

Linear velocity of fan
The linear velocity of fan is determined by the relation: given by Dash and Dash (1989)

V = r□ (9)

Where;
V = linear velocity (m/s)
r = radius of pulley (mm)
□ = angular velocity (rad/s)

2.5.1 *Belt Selection*

The selection of belt sizes depends on the length, thickness and properties of the materials from which the belt is made.
The belt selection as based on ASAE (1979) standard. It is given as:

$$L = 2C + 1.571(D+d) + \frac{1}{4c}(D-d)^2$$

(10)

Where;
L = effective belt length (mm)
C = distance between the centre of the driven and the driving pulley (mm)
D = diameter of driven pulley (mm)
d = diameter of the driving pulley (mm)

The cross section area is given by: (Hall and Halowwank, 1980)

A = (b + c) K/2 (11)

Where;
A = Area (m^2)
K = thickness of belt (mm)
b = top width of belt (mm)
c = bottom width of belt (mm)

2.6 *Experimental Procedures and Design*

The operation started by putting on the prime mover. A batch of a weighed millet heads were fed into the machine through the hopper. After each operation,samples were collected at the grain outlet and non-grain outlets. Grains and non-grain materials were separated for all the simples and weight separately in order to calculate the performance indices. Randomized completely design experiment (RCD) was used. A layout of 5 levels of fan peripheral speed (17.8, 20.5, 20.9, 24.7 and 25.5 m/sec, by 2 levels of feed rates (3kg/m and 4 kg/min) at constant moisture content of 22.2%.

2.6.1 *Performance Indicators*

The cleaning efficiency and scattered loss were determined based on FAO (1994) guidelines are as follows:

(i) Cleaning efficiency

$$C_e = \frac{B}{D} X100 \tag{12}$$

Where,

C_e = cleaning efficiency, %

B = Weight of whole clean seed at main outlet, kg

D = Weight of whole material collected at main outlet, kg

(ii) Scattered loss

$$S_L = \left[\frac{W_L}{Ts} X100 \right] \tag{13}$$

Where:

S_L = Scattered loss, %

W_L= Total weight of scattered seed collected, kg

T_s = Total weight of collected seeds, kg

2.6.2 *Determination of moisture content*

The moisture content for grains was determined by oven dry method 105 ^{0}C for 24 hours. It was calculated using relationship given by ASAE (2003) as:

$$M_{db} = \frac{W - W_d}{W_d} x100 \tag{14}$$

Where;

M_{db}= Moisture content dry basis (%)

W = Initial weight of the sample (g)

W_d = Final weight of the sample (g)

3. Results and Discussion

3.1 *Effect of Fan Speed on Cleaning Efficiency at Different Feet Rate*

Fig 1: Shows the effect of peripheral fan speed on cleaning efficiency at different feed rate, the maximum cleaning efficiency of 89% was obtained at 25.5 m/s fan speed and 3 kg/min feed rate while the lowest cleaning efficiency of 79% was recorded at the lowest speed level of 17.8 m/sec and second feed rate 4 kg/min. the results obtained is higher than that of Agidi *et al.,* (2013). The authors reported that the maximum cleaning efficiency of 62.7% at 800 rpm, 13% moisture content and no specified feed rate. This could be associated with the increase in the number of sieve from one sieve to two different sieves

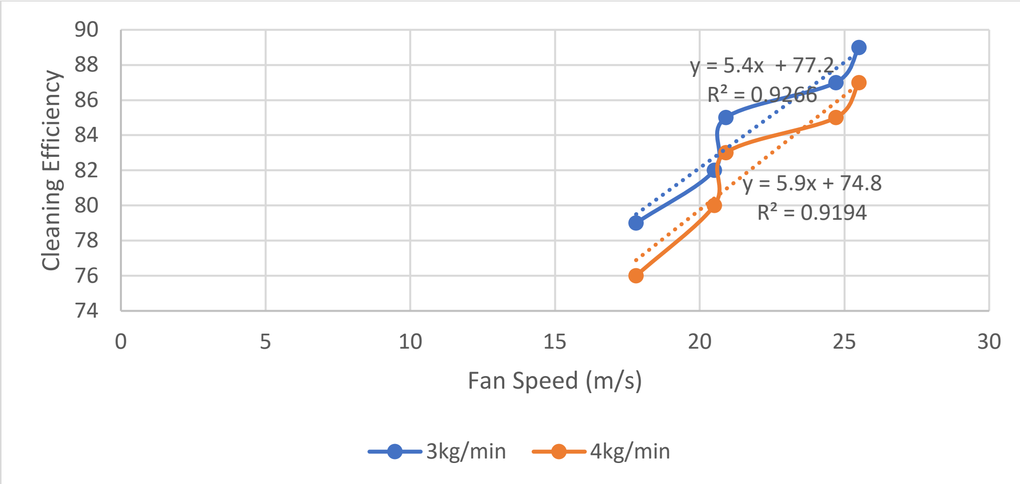


Fig. 2: Effect of fan speed on cleaning efficiency

3.2 Effect of Fan Speed on Scatter Losses at Different Feed Rate

Fig 2 Show the effect the effect of puerperal fan speed on scatter losses at different feed fate. The highest percentage scatter grain of 2.33 % was recorded at 25.5 m/sec fan seed and 4 kg/min feed rate while the lowest value of 0.58% was obtained at 17.8 m/sec, fan speed and 3 kg/min federate. A decrease of scatter grain was recorded as compared with the Agidi et al., 2013; Afolabi (2015) and Singh *et al.,*(2015). The results obtained the maximum value of 27.6, 51.7% and 2% scatter losses at fan speed of 700 and 800 rpm. These decreased scatter grains may be due to redesigning of cleaning unit. Fig.2. Show that an increase of fan speed and feed rate results to an increase of scatter loss. These may be connected to the fact that at higher speed large amount of grain are carry away by the fan.

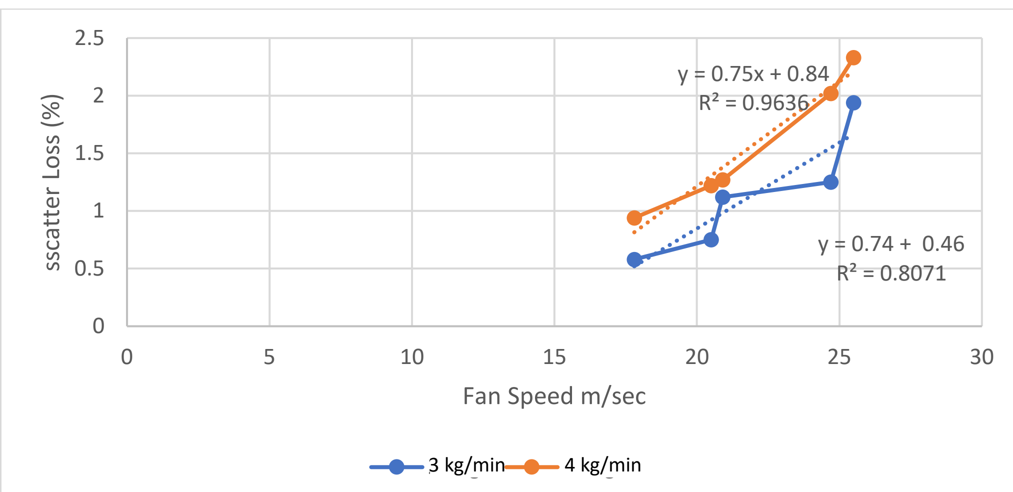


Fig. 3: Effect of fan speed on scatter loss

4. Conclusion

The modification and performance evaluation of the existing IAR millet thresher was conducted and cleaning efficiency was observed to increase in the fan peripheral speed. Scatter loss increased with an increased in cylinder speed and federate at constant moisture content, the performance achieved of the machine were 89%, 0.58% and 22.2%, for cleaning efficiency, scatter loss and moisture content, respectively.

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REVIEW OF TOMATO PROCESSING IN GHANA

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Abstract

Tomato processing reduces high post- harvest losses in tomatoes and also ensures a year-round availability of tomatoes in the right quantities. For three decades, tomato processing in Ghana has decreased considerably following the collapsed of tomato processing plants leading to high importation of tomato paste. This study presents a review of the tomato processing industry in Ghana and assessesthe potential measuresrequired for the sustainable operation and management of the processing plants. This will contribute to revamping the tomato processing industry which will lead to an increase in the income levels of the farmers, processors with corresponding increase in government revenues. Addressing issues of logistics, raw materials supply and equipment needs for operation of the processing facility will help in sustaining the processing plant.

Keywords: Tomato; processing, post-harvest losses, tomato paste.

1. Introduction

Tomato (*Solanum lycopersicon*) is a vegetable belonging to the*solanaceae* family and consists of more than 300 species (Knapp, 2002). Tomato is the most crucial consumed vegetable in Ghana (Schippers, 2000). There is consistent continuous increase in demand for both fresh and processed tomatoes than other vegetables in Ghana (Melomey*et al.,* 2019). In 2013, locally produced tomatoes were estimated at 340, 218 tonnes and 5945 tonnes were imported into Ghana (Melomey*et al.,* 2019). Agro-processing is a techno-economic activity that transforms an agricultural produce into a consumable one through unit operations, storage and distribution. Tomato paste production is essential in creating jobs and facilitating rural development through industrilisation, generate income to farmers and processors, increase government revenue and foreign exchange and greatly reduce post-harvest losses. Tomato processing has been a daily activity in Ghana since the time of its introduction into the country. Ghana depends heavily on tomato paste as an ingredient in many food sauces. Ghana is the second largest consumer of tomato paste in the world (Baba *et al.,* 2013). Ghana produces about 510 000 metric tonnes of fresh tomatoes per year and imports approximately 7000 tonnes of tomato paste from the Europe (Baba *et al.,* 2013).

In the early 1960s, government of Ghana upon critical observation realized, the country by then depended a lot on the importation of tomato paste and sugar and therefore instituted the policy of import substitution to reduce dependency on importation that can equally be produced locally. Three tomato paste processing plants were developed to aid in the production of tomato paste. These processing plants unfortunately collapsed due to a lot of reasons in the late 1980s. principal factors leading to the collapsed of the tomato processing plants were as a result of frequent breakdown, obsolete machinery, lack of spare parts, poor marketing, lack of technical competence, financial management and structural reforms by the world bank and IMF (Robinson and Kolavalli, 2010a; 2010b, 2010c). The tomato disease complex was also another problem which affected the operations of the tomato processing plants in Ghana. It is not a big deal to obtain a good processing plants machinery these days due to modernization in agricultural machinery. For sustainable operation of a processing plant, continuous supply of raw materials to the processing plants is critical.

2. History of Tomato

Tomato originates from the Andean region consisting notably of the present day Bolivia, Chile, Colombia, Ecuador and Peru (Peralta and Spooner, 2007). Based on empirical hypothesis, Mexico is acceptably presumed to be the domesticated site of tomato whilst Peru is considered as the diversification centre (Larry *et al.,* 2007).

3. Importance of Tomato Processing

Processing of agricultural produce extendsthe shelf-life of produce by means of value-addition, increases income to farmers and drastically reduces post- harvest losses (Chengappa, 2004). United Nations Industrial Development Organization (UNIDO) (2007) reported that, about 40–60% of manufacturing value comes from agro-processing industries and form a major part of exports. A country's growth relies on its complete transformation from the agrarian state to industrial one (Khosla & Dhillon, 2015). Lycopene is makes up about 83% of the total red pigments in tomato (Gould, 2013) and its presence in tomatoes help in reducing weight (Bielig and Werner, 1986). Meals that are rich in lycopene have the capacity to prevent cardiovascular disease and some type of cancers in humans (Arab and Steck, 2000). Consistent consumption of tomato juice, tomato sauce and pizza decreases humans' susceptibility to prostate cancer (Giovannucci*et al*., 1995). Canned tomato and ketchup are largely rich in lycopenewhen compared to fresh tomato since high temperature cooking disintegrates the cell wall resulting in increased in lycopene (Nguyen and Schwartz, 1998).Processing enhances the marketing of tomatoes by making tomatoes more convenient to handle and distribute (Naika*et al.,* 2005). Provides an opportunity for labelling, which will attract consumers, provide a new and better taste for consumers (Naika*et al.,* 2005).

4. History of Tomato Paste Production in Ghana

Full tomato paste processing started in the 1960s when the then Yugoslavian company built three state owned food processing industry in 1967. These tomato pastesprocessing industry was set up to minimize heavy importation of tomato paste. These tomato processing plants were the Pwalugu Tomato Factory in Pwalugu in the Upper East Region, The Ghana Industrial Holding (GIHOC) Corporation Cannery located at Nsawam in Eastern Region, and The GIHOC Tomato Cannery (TOMACAN) in Wenchi in the Bono Region (Deha, 2018). In the late 1980, structural reforms initiated by both The World Bank and The International Monetary Fund led to the closure of the tomato processing plants due to unavailability of spare parts, competent technicians, financial and marketing experts at the time (Deha, 2018; Goodman, 2016). Apart from those factors, farmers in Ghana by then could not continuously supply raw tomatoes to the processing plants which in principle led to the collapse of the plants. For sustainable operation of the processing plants there must be regular and timely supply of fresh tomatoes in the right quantity to the processing plants. Successive governments in Ghana have tried to revamp these processing plants to reduce post-harvest losses, increasefarmers' income and make tomato paste readily available on the local markets butthis has not materialized though the current government has initiated the process once again under one district one factory policy. The new tomato processing plant has currently been established though yet to operate and is located in Doryumu in theShai Osudoku District in the Greater Accra Region. Improvement in the tomato processing in Ghana will reduce importation of tomato paste, increase foreign exchange, generate employment, provide opportunities for development and reduce huge post-harvest losses (Baba *et al.,* 2013).

Pwalugu Tomato Processing plant right from the beginning faced a lot of problems such as tomatoes were inappropriate for processing due to inadequate percent total solids (dry matter), lesser soluble solids (Brix) (Grayson, 1973; Apte*et al.,* 1969), inadequate plant equipment (Weitenberg, 1974), expensive running cost at that time because there were yet to be hooked –up to the national grid which was later completed in 2008 (Ministry of Finance, 2008), poor management (Agricultural Operations Division, 1991) and the processing plant was not able to secure a consistent continuous supply of fresh tomatoes (Grayson, 1973). TOMACAN-Wenchi Tomato Processing plant in the late 1980s was not operational due to farmers inability to access markets at peak tomato harvesting season, farmers especially in the Dormaa District sold to La Cote D'Ivoire to earn more profit, farmers upon contractual agreement were able to supply tomatoes to the processing plant and later diverted to sell directly to the fresh tomato market when tomatoes were scarceand expensive in the markets than the processing plant fresh tomato price (Robinson and Kolavalli, 2010).

5. Impact of Importation of Tomato Paste to Ghana

According to a report by Third World Network (2006), tomato paste importation into Ghana has negatively affected the livelihood of tomato farmers, traders and tomato processing industry employees. Importation of tomato affects the price stability of tomatoes in Ghana. Tomato paste importation makes it difficult to create job opportunities along the tomato value chain especially with the increasing importation of adulterated tomato paste into Ghana (The Ghana Report, 2019). Food and Drugs Authority in 2019 reported 16 tomato paste products that were dangerous to humans due to some credible composition of ingredients such as starch and colourings in the product which was not found on their labels. These tomato brands numbering 16 as reported by Ghanawen (www.ghanaweb.com) in 2019 were banded completely since their composition was proven to be potentially dangerous to human health. Globally, food safety is a major concern especially with regards to both domestic and importation of food products. Producing tomato paste in Ghana under local food safety protocols and strict oversight supervision by Ghana's Food and Drug Authority not only create job opportunities but food safety assurance to consumers. Over the years, local production of tomato in Ghana has increased significantly and to drastically reduce tomato paste importation in Ghana, it will be necessary to invest, revamping or establishing more processing facilities.

6. Tomato Paste Production

To process tomatoes, harvested matured fresh tomatoes that are purely free from contaminants, bruises and with desirable quality attributes are selected for processing. When this is done, there must be weighing of the tomatoes to determine the quality of the tomato. Mixing of ingredients also help in determining the uniformity of the product. The tomatoes are then subjected to sorting. The colour and maturity are critical factors here. Tomatoes that are rotten or have been contaminated are removed leaving only the healthy ones for processing. The sorted tomatoes are then washed thoroughly with a portable water to remove any foreign materials among the tomatoes. Washing of tomatoes are done with special machine. After washing the tomatoes are then crushed into pulp which is filtered. The tomatoes are then uniformly pre-heated in boiling water for about five minutes. Whilst in boiled water, the tomatoes must be well covered. When the time reaches the tomatoes are removed and cooled for by rapidly pouring cold water over the tomatoes. This help in removing any bad odour and help in de-skin as well as de-seeding. After the pre-heating, a heat exchanger is used to concentrate the pulp. Pulp concentration is done in a very short time to prevent the processed product from developing a dark reddish colour. The concentrate is then homogenized and flavouring and maybe spices added to give its organoleptic properties. Tomatoes are then pasteurized using hot water. At this point the bottle and the product have to be at the same temperature. Pasteurization can be done for 45 minutes.The final tomato paste is packaged in canned or films for storage and distribution to market centres.

7. Strategies to Revamp the Tomato Processing Plants in Ghana

1. **Variety**

   Tomato variety to be used should be high yield, high demand in the market, fast maturing and must have a thick pericarp to facilitate mechanical harvesting. The variety must also be disease resistant since tomato at certain stage can be attack by diseases up to the fruiting stage.

2. **Contract Farming**

   In order to ensure continuity in the supply of fresh tomatoes to the processing plants, contractual agreement can be agreed between the facility management and the farmers around to produce to the processing plant. Agro-inputs can be supplied to the farmers and after harvest the exact cost incurred can be quantified and deducted and the remaining amount will be the profit made by farmers. This can therefore be sustained through legal backing since wholesalers and retailers are always looking for opportunities within the supply chain systems.

3. **Commercial Farms**

Establishment of commercial farms could help in the supply of raw materials directly into the facility. The tomatoes under this practice when planned efficiently can be cropped for two to three times a year. This will ensure consistent supply of tomatoes to the facility.

4. **Outsourcing**
   Tomatoes can be outsourced from other producing areas or regions to the processing plant to ensure continuous processing. A lot of cost will be incurred on transportation and mechanical injury can also occur in tomatoes as well as contamination.
5. **Logistics**
   Logistics encompasses transportation, warehousing and management of materials. The production has to be planned to ensure proper movement of agricultural products to the processing plant and also to consumers. These include handling, processing, storage and packaging. An efficient infrastructure is needed to accommodate all product delivery with the right quality and at the right time.
6. **Facility management**
   The processing plant must have competent technicians to manage the daily activities of the processing. There must be training and retraining of technicians as well as all those involve in the value chain activities of tomato processing. Strict adherence to all processing protocols must be observed to ensure quality product processing to meet international standards.

7. Conclusion

Tomato processing generates a lot of income to the processors and also reduces high post- harvest losses in tomatoes. Processing of tomatoes into paste form can earn Ghana foreign exchange. This will make Ghana self-sufficient in the processed tomato products industry by reducing importation of tomato paste. Sustaining tomato processing will help in extending the post-harvest life of tomato and increase its accessibility. The processing plants when revamped will increase the food security capacity of Ghana.

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COMPARATIVE STUDIES ON THE MECHANICAL CHARACTERISTICS OF SOME SELECTED FOREIGN AND INDIGENOUS SPECIES OF KENAF

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Abstract

Adequate management, handling and processing of agricultural products such as Kenaf requires a good knowledge of their physical and mechanical characteristics. The study investigated the strength characteristics of two foreign (Cuba 180, Talinum 2) and 3 locally available varieties of kenaf fibres (Ifeken DI 400, Ifeken 100 and Ifeken 400), with a view to providing insight to optimum conditions for the processing of the fibre into some yarn and other products. It was observed that the Ifeken 100 variety had the least tensile strength with a corresponding value of $23.62x10^{-1}$MPa while Talinum 2 exhibited the highest average value of $62.45x10^{-1}$MPa. Analysis of the modulus of elasticity, however, revealed that Ifeken DI 400 exhibited the highest modulus of elasticity of $66.28\ x10^{7}$ while Ifeken 400 was observed to have the least modulus of elasticity of $17.42\ x10^{7}$. Cuba 108 was observed to offer the highest allowance for an extension before rupture with the value of $79.81x10^{-1}$mm while Ifeken DI 400 has the least fibre extension with the value of $96.67x10^{-2}$ mm. The results of the study will be useful in guiding the utilisation of the materials as well serve as a precursor to the design of appropriate machines for further processing of the fibres to preserve the quality of the products.

Keywords: kenaf, variety, tensile stress, modulus of elasticity, physical properties, mechanical properties.

1.Introduction

The use of synthetic packaging materials for importation and exportation of agricultural produce is being criticised across the world due to its threat to eco-system. This has necessitated the exploration and use of natural fibres and other eco-friendly alternatives in the production of packaging materials. This development has led to the acceptance of kenaf (*Hibiscus cannabinus*) as a promising industrial crop that can be used for high grade agricultural produce bag (Balogun *et al,* 2008)

Kenaf is a single, straight plant, usually with an unbranched stem that consists of two parts; core and bast fibre (Joshi *et al,* 2004).The crop matures between 3 to 4 months after planting (Webber *et al,* 2002) and can be grown under a wide range of weather conditions, to a height of more than 3m and a stem diameter of 1–5 cm (Dauda *et al,* 2014). Studies have shown that the moisture content of kenaf reduces after three months of maturity (Falana *et al*., 2019) and most of the stalk (up to 40%) obtained from kenaf plant has useful and useable fibre that is almost double that of jute, hemo or flax (Nimmo, 2002) This yield percentage makes the fibre more economical compared to that of other plants.

The origin of kenaf can be traced to Africa (Hamidon *et al.,* 2019). However, the continent only produces only 2.9% of the global production of kenaf (FAO, 2003) This has been partly attributed to the poor level of information on the crop as well as processing capacity in the continent . Hence, this study set to determine some desirable and essential mechanical properties of selected indigenous and foreign kenaf varieties (that are readily available for kenaf farmers) with the aim of designing farmer-friendly postharvest equipment that will enhance the acceptability and utilization of the crop.

2. Materials and Methods

2.1 *Selection of Test Materials*

The species of Kenaf fibres used for this study were planted in July and harvested after 12 weeks of planting The harvested fibres were then soaked in water and allowed to ret for a period of 14 days after which the fibres were extracted and sundried. The obtained fibres were taken through a process known as carding in order to straighten them as well as remove portions that were not useful.

2.2 *Strength Characteristics*.

To determine the strength characteristics (tensile stress, tensile strain, Young's modulus, rupture load, and energy) of the kenaf stems, 60 samples each of Cuba 180, Ifeken DI 180, Ifeken 100, Ifeken 400 and Talinum 2 varieties were subjected to tests using a universal Instron testing machine (Instron, USA) The force-deformation, rupture load, and energy of the samples were displayed on the monitor connected with the universal testing machine. Young's modulus was determined from the slope of the stress-strain curve.

2.3 *Statistical Analysis*: the obtained data sets were analysed by carrying out an analysis of variance test (ANOVA) at a 95% confidence interval ($P \leq 0.05$) using a Data Analysis Toolkit on Microsoft Excel Professional software (version 2016).

3. Results and Discussion

3.1 Effect of Specie on Maximum applied load (N): it was observed that the Talinum 2 variety was able to withstand the highest load value of 63 N (figure 1). This was followed by Ifeken DI 400 variety. The Ifeken 100 variety had the least resistance to load deformation as the maximum load before rupture was recorded at 24 N. This consequently makes the maximum tensile stress follow the same trend (Figure 2) as expected of an ideal material and that any equipment design for handling these varieties especially in operations such as spinning and reeling should be such as can be adjusted to care for this peculiarity. The maximum energy required for fibre rupture was also observed to have followed the same trend as the aforementioned characteristics having a maximum value of 0.03 J for Talinum species while Ifeken 100 could only withstand 0.01 J of force before rupture which is the lowest value among the considered species

3.2 Effect of Specie on Maximum tensile strain (mm/mm): comparison of the maximum values of tensile strain for the varieties (Figure 3) revealed that Ifeken 400 gave the largest relative elongation of 0.55 mm/mm under the applied tensile force while Ifeken DI 400 exhibited the least maximum strain of 0.016 mm/mm of fibre. This implies that the bonds holding Ifeken DI 400 are weaker compared to other varieties. According to Samad *et al*. (2002), when fibres are unstretched, the intermolecular chain formed by hydrogen bond is strong. However, at a certain level of load, the bond fails as the strain increases at the end of the Hookean region.

3.3 Comparison of extension per unit time for the various Kenaf varieties: a comparison of the extension per unit time over the length of experiment (figure 4) shows that Talinum 2 had the lowest yield time of 10 seconds with a maximum extension of 2.5 mm while ifeken 400 had the highest yield point at 35 seconds and an extension of 10.4 mm. Ifeken 100 was however observed to have not attained its yield point even after the 40 seconds test period. Although Talinum resisted higher load, it failed in a short time thereby showing almost no visco-elastic effect (Samad *et al*., 2002) The lignin content might be responsible for this phenomenon. This is because the composition of lignin in the fibre may differ based on the variety (Millogo *et al*., 2015) Degradation of the fibre may also have occurred when exposed to adverse environmental conditions. Hence, the time of harvest may influence the strength of the kenaf fibre.

3.4 Modulus of Elasticity: comparison of the modulus of elasticity for the evaluated species as shown in figure 5 revealed that the Ifeken DI 400 variety had the highest value thus indicating that the stress to strain ratio was highest (66.28×10^7 gf/tex) when compared with other species thus indicating that this specie was more stability under load conditions. Ifeken 400 was however observed to have the least value (17.42 x 10^7 gf/tex) for modulus of elasticity also inferring that the fibre condition was the least stable under load condition.

3.5 Statistical Analysis: Analysis of variance of the strength characteristics of the observed Kenaf varieties (Table 1) revealed that the effect of Kenaf variety on the fibre strength was statistically significant ($P \leq 0.05$). It was also observed that the effect of kenaf variety on the performance under different tests was also statistically significant ($P \leq 0.05$).

4. Conclusion

The study concludes that Ifeken DI 400 and Talinum 2 could be classified as exhibiting similar load as well as Tensile Strain characteristics in the higher range while Cuba 180 and Ifeken 400 were similar in the lower range category. Visco-elastic and lignin content were also observed to have considerable effects on rate of extension per unit time.

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Illustrations

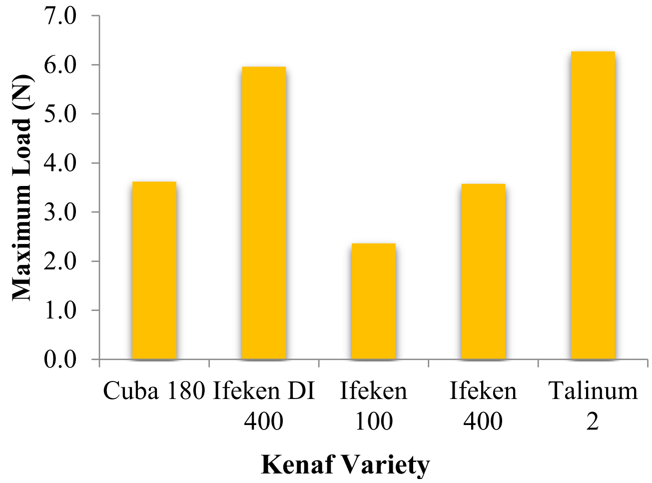

Figure 1: Comparison of maximum applied load (N) for the various kenaf species

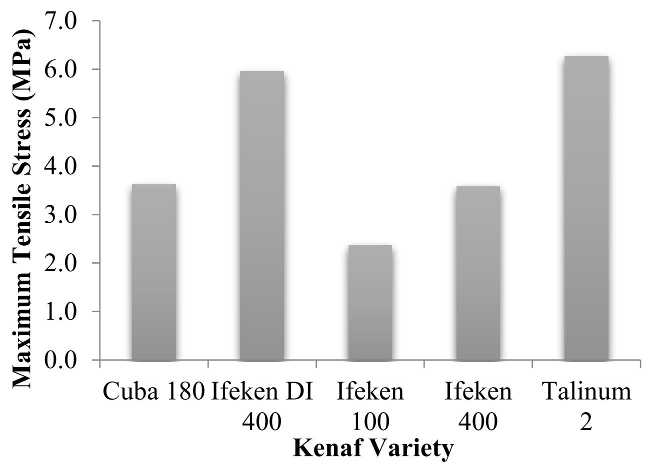

Figure 2: Comparison of maximum tensile stress (MPa) for the various kenaf species

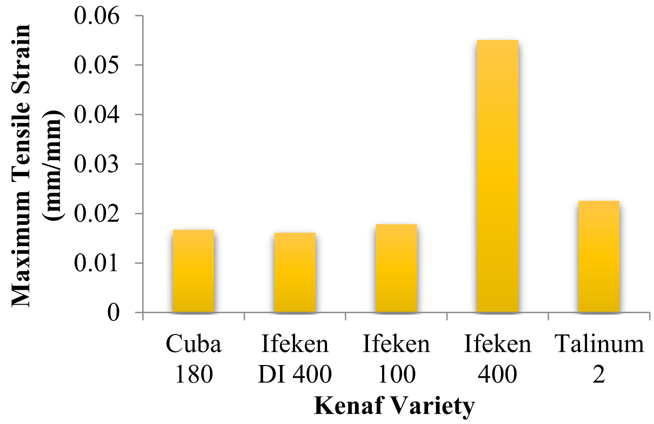

Figure 3: Comparison of maximum tensile strain (MPa) for the various kenaf species

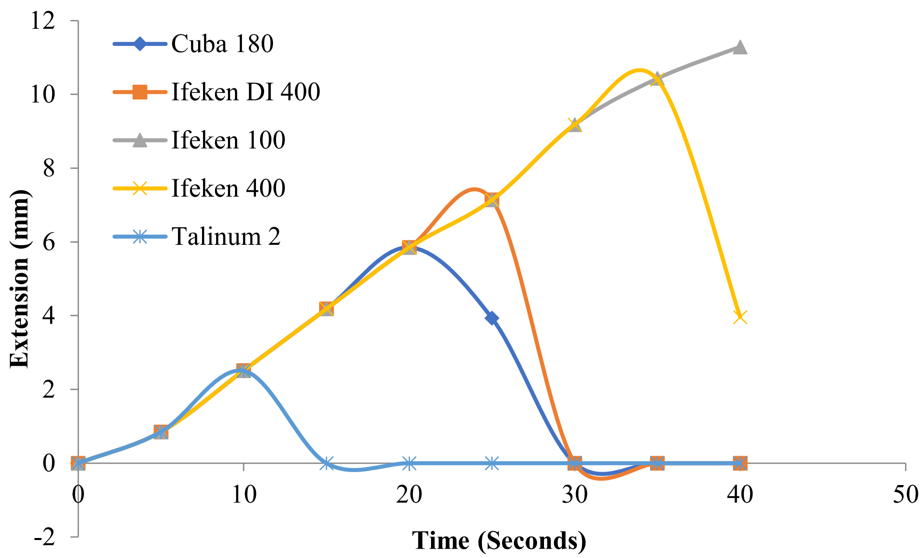

Figure 4: Comparison of extension at different times for the various fibre species

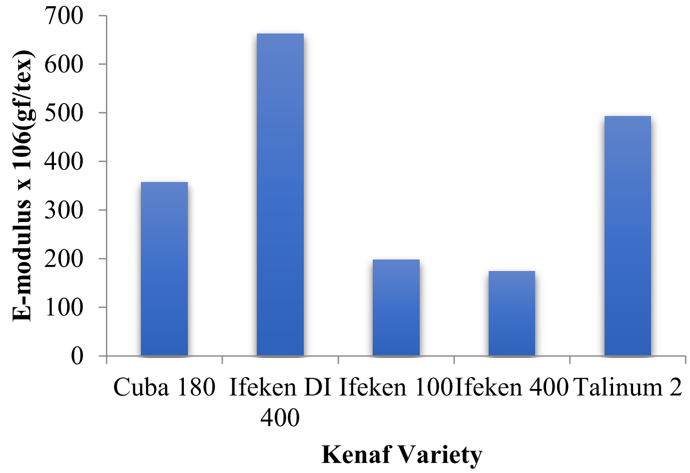

Figure 5: Comparison of modulus of elasticity for the various kenaf species

Table 1: Analysis of variance table for the Strength of kenaf species

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Kenaf variety	6.75E+16	4	1.69E+16	5.664239	0.002184	2.75871
Strength characteristics	1.14E+18	4	2.84E+17	95.44472	9.17E-15	2.75871
Interaction	2.7E+17	16	1.69E+16	5.664237	6.42E-05	2.069088
Within	7.45E+16	25	2.98E+15			
Total	1.55E+18	49				

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A REVIEW ON FOOD FORTIFICATION TECHNOLOGY

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Abstract

Micronutrient deficiency has been reported to be common in the world with iron, vitamin A and iodine deficiency cases on the rise. This is partly as a result of little attention given into the concept of foodstuff enrichment as well as the technology involved for a successful implementation of food fortification. Similarly, since the increase in knowledge of the complexity of human nutrition, there are still cases in which food security is conceptualized as simply the supply of foods to provide metabolic energy. This makes food fortification play a vital role as a supplement to the targeted population affected and with appropriate technological practices. Appropriate fortification processes can be one of the solutions among others used to combat micronutrient deficiencies in a given population. These fortified foods can be consumed by people of different age groups but commonly with children and women of reproductive category. Fortified foods can therefore be classified as either mandatory of voluntary fortification. When fortified foods contain the three basic micronutrients required such as iron, vitamin A and iodine, it is said to be a mandatory fortification. While voluntary fortification is a sole responsibility of food manufacturers, with adhesion to the government regulations to enrich processed foods for a business initiative. With the intervention of food industries, food fortification is achieved through the availability of food vehicles. The idea of food fortification is a process that plays an essential role beyond micronutrient requirement, fortified foods need to be consumed in adequate amount by a large proportion of the target individuals in a population. This makes it necessary and places demand for one to have access to, and to use, fortificants that are well absorbed yet do not affect the sensory properties of food. Food fortification is therefore essential for providing the needed micronutrient deficiency that is prevalent in a population.

Keywords: fortification, food, micronutrients, food vehicle and population

1.0 Introduction

Fortification is defined as the process of foodstuff enrichment with mineral component or a vitamin of choice (Smigielska and Joanna, 2010). It is the process of adding nutrients or non-nutrient bioactive components to edible products which could include food, food constituents, or supplements. In 2002, Nigeria successfully mandated a salt iodization program and the fortification of maize and cooking oil with vitamin A, and sugar and flour with iron. With fortification, the practice of deliberately increasing the micronutrients in food consumed by the population is achieved with minimal health risk (WHO/FAO, 2006). Since food fortification can be carried out at different levels which also refers to the addition of nutrients at a higher level than that found in food origin, the demand for appropriate technology through which this can be achieved is essential. Food fortification technology thereby include the dry mixing of food such as wheat and maize flour and their products, and the supplementation of liquid and powdered milk. Beverage powders as well as breakfast cereals, rice and other processed foods are typical examples that are widely used (Andrew and Theodore, 2015). The concept of food fortification is a very important tool as other food sources supplement others for their nutritional content. Also, since the increase in knowledge of the complexity of human nutrition, there are still cases in which food security is conceptualized as simply the supply of foods to provide metabolic energy (Omar and Michael, 2008). This implies that, food fortification has being considerably on advance because it provides the needed supplement with minimum cost that help combat deficiency of vital micronutrients such as vitamins, minerals and trace elements. These micronutrients are essential for the mental and physical development of both children and adults. Fortified foods if consumed on a frequent and regular bases has the capacity to maintain the required body nutrient more efficiently and effectively than intermittent supplement. The idea of food fortification is a process whose relevance is beyond the micronutrients enrichment, this is because fortified foods need to be consumed in adequate amount by a large proportion of the target individuals in a population. This makes it necessary and places demand for one to have access to, and to use, fortificants that are well absorbed yet do not affect the sensory properties of foods. Fortification has proven to be an effective strategy for combating micronutrient malnutrition around the world, but it is most often applied to processed foods made at industrial scale plants (Ravi and Quentin, 2005). Where often, processed foods from industries known as food vehicles are made use of as support for this purpose (WHO/FAO, 2006).

2.0 Fortification Processes

Fortification processes can be carried out in three ways. First, through the restoration of the lost micronutrients to its natural level such as restoring B-vitamins which could be lost during milling operations. Food restoration adds in exact amount the lost micronutrient during handling or storage. Secondly, by increasing the level of a nutrient above that normally found in the food such as adding extra iron to wheat flour or extra calcium to milk- a process also known as supplementation. Third, when there is addition of nutrients that are not normally present in a food item which could be considered a good vehicle for delivering micronutrients to the consumer, this is mostly practiced when vitamin A is added into sugar or iodine added into salt (Abeshu and Geleta, 2016).

2.1 Food Supplementation

This is simply a process used in the addition of relatively large amount or doses of micronutrients to food in the form of capsules, syrup or pills. Supplementation is also described as one of the fastest way to controlling micronutrient deficiency because of its capability to supply best amount of specific nutrient in a highly absorbable form. Food supplementation has being widely used in developing countries like Nigeria to combat folic acid and iron deficiency in pregnant women and as well as vitamin A deficiency in children. In supplementation, fortificants used as micronutrients are usually expensive and require an effective distribution system that will be a continuous process which pose a major barrier to the success of supplementation. It is a short term strategy of meeting up with the micronutrient deficiency **-** giving a large dose of the micronutrient as a medicinal supplement which have been effective in providing immediate relief in several countries, but this approach is not sustainable in the long term (FAO, 1997)

2.2 Food Vehicles

A food vehicle can also be referred to as a food carrier which serves as a suitable and compatible medium through which fortification can be carried out. Just like the name implies, it facilitate food fortification practices without any changes of the population diet. Most food vehicles are made common as well as available with the aid of industrial intervention through large scale production such as edible oil and flour (Federal Ministry for Economic Cooperation and Development (BMZ), 2012). Food fortification will highly be effective if there is a suitable combination between the selected food vehicle and the chemical form of the micronutrient to be added. Such selection is governed by a range of factors both technological and regulatory. Foods such as cereals, oils, dairy products, beverages and various condiments like salt, sauces and sugar are particularly well suited to mass fortification. These foods share some of the following characteristics:

i. It allow nutrient premix to be added relatively easily using low-cost technology, and in such a way that will ensure an even distribution within batches of the product.
ii. It is consumed by a large proportion of the population especially the population groups at greatest risk of deficiency.
iii. It is used relatively soon after production and purchase. This is because foods that are purchased and used within a short period of time of processing tend to have better vitamin retention and fewer sensorial changes due to the need for only small overage.
iv. It is consumed on a regular basis, in adequate and relatively consistent amount.

2.3 Fortificants to be used

The choice of the chemical form of the micronutrient to be used along with the food vehicle is vital. This is because a wrong choice will lead to exposing the health status of the population to more risk. Therefore when selecting the most appropriate chemical form of a given micronutrient, the following consideration should be noted;

i. ***Cost:*** The cost of fortification must not affect the affordability of the food nor its competitiveness with unfortified alternative. Also, fortification should have a low impact on the price of the food vehicle to facilitate compliance and creation of a level playing field among manufacturers (WHO/FAO, 2006)
ii. ***Sensory challenges:*** The chemical form of the selected micronutrient should not cause unacceptable sensory problems such as; change in colour, flavour and odour at the level of intended fortification – it must be stable within the given limit.
iii. ***Interaction:*** The likelihood or potential for interactions between the added micronutrient and the food vehicle, and with other nutrients either added or naturally present should be properly monitored before full implementation of the fortification programme.
iv. ***Bioavailability:*** The fortificants must be sufficiently well absorbed from the food vehicle and be able to improve the micronutrient status of the targeted population.

3.0 Importance of Food Fortification

Food fortification is important because it utilizes staple foods consumed by a large segment of the population without forcing the people to change their original diet. This is technologically feasible and advantageous where fortified food can easily be implemented in developing countries like Nigeria. Food fortification technology has a great significance as fortified food is important in crisis situations; in situations of fragility triggered by economic crises, natural disasters or long term violence conflict. During this periods, diet is often inadequate and unbalanced, so food fortified with vitamins or minerals is distributed to prevent malnutrition (Federal Ministry for Economic Cooperation and Development (BMZ), 2012). Fortification is important because it help combat the prominent cases of micronutrient deficiency as recorded by World health organization in 2002. The report identified iodine, iron, vitamin A and zinc as some of the most common deficiencies faced by the world, with food fortification recognized as one of the most cost effective method with a long term sustainability as well as good improved health intervention (United Nations International Children's Emergency Fund (UNICEF), 2011). Fortified foods are also better at lowering the risk of the multiple deficiencies, an important advantage to growing children who need a sustained supply of micronutrients for growth and development, and to women of fertile age who need to enter periods of pregnancy and age for lactation with adequate nutrient stores.Fortifying food with micronutrients is a valid technology because it reduces micronutrient malnutrition which is part of a food-based approach, when existing food supplies and limited access fail to provide adequate levels of the respective nutrients in the diet. In such cases, food fortification strengthen and supports ongoing nutrition improvement programmes and should be regarded as part of a broader, integrated approach to prevent micronutrient malnutrition, thereby complementing other approaches to improve micronutrient status (WHO/FAO, 2006).

4.1 Advantages of Food Fortification Technology

Some of the advantages of food fortification include;

i. Fortified foods are better at lowering the risk of the multiple deficiencies that can result from seasonal deficits in the food supply or a poor quality diet.
ii. Fortification is basically aimed at supplying micronutrients in specific quantity whose equivalence is same to those provided by a good and well-balanced diet.

iii. Fortification of widely distributed and widely consumed food has the potential to improve the nutritional status of a large proportion of the population, both poor and wealthy.
iv. Food fortification does not require changes in existing food pattern of the people which makes it socially acceptable.
v. Fortification of foods with several micronutrients simultaneously is highly feasible.
vi. It is usually possible to add one or several micronutrients without adding substantially to the total cost of the food product at the point of manufacture.
vii. Fortification is often more cost-effective than other strategies, especially if the technology already exists and if an appropriate food distribution system is in place.

5.0 Types of Food Fortification and Examples

The degree to which food fortification occur is considerably different based on the technology deployed. Hence, the types of food fortified can be classified as follows;

i. ***Mass fortification:*** Mass fortification involves fortifying foods that are commonly consumed by people within same geographical region. It is generally referred to as mandatory fortification because it contains the three most basic micronutrient needed universally that pose a higher order risk to human health: These include iodine, vitamin A and iron. In mass fortification, one or more micronutrients is added to foods commonly consumed by the general population. This process of food enrichment has a long and lasting value to meeting up with the micronutrient challenges faced by the people, than food restoration which is the addition of vital nutrients to foods to restore amounts originally present in the natural product that are lost inevitably while processing, handling, milling or even storage. This can include foods such as cereals, condiments and milk as well as addition of folic acid to wheat flour with a view to lowering the risk of birth defects (WHO/FAO, 2006). Mass food fortification is highly incited and encouraged by the government through the availability of food vehicles. These food vehicles are processed by adequate manufacturing and industrial settings which ensure cost effective production and supervision.
ii. ***Targeted Fortification:*** In targeted food fortification, fortified food are made available to a set and subgroup of people rather than the whole masses; which is simply the practice of adding sufficient amount of micronutrients to provide large proportions of the daily needs with the aid of processed foods that are readily available for specific population subgroup. This type of fortification usually facilitate the rate of food intake as in complementary foods such as those used for infants, foods for institutional programs including; those aimed at pre-school and school-aged children. Foods used under emergency situations like those displaced from homes, food supplied to refugee camps as well as special biscuits for children and pregnant women are all target food fortification.
iii. ***Market driven fortification:*** This is simply the process by which a food manufacturer picks up the responsibility with adhesion to the government regulations to enrich processed food for a business initiative. These fortified foods produced by the food manufacturers are readily available in the market; this is because market driven fortification makes available as well as improve the supply of micronutrients that are quite complex to add in adequate quantity for mass fortification to handle due to technological or cost control. Market driven fortification which is a voluntary practice by the food industry is aimed at to increase the nutrient content as well as value addition of a highly processed product with the purpose of attracting consumers and increasing sales. With the increasing rate of industrialization in Nigeria as a developing country, market driven fortification will be effective for combating micronutrient deficiencies.

The basic idea of food fortification has given humanity amenable solutions to some of the most common deficiencies prevalent in the world. Challenges such as neuro-tube defects due to folic acid deficiency can be abated, Vitamin A deficiency which causes sight impairness. Rickets which occur as a result of vitamin D deficiency, dental caries through fluoridation of drinking water in endemic areas including goitre and growth delays through iodization of salt, can all be controlled.

5.1 Criteria for a Successful Food Fortification

The addition of micronutrients to food varies from one region to another nevertheless govern by rules and regulation. For a successful implementation of a food fortification programme, a cordial relationship existing between the government, health professionals, food industries and consumers is vital (Wiebe, 2010). The government regulate these practices by coming to a consensus with the food industry, with adequate legislation to ensure strict adherence to set of standards for other voluntary fortification schemes. This aid in eliminating cultural objections toward food fortification as the government makes it mandatory for the target group. Food fortification can thereby be classified based on legal considerations as:

1. ***Mandatory Fortification***

   Mandatory fortification occurs when the government legally constrain food manufacturing industries to fortify particular foods or categories of foods with specified micronutrients. Mandatory fortification, especially when supported by a properly resourced enforcement and information dissemination system, delivers a high level of certainty that the selected food will be appropriately fortified and in constant supply. In deciding the precise form of mandatory fortification regulation, government are responsible for ensuring that the combination of the food vehicle and the fortificants will be effective for the target group, yet safe for target and non-target groups alike. Universally, mandatory regulations are most often applied to the fortification of food with micronutrients such as iodine, iron, vitamin A, and increasingly folic acid. Of these, the iodization of salt is probably the most widely adopted form of example of mandatory mass fortification.

2. ***Voluntary Fortification***

   This is the fortification practice carried out by food industries voluntarily in line with the specified laws enacted by the government. The driving force for voluntary fortification usually comes from food industries and consumers seeking to obtain possible health benefits through an increase in micronutrient intakes (WHO/FAO, 2006). When implementing voluntary fortification arrangements, the government have a duty to ensure that consumers are not misled by fortification practices. Also, government ensures that the market promotion of fortified foods does not conflict with or compromise any national food and nutrition policies on healthy eating. Since the level of fortification differs from country to another because of the differences in the availability of different food sources makes the level of industry uptake of fortification practice influenced by prevailing market conditions (Federal Ministry for Economic Cooperation and Development (BMZ),2012).

5.2 Criteria Governing the Selection of Mandatory and Voluntary Fortification

There are five key factors that determine whether the fortification process will be mandatory or voluntary for a given population with micronutrient deficiency.

i. **The food consumption pattern:** Foods considered for mandatory fortification are widely and frequently consumed by the population group that the fortification is intended to benefit making the technology deployed technically feasible. Therefore the food consumption pattern as regards the relative contribution of certain foods to the diet of the target population, will have a bearing on the choice of mandatory or voluntary fortification (Ajanaku *et al.*.2013).

ii. The relevant population's present level of knowledge about the importance of consuming fortified foods or their interest in consuming fortified foods. Mandatory food fortification is likely to be more effective and more accepted when the knowledge of the consumer is little or demand for voluntary fortified foods is low, this is as a result of less knowledge about community nutrition education.

iii. **Political environment:** The degree to which government intervention is acceptable as well as the value placed on acquainted population group choice is the most significant criteria that affect the regulatory decisions in terms of an environment with political influence. Thus, in environments where consumer choice is highly valued both voluntary and mandatory fortification will be appropriate. In such settings, mandatory fortification tends to be limited to a subset of products within one or more proposed food categories, in order to maintain some degree of consumer choice. Voluntary fortification usually gives a higher level of consumer choice; however, in many developing countries where poverty remains the limiting factor to access to processed foods for the majority of the population.

iv. The significance of the public health need or risk of deficiency as determined by the severity of the problem and its prevalence within a population group.

v. The features of food industries responsible for the production of the proposed food vehicle. In developing countries like Nigeria, mandatory fortification is likely to be successful when the food industrial sector in question is confined to a handful of major producer or well organized.

5.3 Economic Importance of Food Fortification

Although it is well recognised that food fortification is one of the preferred and cost-effective approaches in combating micronutrient malnutrition, its effectiveness in developing countries is yet to be demonstrated. One of the limiting factors is the lack of simple and affordable technology to fortify foods with stable and bioavailable nutrients without compromising commonly accepted taste and appearance (Darnton-Hii and Nalubola, 2002). In recent years a number of African countries have initiated food fortification programmes which have proven to be cost effective in addressing the issue of food security (Andrew and Theodore, 2015). Food fortification can be a simple, efficient and inexpensive strategy for supplying vitamins and minerals to diets of large segment of the population. This is because fortify foods can be introduced quickly through existing marketing and distribution channels, and the benefits are obviously clear. Fortification of staple foods with vitamin A will be a cost effective intervention for reducing vitamin A deficiency, especially in settings where improving the dietary quality through increased food variety is not visible. Foods such as edible oil and fats, cereal grain, condiments, refined sugar and milk have being successfully fortified with vitamin A leading to improved vitamin A status (International Potatoe Centre, 2018). Therefore among the other key strategies identified to address micronutrients deficiency: supplementation, food fortification, dietary improvement, and other control measures. Food fortification is recognized as one of the most cost effective methods. The World Bank, WHO, UNICEF, Micronutrient Initiative (MI) and Global Alliance for Improved Nutrition (GAIN) also have identified fortification, as among the most cost-effective of all health interventions (United Nations International Children's Emergency Fund (UNICEF), 2011).

5.4 Limitations of Food Fortification

The limitations of food fortification are quite obvious and well known, this is because food fortification alone cannot correct micronutrient deficiencies. In situations where large numbers of the targeted population is required, access to fortified food might be difficult or even little because of poverty or locality especially when the level of micronutrient deficiency is too severe. Also, various safety and cost considerations can also place constraint on food fortification intervention. Thus, proper food fortification programme planning does not only require assessment of it potential impact on the nutritional status of the population but also of its feasibility in a given context which needs to be controlled by appropriate legislation (World Health Organization (WHO), 2000). Also, one of the limiting factors is the lack of simple and affordable technology to fortify foods with stable and bioavailable nutrients without compromising commonly accepted taste and appearance (Sasson, 2005)

6.0 Conclusion

The essence of this review paper is to aid combat micronutrient deficiency that is prevalent in the world with appropriate fortification practices that will be of less harm to human health. Most importantly, effective food fortification is one that is able to reach out to the population , therefore fortification of foods of various kinds as vehicles such as starch food vehicles could be an added advantage which can be made available and affordable at all times even to the less privileged.

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ASSESSMENT OF RICE PROCESSING CHALLENGES AND POSSIBLE SOLUTIONS: A CASE STUDY OF IGBEMO RICE COMMUNITY, EKITI STATE

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Abstract

This paper investigates the challenges of local rice processing and recommends probable solutions to boosting rice economy in Nigeria using Igbemo community (Ekiti state), a major player in rice processing with a popular brand called Igbemo rice as a case study. The data for this study were collected from 30 rice processors using a well-structured questionnaire, purposive sampling technique and some focus group discussions to obtain information on the socio-characteristics of rice processors in the study area, production data, economic status and the constraints. Quantitative assessment was also used to measure the degree of rice processing challenges as well as the number of youths involved in rice processing using descriptive statistics. The results were also subjected to analysis of variance ($p<0.05$). The results obtained show that 30%, 13.3%, 0%, and 56.7% of the respondents' population have primary, secondary, tertiary and informal education, respectively. It was also found that 56.7 % of the respondents make use of milling machine, while all the rice processors make use of the local processing methods to achieve harvesting, threshing, parboiling and drying operations. In addition, 37 %, 30 %, 17 %, 7% and 10% of respondents had their sources of income from cooperative society, farm output, salaries, bank loans and borrowing from friends respectively. Furthermore, it was gathered that 6.60%, 16.7 % and 76.7 % had processing experience of 1-5 years, 6- 10 years and above 10 years respectively. Probable recommended solutions to boost rice economy in Igbemo community and Nigeria as a whole include; the development of appropriate machineries, training and education for rice processors including the youths, awareness campaign to stimulate the interest of respondents in machineries operation, water recycling, filtration and purification, government intervention and assistance in the form of long term loan.

Keywords: Igbemo rice, Quantitative assessment, Rice processors, Processing challenges, Solutions.

1. Introduction

Rice is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). According to the rice almanac of the International Rice Research Institute (Maclean S., 2002), rice is grown worldwide and is one of the two rice species important for human nutrition. In Nigeria, it is one of the major staple foods and very rich in carbohydrate, protein, vitamins with some trace amount of iodine, iron, magnesium and phosphorus as well as insignificant proportion of fat. Rice bran contains proteins and vitamin B complex, E and K while polished rice contains about 25% carbohydrate, with trace amount of iodine, iron, magnesium and phosphorus and almost insignificant amount of fat (Pardee, 2002). The world dedicated 162.3million hectares in 2012 for rice cultivation and the total production was about 738.1million metric tonnes (FAO, 2012). The average world farm yield for rice was 4.5 tonnes per hectare in 2012 with China producing the highest of 204.3million metric ton, India 152.6, Thailand of 37.8 and Nigeria with 4.8 million metric tonnes respectively (FAO, 2014). This shows that the rate of consumption of rice in Nigeria far outweighs production but the consumption of locally produced rice is declining due to its inferior quality compared to the imported ones. Rice is cultivated in virtually all the agro-ecological zones in Nigeria

(Akande, 2001). Nigeria is Africa's second largest economy, with 75 million people living in poverty (Doney, 2005). It has a federal structure of 36 states – Ekiti State inclusive. Rice farming is a primary activity among the farmers in the state where 70 percent are actively engaged in its production (NISER, 2002). Most Nigerians prefer local rice varieties because of their taste and aroma. However, unhygienic processing has hindered our local rice from competing favorably with imported rice (Longtau, 2000). This drives the passion in looking into the challenges being faced by rice farmers in this State using Igbemo; the local rice community as a case study and also addressing these challenges in order to promote rice industry in the country. It is becoming increasingly clear that, Igbemo-Ekiti is acquiring national and international reputation for rice production. Nigerian government has placed embargo on rice importation and has her land borders closed since October 14, 2019 (John C., 2019). This puts Nigeria's rice output at 4.9 million tonnes in 2019, up 60% from 2013 but well below local consumption of 7 million tonnes (Libbby G., 2020). Hence, the need to look into the issues affecting rice processing and address its challenges.

2. Research Methods

2.1 *Area of Study*

The study was conducted in Igbemo Ekiti State, Nigeria which is one of the leading 13 rice producing states in the country with the production of Igbemo rice (Igbemo, 2012). Ekiti state has sixteen local government development areas (Figure 3.1). Igbemo is situated in the eastern part of the state in Irepo/Ifelodun local government area of 356km^2 and a population of 129,149 as at the 2006 census; its headquarters at Igede. A traditionally prosperous agricultural town- 'The Home of Rice' as it is popularly called has a rain fed upland environment with its geographical coordinates of 7° 42' 0" North, 5° 21' 0" East (maplandia.2013).

The sample used for the population of study were those participating in strictly rice processing either using hand tools or mechanized implements in Igbemo community. A sample of about 30 respondents was selected from the population.

2.2 *Data Collection and Analysis*

The data for this study were collected from respondents using questionnaires, purposive sampling technique and some focus group discussions were setup to select 30 rice processors from Igbemo community.

The data obtained from the questionnaire administered were analyzed using frequency counts and percentages. The results were also subjected to Analysis of Variance (ANOVA) test at 5% level of significance ($P < 0.05$) to show the effect of the sources of power on the processing operations.

3. Results and Discussion

3.1 *Socio Characteristics of Rice Processors in Igbemo Community*

As shown in Table 4.1, the 30 respondents comprise 27 males and 3 females. The mean age of the respondents was 32± 7.1 years, which shows that there is a minimal number of youths involved in rice processing. This may imply that the future of rice processing is at risk because of the low involvement or participation of youths in rice processing operation. This observation may suggest a negative impact on the economy of the country in the sense that rice importation would be enhanced since we would have to keep importing rice. Also 30%, 13.3%, 0%, and 56.7% of the respondents' population have primary, secondary, tertiary and informal education respectively. This implies that majority of the population are mostly illiterates while 76.7% have experience over 10 years which shows the level of expertise of the respondents.

3.2 *Participation of the Respondents in Processing Activities*

From Table 4.2, little or no mechanized implements are employed in rice processing right from harvesting to milling. This could be attributed to poverty since majority of the respondents cannot afford the processing machines. The Analysis of Variance (ANOVA) shows that the sources of power have no significant effect on the processing operations ($P < 0.05$) as shown in Table 4.3. These variations in the levels of tools used in the processing operations as reported in Table 4.2 are as follows:

i. ***Harvesting*****:** It was found out that all of the respondents engaged in this operation used hand tools such as knives and sickles to harvest their products. In the process of using hand tools, dirts and stones are accommodated while harvesting and thus reduce rice quality.

ii. ***Threshing*****:** As in the case of harvesting, all of the respondents use hand tools for threshing operation. The harvested rice is placed inside jute bags and then beaten continuously. Here, human energy is being expended and therefore leads to drudgery. Also, much of the time is consumed especially when there are more products to be threshed while destoning/ sorting is compromised.

iii. ***Parboiling*****:** Result from Table 4.2 shows that the respondents make use of crude means of parboiling which is powered by firewood as shown in Figure 4.1. This is an enterprise often frustrated by infrastructural challenges, weak capital base and unskilled labour.

iv. ***Drying*****:** Also, the result from Table 4.2 shows that all respondents carry out drying operations manually. Produce are air- dried on bare floor. This method, though a little bit effective due to drying under direct sunlight attracts dusts and dirts from the surroundings. This gives room for contamination from the surroundings. A typical illustration of drying platform is shown in Figure 4.2.

v. ***Milling*****:** It was found that 56.7 % of the respondents make use of a milling machine while others contract out this service. See Figure 4.3 for milling machine being used.

Fig. 4.1: Local parboiling

Fig. 4.2: Drying

Fig 4.3: Milling Machine

Table 4.1: Status of Rice Processors in Igbemo Community

Status		Frequency	Percentage (%)
Sex	Male	27	90.0
	Female	3	10.0
Age	20-24	-	-

	25-29	4	13.3
	30-34	2	6.7
	35-39	6	20.0
	40 and above	18	60.0
Educational Background	Primary	9	30.0
	Secondary	4	13.3
	Tertiary	0	0
	Informal	17	56.7
Processing Experience	1-5 years	2	6.
	6-10 years	5	16.7
	Above 10 years	23	76.7

N=30

Table 4.2: Rice Processing Operations

Operations	Manual	Percentage (%)	Mechanized	Percentage (%)
Harvesting	30	100	0	0
Threshing	30	100	0	0
Parboiling	30	100	0	0
Drying	30	100	0	0
Milling	0	0	17	56.7

Table 4.3: ANOVA of Processing Operations and Source of Power

Source of Variation	*Df*	*SS*	*MS*	*F*	*P-value*	*F crit*
Operations	4	67.6	16.9	0.076505	0.985566	6.388233
Source of Power	1	1060.9	1060.9	4.802626	0.093536	7.708647
Error	4	883.6	220.9			

Total	1	2012.1

Table 4.4: Sources of Income of Respondents

Source of income	Frequency	Percentage (%)
Cooperative society	11	36.67
Farm output	9	30.00
Salaries	5	16.67
Bank loan	2	6.67
Borrowed	3	10.00

n=30

3.3 *Constraints Encountered by the Respondents in the Processing Operations*

i. ***Technology***: It is obvious that most people involved in rice processing have limited access to mechanized implements due to high initial cost (Table 4.2). Crude implements are mostly utilized for most of the operations except for milling operation which some are able to afford. (Also, some believe that they might not be able to operate these machines due to the technicality involved).

ii. ***Finance***: Majority of the respondents are poor and cannot afford to purchase or hire machinery. Results of Table 4.4 show that 37, 30, 17, 7 and 10% of respondents had their sources of income from cooperative society, farm output, salaries, bank loans and borrowing from friends respectively. This implies that most of them do not have access to bank loans probably due to high interest rates. Therefore, no adequate fund to support the people.

iii. ***Education and Training***: Most of the respondents are illiterates (Table 4.1). Also, there are no available educational enlightenment programmes on ways to undertake mechanized operation.

iv. ***Water Supply***: A portable water supply remains a major challenge especially during the parboiling stage which is water demanding. Majority source water from nearby water bodies**.**

v. ***Species Mixture/Variation:*** A combination of different species of paddy by farmers creates considerable difficulties in the parboiling process thus, causing soaking temperature and overcooking challenges. Paddy supplies are also not thoroughly cleaned by farmers. Paddy usually contains large amount of chaff, dust and immature grains which generate "Black Rice" and overload mill's optical sorter.

4. Conclusion and Recommendations

4.1 *Conclusion*

The major challenges and difficulties facing the rice value chain are capital mobilization, lack of basic mechanization and seasonal availability of paddy as well as absence of marketing board payment system for paddy and rice importation tariff structure. A number of resources abound in different regions of Nigeria that could be effectively harnessed for regional development. With huge rivers, low lands and fertile deltas, Nigeria has limitless opportunity to impact the world with excellent quality rice if current initiatives and policy consistency are maintained. The policy discussions and recommendations however, hold some promises for Ekiti State and Nigeria as a whole.

4.2 *Recommendation*

1. Appropriate machineries should be developed and made available at each processing step to improve production. For example, a rice thresher can be adopted by individual rice processors instead of using the local method of threshing. Furthermore, drying operations can be carried out by using a mechanical dryer and if this is expensive, a simple/ low cost solar drying mechanism can be adopted so as to increase drying rate.

2. There will be need to focus on the training and education of the rice processors especially the youths amongst them because they learn fast and can easily come up with new ideas and innovations. These ideas will aim at improving the Nigerian rice to compete with the imported ones. Trainings must be given by the extension workers on how to operate these machines and safety hazards must be addressed. Seminars should be organized to address the problems of mechanical hazards if machines are to be used to give a technical know-how about the machine because lack of knowledge will lead to misuse of equipment and thus a great loss to the processors.

3. Extension workers must be able to spread awareness to stimulate respondents' interest in the use of machineries so they can desire the adoption of the new technology and thus be convinced using it so that action can be taken and they can also be satisfied using the technology.

4. There should be systems for water recycling, water filtration and purification during the parboiling stage

5. Funding difficulties in terms of interest rate, issues of collateral securities and very short repayment options kill off dreams/ ambitions of indigenous private sector ownership of mills. Therefore, government intervention and assistance in the form of long term loan is absolutely necessary.

6. Research Institutes should develop and transfer sustainable technologies on rice cultivation, processing, packaging and marketing using other method of information dissemination other than print to the farmers.

7. Encouraging large commercial farms that will complement our small-scale farmers e.g. Olam's rice farm in Nasarrawa will not only boost food production, but also provide significant opportunities for jobs in rural areas. Thus, youths would be supported to go into mechanized farming, and to pursue agriculture as a business.

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COOKING CHARACTERISTICS OF MILLED *OFADA* AND *FAROO-44* RICE VARIETIES

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Abstract

Cooking characteristics and physiochemical properties of rice are of fundamental importance in the design, dimensioning, manufacturing and operating of different equipment used in rice post-harvest processing. In this work, cooking characteristics of milled Ofada and Faro-44 rice varieties were examined. Excess-water cooking method was used in which 20 g each of the two varieties was cooked in 200 g of boiling water in a beaker which was heated over an electric coil stove. The rice was considered completely cooked when no white core appears by using two parallel glass plates to press together samples brought out from the beaker. Physical characteristics of the cooked rice examined includes; cooking time, water uptake ratio, grain elongation and solid loss in cooking water. The chemical characteristics considered are; moisture content, gel consistency, gelatinization temperature, amylose, amylopectin and protein. Sensory evaluation of the cooked rice was also carried out. The cooking time, water uptake ratio, grain elongation and solid loss in cooking water of Ofada are respectively 17 minutes, 2.95, 2.7 mm and 0.37 g; while for Faro-44 are 26 minutes, 2.85, 3.2 mm and 0.39 g respectively. The moisture content (db.), gel consistency, gelatinization temperature, amylose, amylopectin and protein of Ofada are respectively 12.99 %, 49.6 mm, 92º C, 23.82 %, 76.18 %, and 6.72 %; while for Faro-44 are respectively 11.22 %, 51.3 mm, 94º C, 21.33 %, 78.67 % and 6.42%. There is significant difference ($p < 0.05$) in the sensory attributes evaluated for Ofada but there was no significant difference ($p > 0.005$) in the sensory attributes evaluated for Faro-44. The cooking characteristics obtained in this work are useful in the design of cooking processes of the varieties considered.

Keywords: Cooking, *ofada, Faro-44*, Rice, Physical, Chemical

1.Introduction

Rice is one of the commonly consumed cereals and food staples for more than half of the world's population. Rice provides 19% of global human per capital energy and 13% of per capital protein (Cristiane *et al*., 2007). After the harvesting of rice on the farm, it undergoes some processing which involve parboiling. Parboiling involves partial boiling of the paddy before milling in order to increase its nutritional value and to reduce breakage in milling (Champagne, 2008). Parboiling is done in three steps, soaking, steaming and drying. Parboiling also mends little cracks that might have developed in the endosperm during postharvest processing and therefore head rice recoveries of parboiled rice are higher (Cheigh *et al*., 2007). There are different cooking methods carried out on milled rice, some of which are excess water cooking and optimal water cooking. Excess water is a method of cooking in which the rice to water ratio is quite high (1:10) and used as a standard laboratory test procedure (Pyan and Kwon, 2005). When rice is almost fully cooked, the excess water is drained off and the rice is then steamed until is fully cooked.

Optimal water cooking is the cooking of rice in a particular rice water ratio, so as to nearly match the exact water required for cooking. The right amount of water can be measured and added to the raw rice before cooking and this water will be completely absorbed into the rice. According to Lucisano *et al*. (2009), the recommended ratio of raw rice to water varies from 1:1.5 (firmer result) to about 1:2 (softer result), depending on the preference. After boiling, the heat is reduced to simmering until the rice is cooked and all water is absorbed. This method is largely practiced compared to excess-water cooking.

The economic value and properties of rice depends on its cooking and processing quality which can be measured in terms of water uptake ratio, grain elongation ratio, solid in cooking water and cooking time. Conventionally, processing quality rice has been assessed by a contribution of the physiochemical properties (Champagne, 2008). Rice varieties with Amylose content more than 25% absorb more water and have a fluffy texture after cooking as reported by Shin *et al*. (2009).

The cooking characteristics and physiochemical properties of rice are of fundamental importance for design, dimensioning, manufacturing and operating different equipment used in post-harvest processing (Afonso, 2011). Das *et al*. (2006) reported that, determination of cooking parameters of rice varieties under appropriate conditions is essential to the design of efficient cookers.

Rice grain characteristics determine to a large extent its market price and acceptability (Megha *et al*., 2019). For example, if the consumers dislike the sensory attributes and ease cooking in any variety, it loses its value irrespective of other outstanding traits it may possess. According to Oko *et al*. (2012), cooking and eating qualities in rice have focused on physico-chemical properties that is, amylose content, Gel consistency, and gelatinization temperature which are directly related to rice cooking quality. Tan *et al*. (1999) reported that cooking quality depends upon the physical and chemical characteristics of starch, such as amylose–amylopectin ratio, gel consistency, and gelatinization temperature. According to Xie *et al*. (2007), amylose content is one of the important characteristics influencing the cooking behavior.

This study aims to determine the cooking qualities, physico-chemical properties and sensory qualities of milled ofada and Faro-44 rice varieties.

2.Materials and Methods

2.1 Experimental Materials

Milled Faro-44 and Ofada rice varieties were obtained from Lagos State rice processing centre, Imota – Lagos, Nigeria. The samples were properly clean to remove debris after which it was used for the experiment.

2.2 Cooking Characteristics

The following cooking characteristics were considered in this work using excess water cooking method; Cooking Time, Water uptake Ratio, Elongation Ratio and Solid Loss in Cooking water.

Cooking Time

200 g of water was taken in a glass beaker and heated over an electric coil stove. A measured quantity of rice, 20 g was added once the water reached boiling state. The end point of cooking was determined by using parallel glass plate method as proposed by Desikachar (2006). In this method, the rice sample were periodically drawn out during the cooking and was pressed between two small glass plates. The sample was considered to be completely cooked when there is no white core observed.

Water Uptake Ratio

The method reported by Juliano and Bechtel (2003) was used to determine the water uptake ratio. Rice sample (2 g) for each variety were cooked in 200 g of boiling water for a minimum cooking time. Water was drained out from the cooked rice and the superficial water on the cooked rice was removed using filter paper sheets. The water uptake ratio was calculated using Equation (1).

$W_{ur} = Wcr / Wrr$ (1)

Where:

W_{ur} = Water uptake ratio

W_{cr} = Weight of cooked rice sample

W_{rr} = Weight of raw rice sample

Grain Elongation during Cooking

The grain elongation ratio was determined by first measuring the initial grain length (L_o) before cooking as employed by Juliano and Bechtel (2003). The final length (L_f) after cooking was then measured. The grain elongation during cooking was then calculated using Equation (2).

$ER = L_f – L_o$ (2)

Where:

L_o= Initial grain length before cooking

L_f= Final grain length after cooking

Solid loss in Cooking Water

This was determined by drying an aliquot of the cooking in a tarred evaporating dish to evaporate the water as steam. The weight of the empty petri-dish was measured as W_1. The weight of the petri-dish and aliquot was measured as W_2. The weight of the petri-dish and the dry aliquot was measured to be W_3. The amount of solid in cooking water was calculated using Equation (3).

$SL = W_3 – W_1$ (3)

Where:

SL= solid in cooking water

W_i=Initial weight (g)

W_f= Final weight (g)

2.3 Chemical Characteristics

The chemical characteristics carried out on the two varieties of rice are moisture content, gel consistency, gelatinization, amylose, amylopectin and protein.

Moisture Content Determination

ASAE (1993) standards was used to determine he moisture content of the rice grain. The moisture content value was computed using Equation (4)

$$MC_{wb} = \frac{W_w}{W_w + W_d} \times 100\% \quad (4)$$

Where; MC_{wb} = moisture content on wet basis, W_w= Weight of water, W_d=Weight of dry matter.

Gel Consistency

The method reported by Oko *et al*. (2012) was used. The gel consistency was determined based on the consistency of milled rice paste that was gelatinized by boiling in dilute alkali and then cooled to room temperature. Total length of the gel was measured in millimeters as tubes were laid horizontally on a table lined with millimeter graph paper.

Gelatilization Temperature

The method of Little *et al*. (1958) as reported by Oko *et al*. (2012) was used. It was determined by weighing 5 g of milled rice flour to which sufficient quantity of water was added to make slurry. The slurry was heated gently on a heater and was stirred until the first appearance of viscous plate was noticed and the temperature was recorded.

Amylose and Amylopectin

Standard published methods were used to determine the amylose and amylopectin of the two rice varieties. The evaluation method described by Perez *et al*. (1987) as reported by Oko *et al*. (2012) was used to analyze the amylose content while the amylopectin content was by the difference method.

Protein Determination by Kjeldhal Method

Protein percentage was determined using the method of Pearson (1996). The result was computed as percentage nitrogen in the sample. The percentage protein in the rice was computed using Equation (5).

$$\%Tn = \frac{tv \times na \times 0.014 \times 100}{ws} \quad (5)$$

Where: T_n= Total nitrogen, T_v= Titrate value, Na= Normality of acid, W_s= Weight of sample

2.4 *Sensory Evaluation*

The cooked rice was served to a discriminating and communicative panel of 10 people to compare individual perspective on the cooked rice. An evaluation card was prepared and given to each panel for multiple difference tests for quality attributes such as aroma, texture, taste, color, an overall acceptability using nine-point scale rating.

3. Results and Discussion

3.1 *Results*

The values of the Cooking Quality Characteristics and Chemical characteristics of Ofada and Faro-44 Rice Varieties are shown in Tables 1 and 2 respectively.

Table 1: Cooking Quality Characteristics of Ofada and Faro-44 Rice Varieties

Characteristics	Ofada	Faro-44
Cooking time (min)	17	26
Water Uptake ratio (%)	2.95	2.85
Grain Elongation (mm)	2.7	3.2
Solid loss in cooking water (g)	0.37	0.39

Table 2: Chemical Characteristics of Ofada and Faro-44 Rice Varieties

Characteristics	Ofada	Faro-44
Moisture Content (% db.)	12.99	11.22
Gel consistency (mm)	49.6	51.3
Gelatinization temperature (°C)	92	94
Amylose (%)	23.82	21.33
Amylopectin (%)	76.18	78.67
Protein (%)	6.72	6.42

3.2 *Discussion*

Rice cooking qualities determines their economic values, which can be measured in terms of cooking time, water uptake, grain elongation during cooking and solids loss in cooking water. It takes a longer time for Faro-44 to cooked than ofada. This can be attributed to gelatinization temperature, since gelatinization temperature positively determines the cooking time of rice. It has been asserted that the higher the value of gelatinization temperature, the longer time it takes rice to cook and from our results, Faro-44 has a higher gelatinization temperature and thus took a longer time to cook than ofada. Faro-44 rice has a higher elongation compared to ofada rice. This is a good cooking quality of rice as lengthwise increase on cooking is preferred and is characteristics of a high-quality rice variety according to Danbaba *et.al*. (2011). However, comparing the values of the elongation of both Ofada and Faro-44 in this work with some varieties reported by Oko *et al*. (2012), it can be said that both rice is of high quality. The values for water uptake ratio obtained for the rice varieties in this work compares well with the values reported by Frei and Becker (2007). The higher value of water uptake ratio for Faro-44 is in agreement with the report of Frei and Becker (2007), who posited that amylose content might be responsible for high water uptake ratio, because rice with high amylose content tends to absorb more water upon cooking.

According to Xie *et al*. (2007), amylose content is one of the important characteristics influencing the cooking behavior of rice. It is recognized as the most important determinant of rice quality (Juliano, 1975; Webb, 1979). From this work, Ofada rice has higher amylose content than Faro-44. This suggests that Ofada will be more ideal for consumption by diabetic patients, since starch food with high amylose content are attributed to low-blood glucose level and slower the emptying of human gastrointestinal trait compared to those with low level of the macro-molecules as reported by Frei and Becker (2003). Amylopectin is a compound of glucose molecules with branched links and is less resistant to digestion as reported by Shin *et al*. (2007). This means that Ofada rice has a greater proportion of starch in form of amylopectin and tends to have a higher glycemic index (GI). As reported by Chrastil (1992), for variety having low amylose content, rice texture is soft and sticky, whereas, for varieties with high amylose content rice texture become stiff and fluffy on cooking. Gel consistency is a good index of cooked rice texture, especially among rice of high amylose content. Gel consistency measures the tendency of cooked rice starch to harden after cooling. Harder gel consistency and firmer cooked rice are associated with high amylose rice. Hard cooked rice also tends to be less sticky. Based on gel consistency classification according to Oko *et al*. (2012), ofada can be said to be harder than Faro-44. When cooked, rice types with hard gel consistency harden faster than those with a soft gel consistency. Rice with soft gel consistency cook more tenderly and remain soft even upon cooling. Therefore, Faro-44, would be preferred by consumers due to their tender texture as supported by Tang *et al*. (1991). Juliano (1985), stated that, rice that has high protein content suggests high gelatinization temperature and tend to be undercooked. Gelatinization temperature of Faro-44 is higher than that of Ofada which could be traced to its cooking time as reported by Bhattacnary (2007), that the higher the value of gelatinization temperature, the longer the time it takes to cook completely. Gel consistency of Faro-44 is higher than that of Ofada rice. The protein content of Ofada rice is quite higher than Faro-44, showing that Ofada contains all essential amino acids, that is, amino acid that cannot be synthesized within the human body, thus need to be supplied by the diet as reported by Cagampang *et al*. (1996).

Results from sensory evaluation shows that greater percentage of the panelists preferred most of the sensory attributes of ofada; especially the taste, aroma and colour than Faro-44. This may not be far too fetched from the likeness associated with ofada rice by the consumers. There is significant ($p < 0.05$) difference in the sensory attributes for Ofada rice and there was no significant ($p > 0.05$) difference in the sensory attributes for Faro-44.

4. Conclusion

The result obtained from the physical characteristics of the cooked rice shows that Faro 44 had a better cooking quality than Ofada but the chemical characteristics of Ofada is far better than Faro-44. There is significant ($p < 0.05$) difference in the sensory attributes for Ofada rice and there was no significant ($p > 0.05$) difference in the sensory attributes for Faro-44.

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EFFECT OF SODIUM METABISULPHITE PRE-TREATMENT AND DRYING TEMPERATURE ON THE PROXIMATE QUALITY OF DRIED OKRA

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Abstract

The cultivation and production of okra have been widely practised due to its nutritional and medicinal value. This vegetable crop is seasonal and highly perishable after harvest in its natural state, leading in huge post-harvest losses during the production season and serious off-season scarcity. Drying has proven to be an important and valuable way of preserving okra since it has great effect on the quality of the dried product. This study was carried out to determine the effect of sodium metabisulphite ($Na_2S_2O_5$) pre-treatment concentration level and drying temperature on the proximate quality of dried okra. Fresh okra was purchased from a vegetable market. The okra samples were sorted, washed using sterilised water, drained and sliced into 5 mm thickness. The proximate analysis of the fresh and dried okra was determined using standard methods. The drying was carried out using a vacuum oven dryer with the drying temperature varied at 40^{o}C, 50^{o}C and 60^{o}C while the pre-treatment concentration level of sodium metabisulphite was varied at 0%, 0.5% and 1%. The proximate composition of the fresh okra used for this study was 90.5% moisture, 0.21% crude fat, 0.50% crude fibre, 0.81% ash, 0.95% crude protein and 7.03% carbohydrate. The results showed that 1% $Na_2S_2O_5$ pre-treatment concentration level and 50^{o}C drying temperature produce the dried okra with an optimum proximate composition of 2.21% protein, 19.00% fat, 49.50% crude fibre, 7.00% moisture content, 15.50% ash and 6.80% carbohydrate. It was concluded that pre-treatment using sodium metabisulphite and drying temperature of the vacuum oven had significant effect ($p<0.05$) on all the proximate qualities of the dried okra.

Keywords: Okra, Proximate composition, Sodium metabisulphite, Drying, Pre-treatment, Vacuum oven

1.0 Introduction

Okra (*Abelmoschus esculentus* L. Moench) is a semi-woody, fibrous and herbaceous annual plant which is believed to have originated from East Africa and today is widely distributed in the tropics, subtropics, and warmer portions of the temperate region (Germain *et al*., 2017). Okra is a vegetable crop that belongs to the genus *Abelmoschu*s, family *Malvaceae* and has two main species: *Abelmoschus esculentus* (L.) Moench and *Abelmoschus caillei* (A. Chev.) Stevels. *Abelmoschus esculentus* (L.) Moench is the widespread species in tropical, subtropical, and warm temperate regions while *Abelmoschus caillei* (A. Chev.) Stevels is restricted to the humid and per humid climates of Africa (Hussein *et al*., 2018).

The cultivation and production of okra have been widely practised due to its nutritional importance and medicinal value. Okra is a good source of carbohydrate, protein, dietary fibre, calcium, magnesium, potassium, vitamins A and C (Hussein *et al*., 2018). The essential and non-essential amino acids that okra contains are comparable to that of Soybean (Habtamu *et al*., 2015). Okra is a powerhouse of valuable nutrients, nearly half of which is soluble fibre in the form of gums and pectins which help to lower serum cholesterol, reducing the risk of heart diseases. The other fraction of okra is insoluble fibre, which helps to keep the intestinal tract healthy (Habtamu *et al*., 2015).

In Nigeria, okra is usually boiled in water resulting in slimy soups and sauces, which are relished. The fruits also serve as soup thickeners. The leaves, buds and flowers are also edible. Okra leaves are considered good cattle feed, but this is seldom compatible with primary use of the plant. Okra mucilage is suitable for medicinal and industrial applications. It is used as a plasma replacement or blood volume expander. Industrially, okra mucilage is usually used in glaring certain papers and useful in confectionery among other uses (Ngbede *et al*., 2014).

Okra seed could be dried, the dried seed is a nutritious material that can be used to prepare vegetable curds or roasted and ground to be used as coffee additive or substitute. Okra seeds are a potential source of oil, with concentrations varying from 20% to 40%, which consists of linoleic acid up to 47.4% which is a polyunsaturated fatty acid essential for human nutrition (Habtamu *et al*., 2015). Okra commands a high market price in Nigeria markets because it features daily in the diet of most Nigerians (Nwalieji, *et al*., 2015).

In spite of all the enormous benefits from the production of okra, farmers, marketers, and consumers encounter several challenges regarding the keeping of the fresh okra fruit. Such challenges come from biological and biochemical activities that occur in the fresh product, inefficient handling and transportation, unfavourable storage conditions, inadequate postharvest handling, and poor market outlet (Olaniyan and Omoleyomi, 2013). The freshly harvested okra has very high moisture content of 88-90% wet basis and safe moisture content for storage is 10% wet basis. Due to its high moisture content, its shelf life is short because it is subject to rapid deterioration, resulting in chemical, physical and biological changes (Germain *et al*., 2017).

Also in Nigeria, there are two distinct seasons for okra production, the peak (rainy) and the lean (dry) seasons. During the lean season okra fruit are produced in low quantities, scarce and expensive to get. In the peak season, it is produced in large quantities much more than what the local populace can consume (Nwalieji *et al*., 2015). Adequate processing, preservation, marketing, and utilization of okra are necessary to arrest the wastage being experienced during the peak season (Ngbede *et al*., 2014). One effective way of preserving okra, is by drying. Drying is the heat and mass transfer process for removal of water by application of heat, from a solid or liquid food, with the purpose of obtaining a solid product sufficiently low in water content (Kumar *et al.,* 2015). The removal of moisture prevents the growth and reproduction of microorganisms which cause decay and minimizes many of the moisture-mediated deteriorative reactions (Wankhade *et al.,* 2013).

Drying of okra will prevent the huge post-harvest losses of the okra during production and ensure its availability during off seasons at comparatively lesser cost. In addition to preservation, drying of okra will reduce its weight and volume by significant amounts and improves the efficiency of product transportation and storage (Olaniyan and Omoleyomi, 2013).

The aim of this work is to evaluate the effect of sodium metabisulphite pre-treatment and drying temperature on the proximate quality of dried okra.

2.0 Materials and Methods

Good quality Okra fruits was purchased from Engr. Kure Market Minna, Niger State and prepared at the Agriculture and Bioresources Engineering laboratory in Federal University of Technology, Minna, Niger State.

The fresh okra samples were sorted washed using sterilised water, drained, and sliced into 5 mm thickness with the initial proximate qualities of fresh okra determined, the sliced okra was then divided into 500g for each treatment and was varied at three levels each: pre-treatment concentration level of sodium metabisulphite (0%, 0.5% and 1%) and the drying temperature (40ºC, 50ºC and 60ºC). Drying was conducted using a vacuum oven dryer. The drying was carried out until a water activity less than 0.6 was achieved, which was measured using a mini hygrometer. The experiment was carried out at three replicates and the average reading recorded. The proximate qualities of the dried okra were determined as described by Association of Analytical Chemist (AOAC), 2005 as follows:

i. *Determination of moisture content*

The moisture content present was calculated using the equation:

$$\text{Moisture content (\%)} = \frac{Loss\ in\ weight\ of\ the\ sample}{weight\ of\ the\ sample} \text{ X } 100\% \quad (1)$$

ii. *Determination of Total Ash*

The ash content was calculated using the equation below.

$$\text{Ash (\%)} = \frac{weight\ of\ the\ ash}{weight\ of\ the\ original\ sample} \text{ X } 100 \quad (2)$$

iii. *Determination of Crude Fibre* The equation used to calculate the crude fibre is given as:

$$\text{\% Crude Fibre} = \frac{Weight\ of\ sample\ before\ ashing - Weight\ of\ sample\ after\ ashing}{Weight\ of\ sample} \text{ x } 100 \quad (3)$$

iv. *Determination of Fat content*

The fat content was determined using the Soxhlet solvent extraction method. The flask was weighed, and percentage fat was calculated as follows:

$$\text{\% Fat} = \frac{W2 - W1}{W3} \text{ x } 100 \quad (4)$$

Where:

W_1 = Weight of empty flask

W_2 = Weight of flask + fat

W_3 = Weight of slices taken

v. *Determination of Crude Protein content*

The crude protein content was determined using the kjeldahl method and calculated using the equation for the percentage nitrogen given as:

$$\text{\% Nitrogen} = \frac{Vs - Vb\ X\ Nacid\ X\ 0.01401\ X\ 100}{W} \quad (5)$$

Where,

V_s = Volume of acid required to titrate sample (ml)

V_b = Volume of acid required to titrate the blank (ml)

N_{acid} = Molarity of acid

W = weight of sample (g)

The percentage protein was then calculated using the equation:

% Crude protein = %N x conversion factor (6)

$$\text{Where: conversion factor} = \frac{100}{\%\ Nitrogen\ in\ protein}$$

Protein conversion factor = 6.25

vi. *Determination of Carbohydrate*

The carbohydrate was calculated by difference given as:

Carbohydrate (%) = 100 – (%P + %F + %A + M + %C.F) % (7)

Where;

P = Protein

F = Fat

A = Ash

M = Moisture

C.F = Crude fibre

All data collected was subjected to descriptive statistical analysis. The computer statistical software Design expert 11.1.2.0 was used to perform the analysis.

3.0 Results and Discussion

3.1 *Proximate composition of fresh okra*

The proximate composition of the fresh okra used for this study include 90.5% moisture, 0.21% crude fat, 0.50% crude fibre, 0.81% ash, 0.95% crude protein and 7.03% carbohydrate. The proximate composition was similar to that reported for fresh okra by Vinay (2016), Javid *et al.,* (2009) and Hussein *et al.,* (2018). Okra like other vegetables had high moisture content but lower than other leafy vegetables such as water leaf and fluted pumpkin leaves (Saidu and Jideobi, 2009).

3.2 *Proximate composition of the dried okra*

The average proximate composition of the dried okra using a vacuum oven dryer at different sodium metabisulphite ($Na_2S_2O_5$) concentration levels and drying temperature are shown in Table 1.

Table 1: Proximate composition of the dried okra using a vacuum oven dryer

Run	Pre-treatment	Drying Temperature (°C)	Protein (%)	Fat (%)	Crude Fibre (%)	Moisture content (%)	Ash (%)	Carbohydrate (%)
1	**Fresh okra**		**0.95**	**0.21**	**0.50**	**90.5**	**0.81**	**7.03**
2	0% $Na_2S_2O_5$	40	1.96	27.00	26.00	3.50	13.50	28.04
3	0.5% $Na_2S_2O_5$	40	0.80	32.23	14.76	10.50	7.83	33.90
4	1% $Na_2S_2O_5$	40	0.82	29.80	16.76	10.23	8.22	34.19
5	0% $Na_2S_2O_5$	50	1.32	25.20	38.97	4.99	12.68	16.85

6	0.5% $Na_2S_2O_5$	50	2.10	0.50	48.00	4.00	12.50	32.90
7	1% $Na_2S_2O_5$	50	2.20	19.00	49.50	7.00	15.50	6.79
8	0% $Na_2S_2O_5$	60	1.15	29.55	21.75	8.05	10.41	29.09
9	0.5% $Na_2S_2O_5$	60	1.27	27.00	33.43	5.50	12.23	20.58
10	1% $Na_2S_2O_5$	60	1.65	4.00	39.00	5.00	13.50	36.85

The protein content in the dried okra was lowest (0.80%) at 40°C and 0.5% sodium metabisulphite ($Na_2S_2O_5$) concentration. The highest protein content in the dried okra was found to be 2.20% at 50°C and 1% $Na_2S_2O_5$. At a low temperature of 40°C, the protein content decreases with increase in the pre-treatment concentration. On the other hand, protein content increases with increase in pre-treatment concentration levels for higher drying temperatures and was found optimum at a mid-temperature of 50°C. The reduction in protein content of the okra at lower temperature may be due to prolong time of drying. The higher rate of drying at higher temperature result in increase of dry matter contents due to concentration of soluble solids and the pre-treatment significantly affect the protein content. Excessive heat could lead to the destruction of the protein cells.

Pre-treatment and drying temperature also had significant effect on the fat and crude fibre content of the dried okra with the lowest fat content (0.50%) at 50°C and 0.5% sodium metabisulphite ($Na_2S_2O_5$) concentration. The highest fat content was 32.23% at 40°C and 0.5% $Na_2S_2O_5$ concentration. While the lowest crude fibre content was 14.76% recorded at 40°C and 0.5% $Na_2S_2O_5$ concentration and the highest at 50°C and 1% $Na_2S_2O_5$ concentration with 49.50% crude fibre. Fibre is useful for maintaining bulk, motility and increasing intestinal tract. It is also necessary for the healthy condition, curing of nutritional disorders and food digestion (Hussein *et al.,* 2018). Pendre *et al.,* (2012) reported that the crude fibre of dried okra ranges between 19.0% and 24.0% which is lower than the highest crude fibre content obtained in this study. Habtamu *et al.,* (2015) also reported the crude fibre of dried okra to range between 11.97% and 29.93%.

Ukegbu and Okereke (2013) reported that moisture content of a food is very important factor on nutritional qualities and the shelf-life of that particular food. Drying is primarily done on food to reduce its moisture content thereby increasing the relative concentration of other food nutrient and hence improve shelf life. The okra dried at 40°C with 0.5% $Na_2S_2O_5$ concentration had the highest moisture content of 10.50%. This is probably as a result of the lower drying rate at lower temperature. Habtamu *et al.,* (2015) reported that the moisture content of dried okra ranges between 9.69% and 13.33%.

The ash content is a measure of the nutritionally important mineral contents present in a food material. The highest ash content of 15.50% was recorded at 50°C and 1% $Na_2S_2O_5$ concentration while the lowest was 7.83% at 40°C and 0.5% $Na_2S_2O_5$ concentration. Olaniyan and Omoleyomi (2013) also recorded the highest ash content of 2.9% at 50°C. Hussein *et al*., (2018) reported ash content value between 9.23% and 10.12%.

The carbohydrate content of dried okra from this study ranges between 6.79% at 50°C and 1% $Na_2S_2O_5$ concentration to 36.85% at 60°C and 1% $Na_2S_2O_5$ concentration. Hussein *et al.,* (2018) reported the carbohydrate content of dried okra to range between 34.36% and 58.98%.

Based on the result from this study, crude protein, crude fibre, ash, and fat content in dried okra can be maximized by drying at 50°C after pre-treatment with 1% $Na_2S_2O_5$ concentration. Run 7 from Table 1 produced dried okra with the optimum proximate composition with 2.21% protein, 19.00% fat, 49.50% crude fibre, 7.00% moisture content, 15.50% ash and 6.80% carbohydrate.

The result of the statistical analysis of variance (ANOVA) of the data obtained from the experiment (Table 2) indicated that the linear model is significant for all the proximate analysis. Statistical analysis showed that the drying temperature and pre-treatment had significant effect ($p \leq 0.05$) on the protein, fat, crude fibre, ash and moisture content of the vacuum oven dried okra. Pre-treatment had no significant effect ($p > 0.05$) on the carbohydrate content while the drying temperature had a significant effect. The interactions between the pre-treatment and the drying temperature had significant effect on all the proximate composition of the dried okra. This implies that drying temperature and pre-treatment using sodium metabisulphite had appreciable effects on the proximate qualities of okra. This was acknowledged by Olaniyan and Omoleyomi (2013) who investigated the effects of osmotic dehydration process pre-treatment and drying temperature on drying rate and quality attributes of okra. The ash content, crude fibre, crude fat, crude protein, least gelation concentration and water absorption capacity were significantly affected by the pre-treatment and drying temperature. Therefore, while drying okra, these factors must be carefully controlled.

Table 2: Analysis of variance (ANOVA) of the effect of pre-treatment and drying temperature on the proximate composition of vacuum oven dried okra

Source	Sum of Squares	df	Mean Square	F-value	p-value	
PROTEIN						
Model	3.01	8	0.3757	91.04	< 0.0001	significant
A-Pre-treatment	0.0525	2	0.0263	6.36	0.0423	
B-Drying Temperature	1.08	2	0.5397	130.78	< 0.0001	
AB	1.87	4	0.4683	113.49	< 0.0001	
Pure Error	0.0206	5	0.0041			
Cor Total	3.03	13				
FAT						
Model	1270.96	8	158.87	433.88	< 0.0001	significant
A-Pre-treatment	230.19	2	115.10	314.33	< 0.0001	
B-Drying Temperature	495.21	2	247.60	676.21	< 0.0001	
AB	676.39	4	169.10	461.81	< 0.0001	
Pure Error	1.83	5	0.3662			
Cor Total	1272.79	13				
CRUDE FIBRE						
Model	1934.51	8	241.81	448.00	< 0.0001	significant
A-Pre-treatment	117.16	2	58.58	108.53	< 0.0001	

B-Drying Temperature	1620.38	2	810.19	1501.02	< 0.0001	
AB	308.18	4	77.05	142.74	< 0.0001	
Pure Error	2.70	5	0.5398			
Cor Total	1937.21	13				
MOISTURE CONTENT						
Model	85.34	8	10.67	81.25	< 0.0001	significant
A-Pre-treatment	3.70	2	1.85	14.09	0.0088	
B-Drying Temperature	26.48	2	13.24	100.83	< 0.0001	
AB	47.83	4	11.96	91.09	< 0.0001	
Pure Error	0.6565	5	0.1313			
Cor Total	85.99	13				
ASH						
Model	79.00	8	9.88	92.75	< 0.0001	significant
A-Pre-treatment	2.40	2	1.20	11.25	0.0141	
B-Drying Temperature	38.82	2	19.41	182.27	< 0.0001	
AB	35.14	4	8.79	82.50	< 0.0001	
Pure Error	0.5324	5	0.1065			
Cor Total	79.54	13				
CARBOHYDRATE						
Model	1035.41	8	129.43	76.87	< 0.0001	significant
A-Pre-treatment	6.07	2	3.03	1.80	0.2575	
B-Drying Temperature	417.33	2	208.66	123.93	< 0.0001	
AB	560.44	4	140.11	83.21	< 0.0001	
Pure Error	8.42	5	1.68			
Cor Total	1043.83	13				

4.0 Conclusion

It can be concluded that drying fresh okra using a vacuum oven dryer and pre-treatment will improve its availability, quality and assist in reducing postharvest losses of okra. Further studies should be carried out on effective ways of preserving the quality of the dried okra over a long period of storage duration.

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DEVELOPMENT OF MOBILE PROCESSING PLANT TO REDUCE CASSAVA POSTHARVEST LOSSES

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Abstract

Cassava (Manihot esculenta Crantz) root contains much water, which increases the cost of transportation and perish ability of the crop when harvested for processing. More than 70% of the total roots produced in Nigeria are processed into garri using mechanical devices. Farms along the route seem to be too small. While most of the food factories are located in the urban areas, lack of power, poor road networks to the villages hinder farmers' ability to transport cassava roots effectively to the HQCF factories mostly located in the urban areas. Poor access and connection within the farms and villages and between the root producers and urban-based processors hinder root marketing and continuity of cassava root production. Processing operations are expensive due to the high transportation costs of roots. To solve this problem a mobile processing system was developed by the Cassava Compact of TAAT to fast-track cassava root processing at farm-gate using modern gari machinery. The system was made with an automobile with a flatbed truck with a high doggedness and crane, which can travel with relative ease on rough Nigerian roads when loaded with cassava processing machinery. The truck was rebuilt to travel with the processing equipment and flatten at the farm-gate to form a wide floor or platform for processing. Parameters for peeling, grating, and dewatering were considered during construction and installation. Production of unfermented cake with the aim to have a good mash cake delivery to the central factory in case of HQCF is made possible. The truck has all comfortable ready-made structures within including a generator and water pump for on-farm Garri or Gari be consistent production. This innovation allows processors to produce the flour and garri with reduced drudgery. Commercial use of this truck will improve cassava business across Africa in the face of climate change-calamities.

Keywords: Mobile; TAAT; Cassava; Mechanization; Drudgery; Processing

1.Introduction

Agricultural mechanization in developing countries has at least two contested innovation pathways; the one that promotes industrial agriculture and another that supports small-scale mechanization for sustainable development (Devkota, et al., 2020). Both can reduce drudgery in Africa where there is a neglect of mechanization for smallholder farmers. Infrastructures such as highways and rails are needed to transport crops that can perish easily; no electricity in the villages to power industries. Many crops are at risk of spoiling, producers of such crops are unknowingly forming a pattern of production due to losses. Cassava (Manihot esculenta Crantz) root is one of such crops that farmers reduce its production whenever they do not make profit. It contains much water, which increases the cost of transportation and perish ability when harvested for processing. More than 70% of the total roots produced in Nigeria are processed into garri. In the 1990s, the gari machinery was adapted for processing High Quality Cassava Flour (HQCF) (ICP, 2005). While most of the HQCF factories are located in the urban areas, poor road networks to the villages hinder farmers' ability to transport cassava roots effectively to the HQCF factories mostly located in the urban areas. Poor access and connection within the farms and villages also between the root producers and urban-based processors hinder root marketing and continuity of cassava root production. Processing operations are expensive due to the high transportation costs. To solve this problem a mobile processing system was developed by the Cassava Compact of Technologies for African Agricultural Transformation (TAAT) to fast track cassava root processing at farm-gate using modern gari machinery.

The idea of functional commercial type of mobile processing system for cassava was implemented by International Institute of Tropical Agriculture (IITA) in partnership with Federal Institute of Industrial Research Oshodi (FIIRO) under cassava compact, TAAT project (IITA, 2020).

Feed Africa is a strategy of the African Development Bank (AfDB) to transform agriculture and scale up agribusiness opportunity throughout 18 key agricultural commodity value chains. The strategy involves increased crop and animal productivity, value addition, investment in infrastructure, creating an enabling agribusiness environment, catalyzing capital flows, and ensuring inclusivity, sustainability, and nutritional security in a coordinated manner. Technologies for African Agricultural Transformation (TAAT), supports Feed Africa by providing the needed, proven agricultural and food processing technologies and implementation strategies for inclusion within the Bank's loans to Regional Member Countries (RMCs). It has been estimated that overall TAAT will lead to 120 million tons of additional raw food production per year and will contribute to lifting about 40 million people out of poverty. TAAT is essentially knowledge and innovation based response to the recognized need for scaling up proven technologies across Africa.
Mobile processing started with use of bicycle or motorcycle in conveying some processing tools to farms. FIIRO produced a smaller version of Mobile Cassava Processing Innovations (MOCAPI), as a mechanization project meant to upgrade production of garri at cottage level but targeted women processors in the rural areas who do not have access to improved processing methods and equipment in 2017. The project was a cooperation partnership between the Federal Institute of Industrial Research Oshodi (FIIRO), GIZ Nigeria and Robert Bosch Ltd., Nigeria. All the machineries were packed into an Indian made tricycle to improve stationary processes as grating and pressing, implement hygienic and sustainable packaging and improve business skills, diversify product lines and strengthen women and cooperatives (FIIRO, 2017).
DADTCO introduced another version of Cassava mobile processing (DADTCO, 2017., This was a large mobile cassava processing factory meant to transform village level cassava roots from smallholder farmers into food grade cassava cake. The technology was meant to bridge the gap between farmers and large food companies. Instead of attempting to transport the watery perishable crop over long distances to a central factory the technology overcomes the four main obstacles to the commercialization of cassava across Africa, namely the high water content of the roots (65%-75%), the rapid perish ability of the roots once harvested (must be used within 48 hours, preferably 24), its bulky and irregular shape and the wide scattering of smallholder farmers. The technology which consists of several processing components developed in two scenarios do not contain clean peeler.
The technology did not include garri production and the equipment look too heavy and bulky, small-scale farms are far apart with very little cassava root which are not sufficient to make any impact. No good roads to the villages, the capital involved look too high for small and medium scale farmers. The heavy machinery at the village level became difficult and unpopular. Cassava Mobile processing technology was indeed a proven technology that met the TAAT standard and IITA carefully developed the mobile processing truck differently.

2. Methodology

Visits were made to Ijebu-Igbo roads via Ikire and other similar roads checking the terrain for the vehicle that fits. After several searches and studies, a medium size truck, Mercedes 410 lorry with crane (HIAB) good for rough roads was considered. Commercial GARI machinery that can as well be used for production of cake was examined. That of NOBEX Technical Company Limited (RC: 337157) licensed fabricator and a designer of Agro-Allied/Food processing equipment, located at Nobex Bus stop on Ikotun - Idimu Road No15 Vic Morak Street Idimu Lagos Nigeria was selected. Those machines were tested before being mounted on the truck as shown in Plate 1 (a and b)
Sketches were made and positioning of the equipment were considered see Figures 1, 2 and 3.

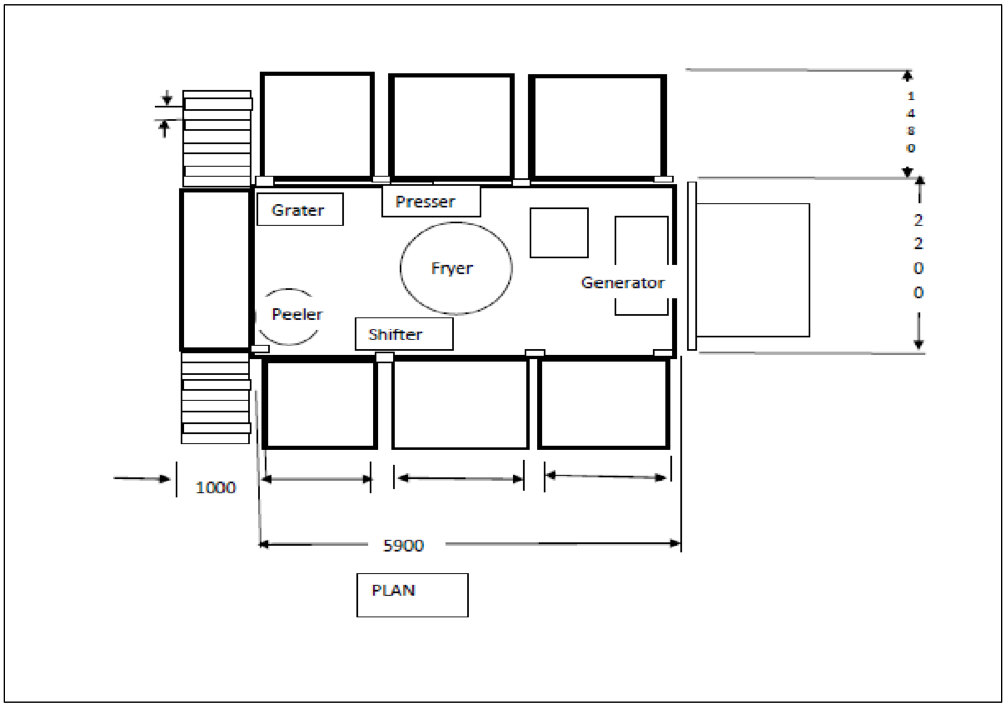

Figure1. Equipment Layout on the Cassava Compact Truck (Plan view)

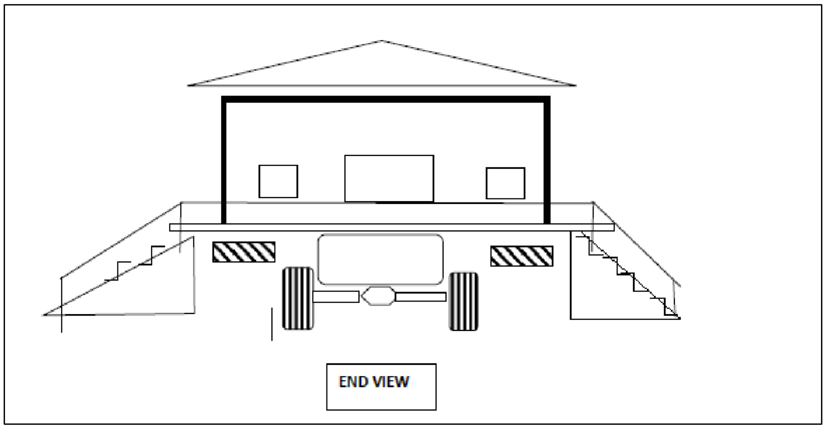

Figure 2. Rear view of the Cassava Compact Truck

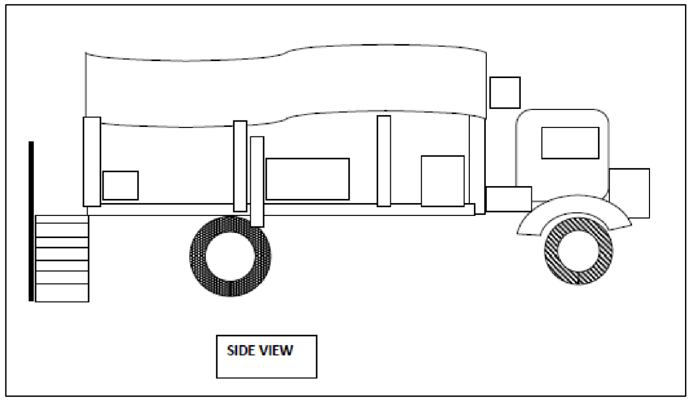

Figure 3 Side View of the Cassava Compact Truck

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a b

Plate 1 (a and b) Testing of Peeling Machine (a) and Grater (b)

Table 1: Specification for the Processing Machines

S/N	Machine Type	QTY	Required Specification
1	Cassava peeler	1	5 to 10HP, 0.5 to 1T/hr. capacity; electric motor, Motor stand, belt, anchor bolts, with a hook for lifting/ loading-off-load
2	Cassava graters	2	2T/hr. capacity, Stainless materials, 10HP, Petrol engi drum, motor stand, belt, anchor bolts, stainless steel surfaces; with a hook for lifting/ loading-off-loading
3	Pressing Machine	2	With 2 Jacks (32Tons)), pressing hardwood, pressing b per batch, 45 minutes to 1hrs; with a hook for lifting/ loading

4	Automatic Gari roaster	1	Stainless pot, 8 hands; Capacity: 150kg per day; dual walled heat chamber using a diesel burner;
5	Stitching Machine	2	No Specification
6	Weighing Scale	2	Electronic/Digital, broad platform, 0.1-150kg
7	Cassava Gari Sifter	2	3 to 5HP engine, stainless mesh; capacity: 0.5 to 1T motor stand, belt, anchor bolts, with a hook for lifting/ loading
8	Toasting pan	2	Stainless steel; complete with chimney; - – further specification needed

Equipment parameters were determined as shown on Table 1 after confirmations.

The Cassava Compact Truck

The truck (Plate 3) was fabricated to have wet section (Plate 2) and dry section at the international Institute of Tropical Agriculture (IITA). The equipment were mounted on the truck with a 15kVA generator, (see plate 2) water tank for washing, and Water pump that are capable of meeting the production on the platform.

Plate 2

Plate 3 Truck on motion

Test and Evaluation

Each of the equipment for the Cassava Compact was tested separately in IITA to ascertain their capacities before being mounted on the truck and subsequent demonstration in some locations in Oyo and Ogun states.

3. Results and Discussions

Table 2 shows the result of the evaluation of the machine and confirmation of the specification of the machines.

Table 2. Confirmation of the Capacity and Specifications of the Machines

S/N	Machine Type	QTY	Required Specification	Observed Specification
1	Cassava peeler	1	5 to 10HP, 0.5 to 1T/hr. capacity; electric motor, Motor stand, belt, anchor bolts, with a hook loading-off-loading	10HP, 1.6T/hr. Motor stand, belt, with a hook for off-loadin
2	Cassava graters	2	2T/hr. capacity, Stainles: 10HP, Petrol engine; Abr motor stand, belt, anchor bc steel food contact surfaces; for lifting/ loading-off-loadi	3T/hr. capacity, Stainless mater 13HP Petrol engine. Abrasive c motor stand, belt, stainless steel hook for off-loading
3	Pressing Machine	2	With 2 Jacks (32Tons) hardwood, pressing bags, batch, 45 minutes to 1hrs; wi lifting/ loading-off-loading	2 Jacks of 32Tons, pressing wood, capable of pressing 10kg X10 bags per batch in40 minutes; with a hook for loading-off-loading
4	Automatic Gari roaster	1	Stainless pot, 8 hands; Capacity: 150kg pe	Stainless pot, 6 hands; Capacity: 350kg/8hr day;

			dual walled heat chamber u burner;	dual walled heat chamber u burner
5	Stitching Machine	2	No Specification	Bought out
6	Weighing Scale	2	Electronic/Digital, broad pl 150kg	Bought out
7	Cassava Gari Sifter	2	3 to 5HP engine, stainless me 0.5 to 1Ton per hour; moto anchor bolts, with a hook loading-off-loading	3hp electric motor vibrator, stainless mesh; capacity: 2Tons per hour; With a hook for lifting.
8	Toasting pan	2	Stainless steel; complete with chimney; - – further specification needed	Made with stainless steel; with chimney

The result of the assessment of the peeling machine is presented in Table 3. Root losses as the percentage of the useful part that was removed with the peel. The lower the root losses the better. Peel retention as the percentage of the peel that remains on the root after passing through the machine. The lower the peel retention, the better. Throughput as the amount of material passing through the peeling machine. Peeling efficiency, root losses, peel retention and throughput. The machine has 95.56 % peeling efficiency and flesh loss of 9%. Poor English; recast the above portion and all the portions below.

Table 3: The peeler data.

Machine peeling	Average(3 times)	MANUAL (Hand) 3 men
Time	3min	47min
Root wt (kg)	50	50
After peeling(kg)	33	36.5
Peels remain(kg)	0.4	0.0
Total removable peels	13.5	13.5
Flesh + Peels Capacity (T/hr) Efficiency (%)	17 1 95.56%	 0.06 Assumed 100%

The grater main performance indices are throughput, specific energy consumption and particle size coefficient of variation. Throughput measures how many kilograms of peeled cassava roots the machine can grate per hour of operation. Specific energy consumption (electric or fuel) measures the amount of energy needed per kilogram of cassava grated into a mash. Roots are fed at the hopper on top of the housing and size reduction is done by grinding. The size of the particle is determined by the space between the drum and the housing walls. The selected models allow changing of this space, and thus permit controlling the size of the particles. Depending on the adjustment made, particle size can range from 0.5 mm to 1.0 mm. Particle size variation is a measure of relative variability on size distribution of the particles. The machine with grits and lower particle size distribution indicates a smoother output. At idle speed Average total peeled cassava feed into the grater was 55.5kg. Horsepower of Internal Combustion Engine (ICE) is 13Hp the grater machine grating capacity is 2.22t/hr meaning that grating capacity on the mobile is 4.44t/hr.
The press was also evaluated by loading 10kg X10 bags per batch. It was capable of pressing 100000g in 40 minutes. This translates to 150kg/hr

The fryer when evaluated gave a capacity of 50.00kg of gari per batch in 45minutes; this means the capacity is about 66.7kg/hr. The dryer is powered with Electricity and Diesel, framed with mild steel for gear wheel; aluminium for paddle blade; stainless steel for the frying pan. It consists of four main units: frying pot, stirrer/paddle system, heater or furnace and product receptacle. The stirrer, which makes planetary motion during operation, is driven by a 2 hp motor at 1400 rpm. The frying pan wall is lagged (insulated) with fibre glass.
A vibration sifter is used for wet pulverized cassava cake to ensure free flowing meal to enhance roasting and garri. It consists of two parts (screening and collector units); Electrical sifter vibrator for sifting made of stainless steel for sieve frame, mild steel for support frame. Simple design, easily removable sieve; product exit chute, most parts of the machine are joined by welding, fabrication quality is high fixed with electric operated vibrator. The process of sifting is continuous.

Evaluation of the Cassava Compact Truck

Freshly harvested roots were fed to evaluate the peeler through movable gate. The peeler is abrasive batch type that rotates to effect peeling within 3 minutes. Then the grater was tested with clean and peeled root to produce mash. Wet mash was packed and pressed. After dewatering to form cakes, it can be transported to central factory. It can also be fried directly into garri on the field. The grater was powered with internal combustion engine as alternative prime mover. Excess moisture that can alter final characteristics of garri and increase in transportation cost were put into consideration. It was also put in mind that Cassava roots varieties are generally harvested at 65-75 % moisture content which must be brought down to 12% or less by toasting and drying before subsequent storage and as quickly as possible. IITA use those machinery approved on truck.

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a  b 

Plate 4: Processing of Gari using Cassava Compact at Ilora, Oyo state

All parts that come in direct contact with the roots were constructed with food-grade stainless and food contact materials were not painted. All components of the belt were enclosed under a safety guard.

To determine the performance of the mobile truck, gari and cake processing tests were conducted with mobile plant for freshly harvested cassava root at major cassava processing locations in Oyo and Ilora see Plate 4).

The performance of the mobile was evaluated in terms of overall capacity and efficiency and financial returns. It was found that the machine is capable of producing 350kg of gari per 8hours. Generally, one hectare of cassava farm can be processed into cake within a shift of 8 hours at the farm gate there by reducing losses.

Profitability of the Mobile Cassava Processing Plant:

Profitability analysis of the Mobile Cassava Processing Plant was carried out for production of Gari and High-quality cassava cake (HQCC) by using data collected from the field operations at Olurunda village in Ogun state, and at Ifon Osun in Osun State both in Nigeria. The profitability analysis was carried out using a financial model on the excel worksheet. The profitability analysis covers a period of the first three years of operation. The financial model captures the start-up capital which could be raised by 30% equity of the business promoter with 70% of the capital as loans from a commercial bank. The interest rate considered for the loan is 17% and the repayment period is spread over 36 months with a moratorium of 3 months. For the first scenario, revenue is generated from sales of gari, and for the second scenario revenue was generated from the processing and sale of high-quality cassava cake and wastes generated using the mobile unit. Costs are captured at different levels, these include salaries, cost of inputs, cost of securities, and operational expenses. Other deductions are made such as interest on loan, depreciation, and tax. Cash flow analysis involving the estimation of net profit, after tax and other deductions, and the cash balance at the end of the 36-month period shows that the enterprise is profitable.

The IRR for Gari processing is 49% while that of HQCC is 50%. The return on investment for Gari processing is 156% while that of HQCC is 155%over a period of three years.

4. Conclusion

Cassava grating was done with a rotating drum grater producing smooth paste with consistently small particle size after being peeled and washed, cassava roots was reduced to a smooth mash, with particles of uniform size. The equipment converts pressed wet cassava mash (40-50% moisture) to pre-gelatinized dry meal or gari (<12% moisture). It mimics manual operation but produces gari of lesser contamination with faster throughput. It is driven by a 3-phase 3 hp motor at 1480 rpm with a reduction gear at the farm gates saving time and transportation wastages. The Mobile cassava processing plant is profitable with IRR for Gari processing of 49% while that of HQCC is 50%. Also, the return on investment for Gari processing is 156% while that of HQCC is 155%over a period of three years. Helping the farmer to control losses.

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DEVELOPMENT OF A MAIZE SHELLER

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Abstract

Maize botanically called Zea mays is a cereal crop that is grown widely throughout the world, in a wide range of agro ecological environments. Maize is one of the most extensively studied crop plants in the history. Maize is an important stable food for more than 1.2 billion people in Sub-Sahara Africa and Latin America. Manual methods of shelling maize which results in low efficiency, high wastage and huge labour requirement has been the usual way of maize shelling by many local farmers because they could not afford the high cost of imported shelling machines. In this project, basic design of maize shelling machine was carried out. This design includes a rotating shaft with shelling tooth on the surface to provide the shelling forces required. The designed parameters obtained were used to fabricate maize sheller using readily available materials such as mild steel sheet 2 mm thick, 50 mm by 50 mm angle iron of 4 mm thickness and steel shaft of 35 mm diameter. Weighing balance and tachometer were used for testing of the machine. A prime mover of 5 hp gasoline engine was used to power the sheller. Result of the developed sheller gave mean percentage whole grain, percentage breakage, throughput capacity and performance efficiency of 54.93 %, 1.70 %, 327.89 kg/h and 86.31 % respectively at shelling speed of 250 rpm while at 300 rpm it was 53.38 %, 2.35 %, 460.56 kg/h and 90.53 % respectively. The result shows that increase in shelling speed leads to decrease in percentage unshelled grain and percentage whole grain but leads to increase in shelling capacity and shelling efficiency.

1.0 Introduction

Maize botanically called Zea mays is a cereal crop that is grown widely throughout the world, in a wide range of agro ecological environments. Maize is one of the most extensively studied crop plants in the history and despite this, conflicting views still exist as to its origin.

Matsuoka et al (2002) reported from a study that, all maize arose from a single domestication in southern Mexico about 9 000 years ago. The study also indicates that the oldest surviving maize types are those of the Mexican highlands. Later, maize spread from this region over the Americas along two major paths.

Maize is the most important cereal crop in sub-Sahara Africa and an important stable food for more than 1.2 billion people in sub-Sahara Africa and Latin America (IITA, 2011).

Maize grains are rich in vitamin A, C and E; carbohydrates; essential minerals and contain 9% protein. They are also rich in dietary fiber and calories which are good sources of energy. After wheat and rice, maize is the most important cereal, providing nutrients for humans and animals and serving as a basic raw material to produce starch, oil, protein, alcoholic beverages, food sweeteners and more recently, fuel (FAO, 1998).

Worldwide consumption of maize is more than 116 million tons with Africa consuming 30% and sub-Saharan Africa 21%. However, Lesotho has the largest consumption per capital with 174kg per year. Eastern and Southern Africa use 85% of their maize production as food, while Africa uses 95%, compared to other world regions that use most of its maize as animal feed (IITA, 2011).

In 2007, FAO estimated that, 158 million hectares of maize are harvested worldwide, Africa harvests 29 million hectares with Nigeria being the largest producer in sub-Saharan African, harvesting 3% of the total production, followed by Tanzania. In industrialized countries, maize is largely used as livestock feeds and as raw material for industrial products, while in low-income countries; it is mainly used for human consumption (Ndirika, 1995).

Large-scale shelling of maize for commercial purposes cannot be achieved by the traditional methods of shelling. Nigeria is the tenth largest producer of maize in the world, and the largest maize producer in Africa (IITA, 2011). The northern part of Nigeria which is the highest producer of maize in the country practices mostly the hand shelling method. Hand shelling is tedious and time consuming even with some hand operated simple tools. With these tools, a worker can only shell 8 to 15kg of maize an hour (Wanjala, 2014). Most mechanical shellers were designed for multi-grain threshing or shelling, which causes great damage to the maize seeds besides breaking the cob to pieces. Also, the cost of purchasing mechanical shellers is high for the rural farmer, and therefore necessitated the design of low-cost system that will be affordable and increase threshing efficiency but reduce damage done to the seed.

Specific presentation of the grain size, geometrical dimensions of the grains and grain mechanical properties were the key parameters that could enhance successful separation of the grains free of plant residues (Olaoye and Oni, 2001). Impact is the primary threshing action for detachment of grain from the ear head (Vas and Harrison, 1969). The shelling capacity at a particular operating speed decreased with increased in the maximum diameter of cobs (Tiwari et al., 2010).

This research aimed at developing a locally fabricated and low-cost maize sheller that is affordable and can easily be maintained by the local farmers. The objectives of the study are:

- To design and fabricate a maize shelling machine
- To evaluate the performance of the maize shelling machine

2.0 Materials and Methods

2.1. *Materials selection*

The appropriate and readily available materials such as mild steel sheet, mild steel flat bar and angle iron were used for the fabrication of the shelling machine. The maize sheller comprises of the following components: frame, hopper, screen, shelling drum, shaft, cob outlet, blower housing, bearing, belt, pulleys, spikes, grain outlet and prime mover.

2.2 Machine Description

Frame: The frame is the main skeleton of the machine which was made up of 50mm by 50mm angle iron of 4mm thickness. It supports other components of the machine.

Hopper: The hopper is the point where the maize is introduced into the machine for shelling. It was fabricated in trapezoidal shape using mild steel sheet of 2mm and it was induced at an angle of 30^o which is sufficient for the maize to slide into the shelling drum by gravity.

Screen: The screen was made from 2mm thick mild steel sheet. It was 810mm long and 450mm wide. It was perforated at intervals and rolled to a concave shape which was bolted to the frame.

Shelling drum: The shelling drum covers the shelling compartment. The shelling drum makes a cylinder with the screen where shelling is achieved by beating, rubbing, and rolling of ear maize against the screen clearance and the spikes tooth. The drum is made from 2mm thick mild steel sheet.

Rotary shaft: This is the most important part of the machine which transmits power from the prime mover to the shelling drum for shelling mechanism. It was made from high-speed steel to resist bending and twisting action during usage. The shaft is 1000mm length and 35mm diameter which was machined to 32mm diameter at both ends to accommodate bearing and pulleys.

Cob outlet: This is the point where shelled cob is led out of the shelling compartment. It is made up of 2mm mild sheet.

Blower: Blower is part that performs the winnowing operation. It comprises of shaft and three blades arranged at equal angle to one another on the shaft. The shaft is of length 495mm and 25mm diameter.

Blower housing: Blower housing protects the blades from external alteration. It is cubic in shape and attached to it is a cylinder where chaff passes through after separated from the grain. The blower housing is made of 2mm mild steel sheet.

Bearing: This is the machine element that support shafts and allow circulatory motion of the shaft. They support shelling shaft for shelling mechanism and blower shaft for winnowing. Steel ball bearings of 32mm and 25mm diameters were used for shelling and blower shafts respectively.

Pulleys and Belt: Pulleys are grooved circular disc which accommodate belts for power transmission. Three pulleys were used, one on the shelling shaft, one on the winnowing shaft and the last on the prime mover. Belt is an element that transmits power from prime mover to the shaft. Belts are frequently necessary to reduce the higher rotational speed of electric motors to lower values required by mechanical equipment (Spott, 1985). Standard V-belts 17mm for top width, 11mm thickness and 38^{o} groove angle were used.

Spikes: The spikes perform the shelling operation by beating and rubbing action against the screen. They were welded spirally on shelling cylinder. They are made from 5mm thick and 25mm wide flat bar and they are of the same height of 85mm.

Grain outlet: This part of the machine is the exit point of the shelled clean grains. It is made of 2mm mild sheet thickness, and it is located beneath the winnowing compartment.

Prime mover: This is a gasoline engine that supplied power for the operation of the sheller. It has 5HP capacity with head pulley of diameter 50mm. It has a control where its power can be regulated.

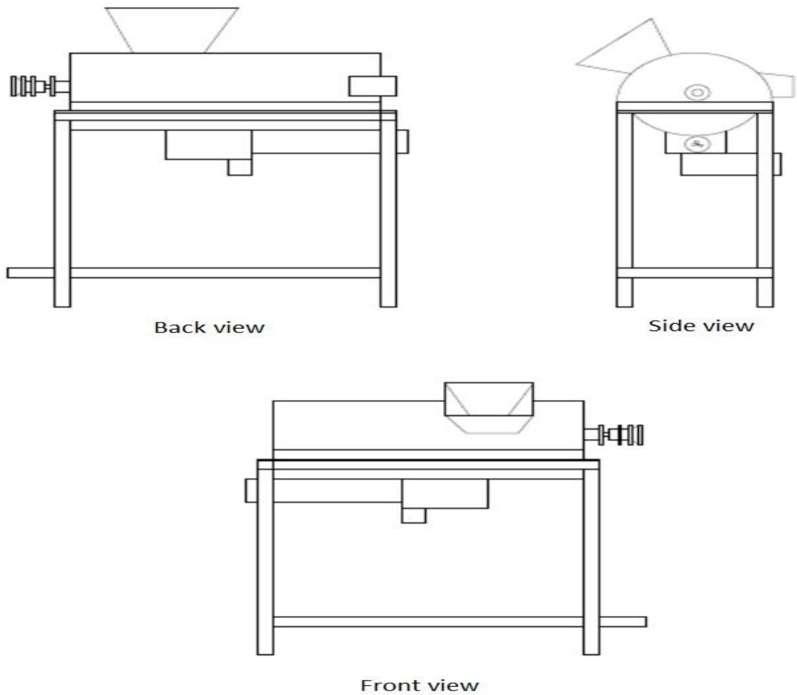

Figure 1: Schematic Diagram of the Developed Maize Sheller

2.3 *Design Analysis*

Hopper: The hopper was designed to take about 10kg of grain at a time. The density of maize is 760kg/m^3, therefore, the volume of the hopper was obtained from equation expressed by (Gbabo et al., 2013).

$$m = \rho \times V \quad (1)$$

Where: m is the mass of maize, ρ is the density of maize, V is the volume of hopper

Volume of shelling unit: Since the shelling unit is cylindrical, the volume of shelling unit was calculated by;

$$v_s = \square r^2 l \quad (2)$$

Where: v_s is the volume of the shelling unit (m^3), r is the radius of shelling chamber (m), l is the length of shelling chamber (m)

The volume of shelling unit determines the volume of rasp bar and the length of spikes.

Power Requirement: The power required to drive the maize shelling machine is given by Khurmi and Gupta (2005) as;

$$P = \frac{2\pi N\tau}{60} \quad (3)$$

Where: P is the power requirement of the machine (watts), N is the speed of shelling (rpm), τ is the torque generated (N)

Shift diameter:

$$T = \frac{\pi\tau D^3}{16} \quad \text{(Khurmi and Gupta, 2005)} \quad (4)$$

$$T = \sqrt{\tau^2 + M_b^2} \quad (5)$$

$$M_b = (T_1 + T_2 + T_C) \times H \quad (6)$$

Where: T is the equivalent twisting moment (Nm), □ = permissible shear stress, D is the shaft diameter (m), τ is the torque transmitted (Nm), M_b is the bending moment of shaft due to the pull on the belt (Nm), T_1 is the belt tension in the tight side (N), $T_2$is the belt tension in the slack side (N), T_c is the centrifugal tension in belt (N), H is the distance of the pulley from the nearest bearing (m).

2.4 *Principle of operation of the maize sheller*

The working principle of maize shelling machine is a virtual part of its use. It applies to separate maize kernels from the cob. Maize enters into the shelling unit through the hopper by gravity. The maize is then impacted by the high speed rotating shaft with the help of spikes which shell the maize kernels from its cob by impact force. The maize kernels are separated through sieve pores by gravity and vibratory action of the machine to the winnowing chamber where clean grain is separated from chaff by pneumatic force from the blower. The shelled cob is expelled from shelling unit through cob outlet since it cannot escape through the sieve pores.

2.5 *Test Methodology*

The developed maize sheller was tested to ascertain its efficiency using 300kg of ear maize. The mass of the maize was measured by an analogue weighing balance. The speed of the shelling was measured using a digital tachometer. The model of the tachometer used was MASTECH serial number DT-2234a.

Prior to the test of the developed maize sheller, the prime mover and belt tension were checked and tested. The machine was placed on a tarpaulin to ensure minimum loss to the environment. The machine was then loaded with weighed sample at the shelling speeds of 250 rpm and 300 rpm. Mass of input grain (w_i), mass of whole grain (w_g), mass of unshelled cobs (w_u), mass of shelled grain (w_s), mass of dust (w_d), mass of broken grain (w_b), time of operation (h) and speed of shelling (rpm) were recorded.

After obtaining the above parameters, the following quantities expressed by Naveenkumar (2011) were computed:

$$Percentage\ broken\ grain = \frac{mass\ of\ broken\ grain}{mass\ of\ input\ grain} \text{ x } 100 \quad (7)$$

$$Percentage\ whole\ grain = \frac{mass\ of\ whole\ grain\ (kg)}{mass\ of\ input\ grain\ (kg)} \text{ x } 100 \quad (8)$$

$$Throughput\ capacity = \frac{Maass\ of\ shelled\ grain\ (kg)}{Time\ taken\ (h)} \text{ x } 100 \quad (9)$$

$$Shelling\ efficiency = \frac{Mass\ of\ shelled\ grain}{Mass\ of\ input\ grain} \text{ x } 100 \quad (10)$$

3.0 Results and Discussion

At the end of experimental evaluation carried out on the developed maize sheller, the results are discussed in this chapter. The percentage whole grain, percentage broken, throughput capacity and performance efficiency at different speeds of 250 rpm and 300 rpm were evaluated and discussed. The performance efficiency increases with speed, but broken grain was more at 300 rpm as shown in the Tables 1 and 2

Table 1: Performance Evaluation of the Developed Maize Sheller at the Speed of 250 rpm

N	Input (Kg)	Whole ain (Kg)	Broken grain (Kg)	Dust (Kg)	Shelled obs (Kg)	Unshelled obs (Kg)	Time taken (min)	Whole grain (%)	Broken ain (%)	Throughput capacity (Kg/h)	Performance efficiency (%)
1	30	16.69	0.55	0.71	7.55	3.95	4.9	55.63	1.83	318.98	86.83
2	30	16.40	0.53	0.98	7.56	4.48	4.7	54.67	1.77	325.79	85.10
3	30	16.35	0.42	0.54	8.51	4.12	4.8	54.50	1.40	323.50	86.27
4	30	16.12	0.60	0.89	7.80	4.52	4.7	53.73	2.00	325.28	84.93
5	30	16.84	0.45	0.62	8.53	3.48	4.6	56.13	1.50	345.91	88.40
Mean	30	16.48	0.51	0.75	8.05	4.11	4.74	54.93	1.70	327.89	86.31

Table 2: Performance Evaluation of the Developed Maize Sheller at the Speed of 300 rpm

N	Input (Kg)	Whole grain (Kg)	Broken grain (Kg)	Dust (Kg)	Shelled cobs (Kg)	Unshelled obs (Kg)	Time taken (min)	Whole ain (%)	Broken ain (%)	Throughput capacity (Kg/h)	Performance efficiency (%)
1	30	16.11	0.68	0.54	10.14	2.53	3.6	53.70	2.27	457.83	91.57
2	30	15.85	0.71	0.72	9.34	3.38	3.5	52.83	2.37	456.34	88.73
3	30	15.92	0.69	0.61	9.56	3.22	3.7	53.07	2.30	434.27	89.27
4	30	16.15	0.62	0.59	9.96	2.68	3.5	53.83	2.07	468.34	91.07
5	30	16.04	0.82	0.65	10.03	2.46	3.4	53.47	2.73	486.00	91.80
Mean	30	16.01	0.70	0.62	9.81	2.85	3.54	53.38	2.35	460.56	90.53

Percentage of whole grains: The whole grain recovery was affected by varying shelling speed. The whole grain reduced from 16.48 kg at the shelling speed of 250 rpm to 16.01 kg at the shelling speed of 300 rpm. The percentage whole grain of 54.93 % and 53.38 % obtained using equation (8) were evaluated at the speeds 250 rpm and 300 rpm respectively.

Percentage broken grain: The broken grain increased with increase in shelling speed. The percentage broken grain obtained using equation (7) increased from 1.70 % at 250 rpm to 2.35 % at 300 rpm shelling speeds and this was because shelling spikes strike more rapidly with impact force.

Throughput capacity: The throughput capacity measured by equation (9) was obviously different at the two shelling speeds. Higher shelling capacity of 460.56 kg/h was found at the shelling speed of 300 rpm and this was because, the time of shelling was less at this speed.

Performance efficiency: The shelling efficiency of the developed machine increased significantly from 86.31% to 90.53% at the shelling speeds of 250 rpm and 300 rpm respectively. This increase in shelling speed also led to obvious reduction in unshelled cobs from 4.11kg to 2.85kg. The shelling efficiency was obtained by equation (10).

4.0 Conclusion and Recommendations

4.1 *Conclusion*

A maize shelling machine was designed, fabricated, and tested at varying shelling speed. The effects of speed on the performance of the machine can be deduced as:

- Increase in speed resulted to decrease in percentage whole grain
- Percentage damaged grain increased with increase in shelling speed
- Unshelled cobs decreased significantly with increase in shelling speed
- Increase in shelling speed led to increase in shelling capacity due to reduction in shelling time
- Shelling efficiency significantly increased with increase in shelling speed

4.2 *Recommendations*

- Since the shelling capacity of the developed maize sheller increased with increasing shelling speeds, the performance of sheller at higher speeds should be evaluated.
- Germination tests should be performed on kernels shelled by the developed sheller to determine its suitability for maize seed production.
- Awareness should be created among farmers to adopt mechanical method of shelling maize to reduce or eliminate energy and time wastage and, mechanical shellers should be easily available through government agricultural programmes.

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INFLUENCE OF MOISTURE CONTENT, MACHINE SPEED AND SIEVE TILT ANGLE ON THE EFFICIENCY OF A RICE CLEANING MACHINE

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Abstract

In rural areas, rice harvesting is mostly carried out manually using sickles or knives. During this process, grains which falls to the ground are packed with sands and dirt thereby contaminating milled rice and reducing its commercial value. This paper therefore investigates the efficiency of an existing rice cleaning and grading machine over a varied range of moisture content, machine speed and sieve's angle of tilt in order to improve the quality of locally milled rice using response surface analysis. The machine was evaluated for five different moisture content levels of 10, 12, 14, 16 and 18 % dry basis with tilt angle of intermediate sieve at 2, 4 and 6 ° and machine speed of 210, 240 and 286 rpm. Highest efficiency for the separation of whole grains was 91.0 % obtained at a moisture content of 12 % db and 4 ° angle of inclination of the intermediate sieve while the lowest efficiency of 50.4 % was recorded at a tilt angle of 6 ° and moisture content of 18 %. Moisture content and tilt angle had significant effect on the efficiency of separation of whole grain at 95 % confidence level. The work further seeks to determine the appropriate performance factors for rice milling applications through model fitting and percent contribution of factors to machine efficiency. The machine is therefore recommended for rice processors who are involved in rice milling operation. The adoption of the performance variables obtained would boost the efficiency of the machine for clean rice production.

Keywords: milled rice, moisture content, tilt angle, separation efficiency, response surface

1.Introduction

Two species have emerged as the most popular cultivated rice, *Oryza sativa* and *Oryza glaberrima*, of these two species, the more widely produced is O. sativa. From an early history in the Asian areas, rice has spread and is now grown on all continents except Antarctica. Being able to grow in this wide spectrum of climates is the reason rice is one of the most widely eaten foods of the world (Thomas, 1997). Rice is cultivated in virtually all the agro-ecological zones in Nigeria (Akande, 2001). Cultivation of rice in appreciable scale and dimension commenced in Nigeria during the Second World War due to a halt in the importation from the far East (Ojo, 1991) . From the mid-1970s, rice consumption in the country rose significantly as a result of accelerating population growth rate of 2.8% per annum (Akpokeje *et al.*, 2001). No doubt, rice production has also expanded as a result of vast increase in land area put under cultivation, "but this was still considered insufficient to match the consumption increase" (NISER, 2002). As a result of increase in human population in Nigeria, rice consumption has surpassed its production.

It was estimated that rice production in Nigeria between 2001 and 2003 was estimated as 2.03 million tons while consumption was 3.96 million tones. The balance of 1.93 million tones was obtained by importation (FAO 2004). This shows that the rate of consumption of rice in Nigeria far outweighs production but the consumption of locally produced rice is declining due to its inferior quality compared to the imported ones. It is so surprising that Nigeria with all the natural resources (land) has not dedicated a certain percentage of it to rice farming and ensures its production on a large scale instead of importing. Rapid Nigeria's population growth has created a surge in the demand for rice with very large proportion imported in order to augment local production.

Unmilled rice known as paddy is usually harvested when the grains have a moisture content of around 25%. In rural areas, harvesting is mostly carried out manually by using sickles or knives but it can also be done mechanically by using a rice combine harvester. The use of hand tools give rise to post-harvest loss because in the process of harvesting, most grains fall to the ground and are later packed with sands and dirt thereby making the cleaning process more difficult (IRRI, 2013) . Okunola and Bamgboye (2011) developed a rice cleaning and grading machine so as to improve the quality of rice produced in Nigeria. This present work therefore intends to assess the influence of moisture content, machine speed and tilt angles on the performance of a rice cleaning machine. The work further seek to use response surface experimental design to perform model fitting and significance of factors to response for improved level of efficiency and acceptability of the developed machine for usage to processors.

2. Materials and Methods

2.1 *Source of Materials and Samples Preparation*

Rice grain seeds used in this experiment were obtained from Igbemo, Ekiti State, a local rice producing area in Nigeria. The initial moisture content of the grains as brought in from the study area was determined by drying samples in an air circulating oven set at 105°C for 24 hours according to ASAE standards (2003). It was carried out in triplicates and the average value was recorded. The moisture content was calculated using equation 1.

$$M_{DB}=\frac{Mw-MD}{MD}\times 100 \qquad (1)$$

Where,

M_{DB} = Moisture content on dry basis of the grains; M_W = Initial weight of the grain;

M_D = Weight of the grain after drying

The machine was accessed at five different moisture content levels of 10%, 12%, 14%, 16% and 18% on dry basis in order to relate the machine performance over a wide range of moisture content as suggested by Okunola and Bamgboye (2012). Moisture levels higher than the initial moisture content of the sample were attained by adding the required amount of distilled water, Q as calculated from equation 2. The samples were kept in a refrigerator at 5°C for 5 days for the moisture to distribute uniformly throughout the sample.

$$Q = \frac{A(b-a)}{(100-b)} \quad \ldots\ldots 2$$

Where,

Q= mass of water to be added in Kg

A= initial mass of sample in kg,

a= initial moisture content of the sample in % d.b.

b= final (desired) moisture content of sample in % d.b.

2.3 *Machine Description and Operation*

The machine is made up of a hopper with a slide gate mechanism positioned underneath it for metering of grains into the sieve assembly; cleaning and grading unit with provision of 3 set of oscillating sieves assembly and a blower fan; the power unit which is composed of the belt, pulley, shaft, connecting rod and the electric motor; the discharge unit which consists of two outlets- the product receptacle and the reject receptacle (See Figure 2.1). The to and fro movement of the sieves is effected by an eccentric connection to the power source. There is a deflector in between the intermediate and bottom sieves to convey materials that passed through the top sieve to be further separated at the bottom sieve. The cleaned separated grains pass downwards over the bottom sieve and discharge on the opposite side of the machine into the product receptacle while the chaffs, small stones and broken grains discharges at the reject receptacle. A provision was made to vary the angle of tilt of intermediate sieve for more effective separation of reject from the whole grains.

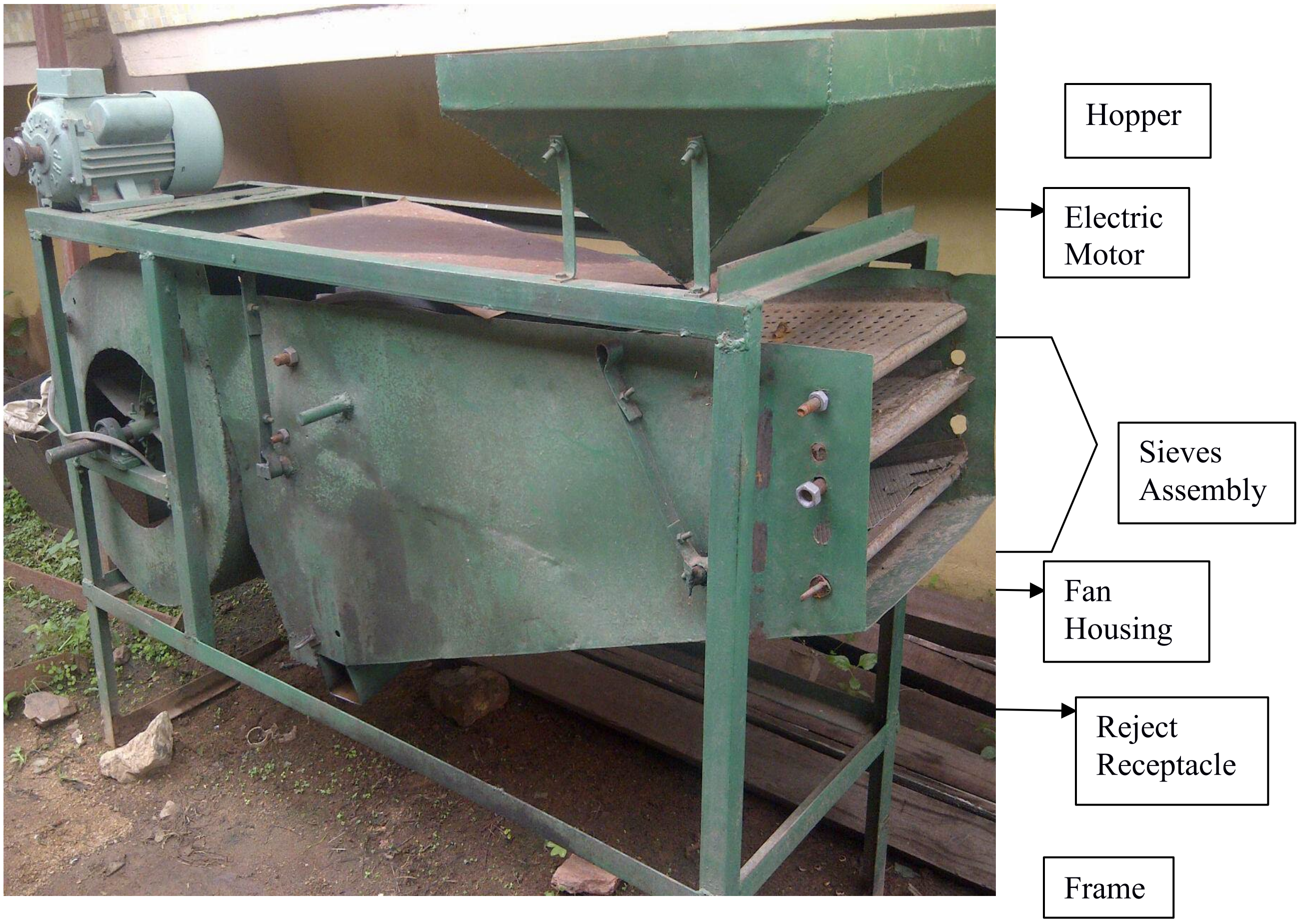


Figure 2.1: The rice cleaning machine

2.4 *Experimental Procedures*

The machine was evaluated at five different moisture content levels of 10%, 12%, 14%, 16% and 18% on dry basis considering the moisture content safe for storage to be between 12%- 14% (IRRI, 2013) and varied at 3 levels of intermediate sieve angle (2°, 4° and 6°) to study the effect of variation of tilt angles. Three levels of fan speed were selected in combination with different diameters of pulley (250 mm, 300 mm and 350 mm) based on equation 3 below. Thus the resulting speeds are 286 rpm, 240 rpm and 210 rpm.

$$N_1D_1 = N_2D_2 \qquad \qquad (3)$$

(Khurmi and Gupta, 2005)

2.4 *Performance evaluation*

Mixtures of known weights of whole grains and undesirable materials were fed into the machine at five different moisture content levels of 10%, 12%, 14%, 16% and 18% on dry basis and varied at 3 levels of tilt angle of intermediate sieve at 2°, 4° and 6° at a varying speed of 286 rpm, . The milled rice was cleaned into two categories; reject (small stones, chaffs and brokens) and product (whole grains). The flow chart in Figure 2.2 was used to show a typical way of characterizing the quality of separation in a two-way separation.

For the purpose of evaluation, equation 4 below was adopted for the separation efficiency as used by Igbeka (1984) as well as Nigeria Industrial Standard (NIS, 1997):

1. Efficiency of separation of whole grain

$$E_{gr} = \frac{GP}{GP+GR} \times 100\% \quad \ldots\ldots 4$$

Where GP= good product

GR= good reject

2. Efficiency of separation of materials other than grain

$$E_{bc} = \frac{BR}{BR+BP} \times 100\%$$

Where BR= bad reject; BP= bad product

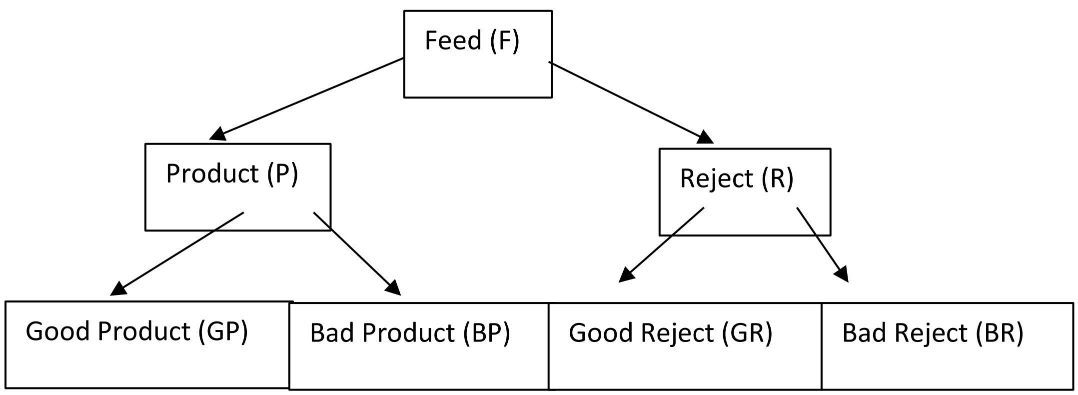


Figure 2.2: Characterization of quality separation of grains

2.5 *Experimental Design and Optimization*

The historical data design of response surface methodology (RSM) was used to establish the interactions between the crop parameter (moisture content) and operating parameters (speed and tilt angle). The independent variables considered in this study were moisture content, fan speed and tilt angle of sieves. The five levels of moisture content are 10%, 12%, 14%, 16% and 18%, speed at 286 rpm, 240 rpm and 210 rpm while the tilt angle are varied at three levels of 2°, 4° and 6°. A total of 45 experiments were carried out (Figure 2.3). In optimizing the operation, primary product (whole grain) was maximized while the minor (materials other than grain) was minimized (Table 2.1).

Table 2.1: Constraints to Optimization Technique

Name	Goal	Lower Limit	Upper Limit
MC	is in range	10	18
SPD	is in range	210	286
ANG	is in range	2	6
Egr	maximize	47.586	91

2.6 *Development of Models*

Design Expert 8.0 version was used to generate models showing the relationship between the process variables (moisture content, speed and tilt angle) and the response parameters (efficiency of separation of whole grains and materials other than grains). The models were generated using multiple regression analysis to fit a second order equation (eqn 5) to the response parameters as reported by Bamgboye and Adejumo (2015).

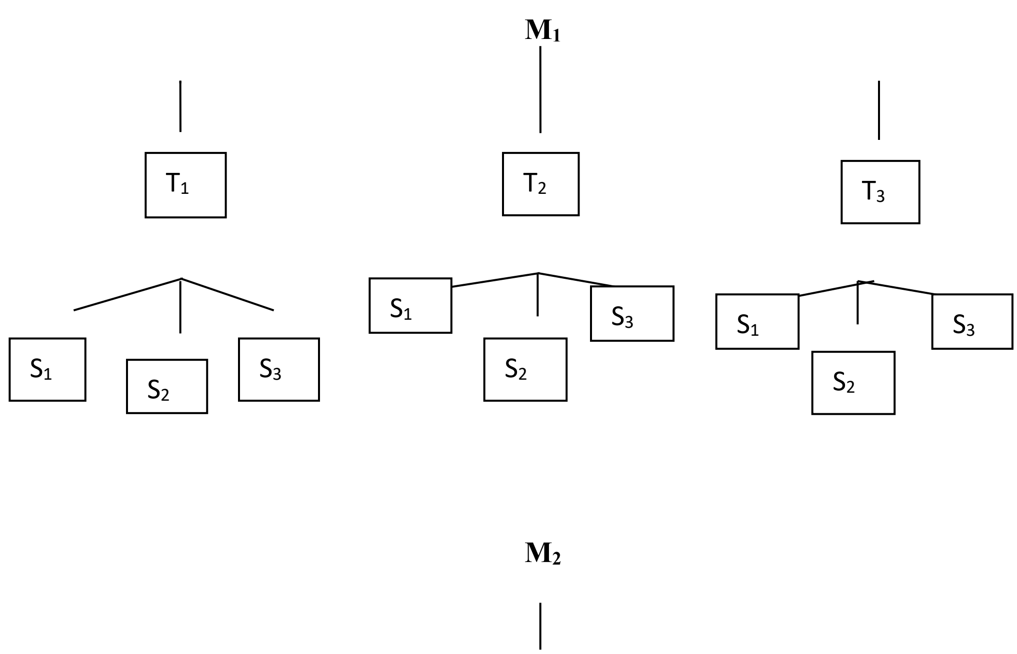
$$Y= a_o + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_3 x3 + \alpha_{11} x_1^2 + \alpha_{22} x_2^2 + \alpha_{33} x_3^2 + \alpha_{12} x_1 x_2 + \alpha_{13} x_1 x_3 + \alpha_{23} x_2 x_3 + \ldots\ldots + \alpha_{ij} x_i x_j \ldots\ldots (5)$$

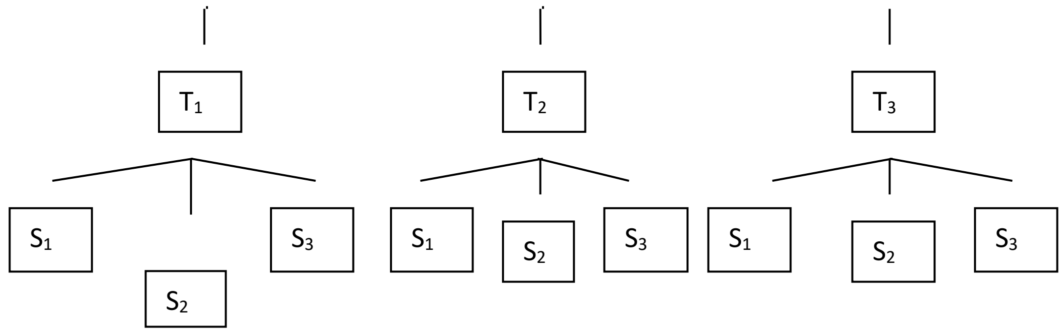
Where Y= efficiency of separation

α_0= constant term

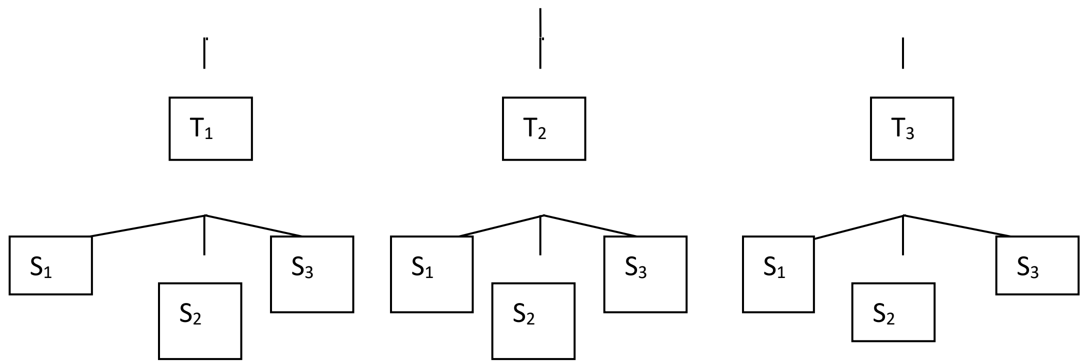
α_2………α_{ij} are regression coefficients of the model

x_1= independent variable




T_1
T_2
T_3
S_1
S_2
S_3
S_1
S_2
S_3
S_1
S_2
S_3

M_3


T_1
T_2
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S_1
S_2
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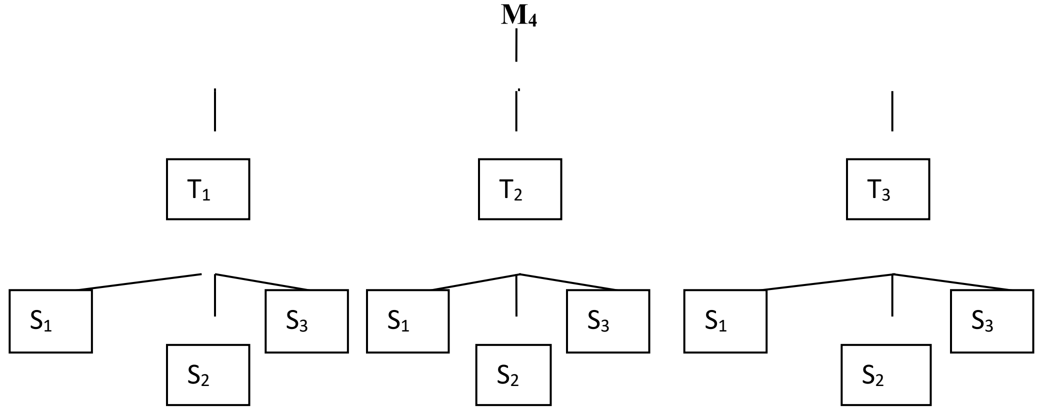
S_1
S_2
S_3
S_1
S_2
S_3

M_4


T_1
T_2
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S_1
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S_2
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S_1
S_2
S_3

M_5

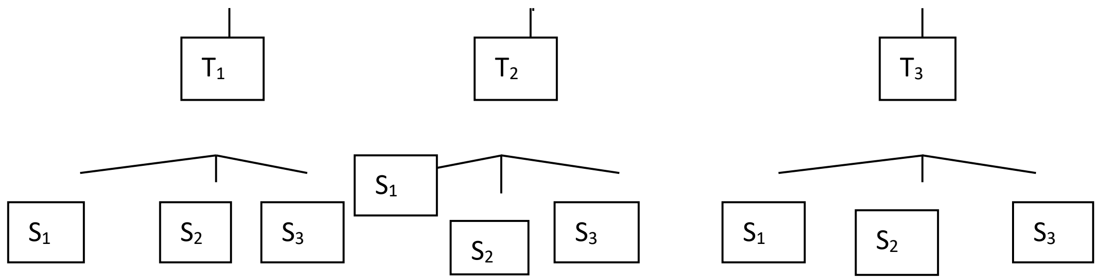

Figure 2.3: Experimental design

3. Results and Discussion

3.1 *Effect of Process Variables on the Efficiency of Separation of whole grains*

From Figures 3.1- 3.2, the highest efficiency for the separation of whole grains was 91% at a moisture content of 12% db, 286 rpm of fan speed and 4° angle of inclination intermediate sieve. Figure 3.1 shows the effect of tilt angle on whole grain separation varies from 89.99% at 2° and increased to 91% at 4° and experienced a decrease at 6°. Okunola *et al.* (2015) got a similar efficiency of 87% at a tilt angle of 5° for the separation of paddy rice from impurities. He further explained that there would be a decrease in the efficiency as tilt angle increases. The lowest value of efficiency of separation of 47.59% was obtained at sieve angle of 6º. This may be due to the fact that the tray is closer to the bottom sieve thus no sufficient height to prevent the grains from bouncing back to the intermediate sieve.

Moreover, moisture content also affects the separation efficiency of the whole grains, an increase in moisture content causes slight increase in the efficiency of separation of whole grain which later decreases with increasing moisture content as shown in Figure 3.1. Increasing moisture content may lead to more adhesiveness between the rice grain and other constituents to be separated. These findings are in tandem with Dauda *et al*. (2011) who reported a cleaning efficiency of 90.2% for milled rice. Okunola and Igbeka (2009) and Okunola *et al.* (2015) also reported a machine optimum performance of 98% product purity. Also, Simonyan (2006) reported an efficiency of 96% at 7.63% wb for grains.

Figure 3.2 shows that as the speed increases there is a slight increase in the efficiency at 240 rpm. The lowest speed at 210 rpm gives a lowest efficiency, this indicate that the air is insufficient to separate the impurities however, an increase in air speed led to an increase in the efficiency. At the highest fan speed of 286 rpm, there was loss of grains depending on the moisture content because it affects bulk weight and density of grains. Hollatz and Quick (2003) reported that excessive air velocity fluidizes the grain, carrying it to the back of the sieve and depositing it along with the chaff.

ANOVA result (Table 3.1) showed significant influence on the factors. In this case, moisture content, sieve angle and speed are significant ($P \leq 0.05$) on the efficiency of separation of whole grain. The regression analysis on the experimental results showed a quadratic relationship ($p \leq 0.05$) among efficiency of separation of whole grains, moisture content, fan speed and tilt angle as given in the model below:

$$E_{gr} = -111.14629 + 25.16076MC + 3.34374VA + 0.34595SPD - 1.10291MC^2 - 0.67942VA^2 - 9.90286E-004SPD^2 - 0.10592MCVA + 9.74628E-003MCSPD + 0.010560VASPD \quad (R^2 = 0.93)$$

Where:

E_{gr} is the Efficiency of separation of whole grains, MC is the moisture content,VA represents the angle of tilt of intermediate sieve and SPD is the fan speed

High coefficient of determination (R^2) justifies the suitability of the model in that it satisfies a good fit test at 5% level of significance.

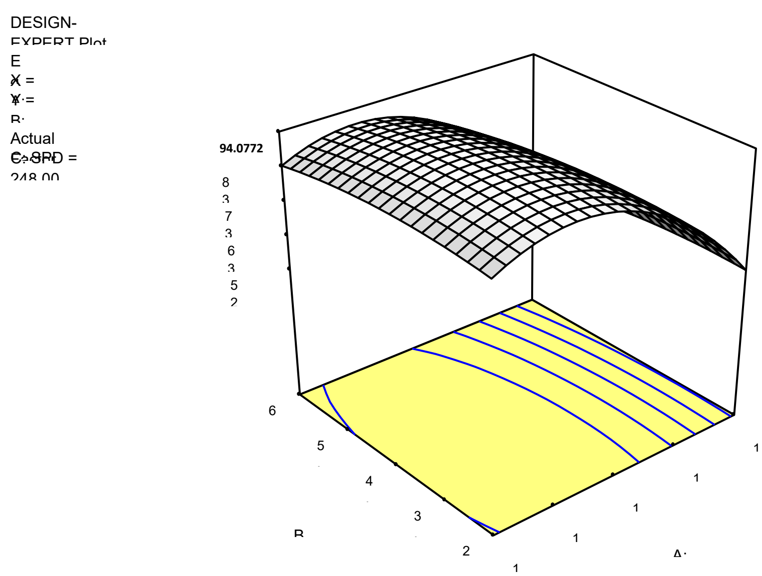

Figure 3.1: Effect of tilt angle and moisture content on the efficiency of separation of whole grain

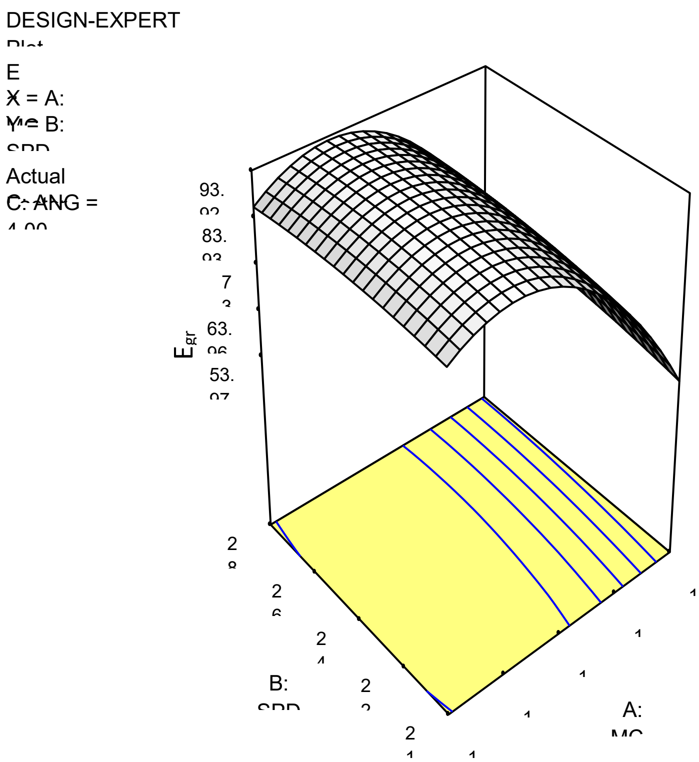

Figure 3.2: Effect of fan speed and moisture content on the efficiency of separation of whole grains

Table 3.1: ANOVA Table for

Effect of Process Variables on the Efficiency of Whole Grains

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	7831.53	9	870.17	78.72	< 0.0001	significant
A	*4965.32*	*1*	*4965.32*	*449.21*	*< 0.0001*	
B	*108.77*	*1*	*108.77*	*9.84*	*0.0035*	
C	*48.48*	*1*	*48.48*	*4.39*	*0.0435*	
A^2	*2452.29*	*1*	*2452.29*	*221.86*	*< 0.0001*	
B^2	*73.86*	*1*	*73.86*	*6.68*	*0.0141*	
C^2	*18.40*	*1*	*18.40*	*1.66*	*0.2054*	
AB	*10.77*	*1*	*10.77*	*0.97*	*0.3304*	
AC	*33.41*	*1*	*33.41*	*3.02*	*0.0909*	
BC	*13.07*	*1*	*13.07*	*1.18*	*0.2842*	
Residual	386.87	35	11.05			
Cor Total	8218.40	44				

Where A, B and C are moisture content, tilt angle and fan speed respectively.

3.2. Effect of Process Variables on the Efficiency of Separation of Materials other than Grain (MOG)

In analyzing the efficiency of separation of materials other than grain, the lowest efficiency of 9.926% was obtained at angle 6° and 18% moisture content dry basis. It was observed that as the sieve angle increases, the efficiency reduces as presented in Figure 3.3. The highest efficiency was recorded at fan speed of 286 rpm and moisture content also affects the efficiency of MOG; as it increases from 10 – 14%, the efficiency increases to 86.42% as shown in Figure 3.4.

ANOVA result (Table 3.2) showed that moisture content, sieve angle and speed had significant effect on the efficiency of separation of materials other than grain at $p \leq 0.05$. A model was generated which shows the relationship between moisture content, tilt angle and fan speed and the efficiency of separation of materials other than grains. The regression analysis on the experimental results showed a quadratic relationship ($p \leq 0.05$) among efficiency of separation of materials other than grains, moisture content, fan speed and tilt angle as given in the model below:

$$E_{bc} = -170.33520 + 41.61694MC + 3.94947VA - 0.14503SPD - 1.94151MC^2 - 0.59822VA^2 - 7.25835E - 004SPD^2 - 0.073429MCVA + 0.035245MCSPD - 4.16269E - 003VASPD \quad (R^2 = 0.47)$$

Where

E_{bc} means the efficiency of separation of materials other than grains and other parameters remain as earlier stated.

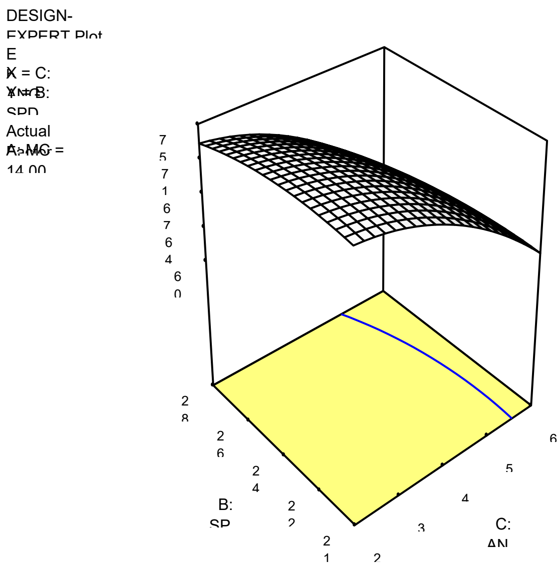

Figure 3.3: Effect of tilt angle and fan speed on the efficiency of separation of materials other than grain

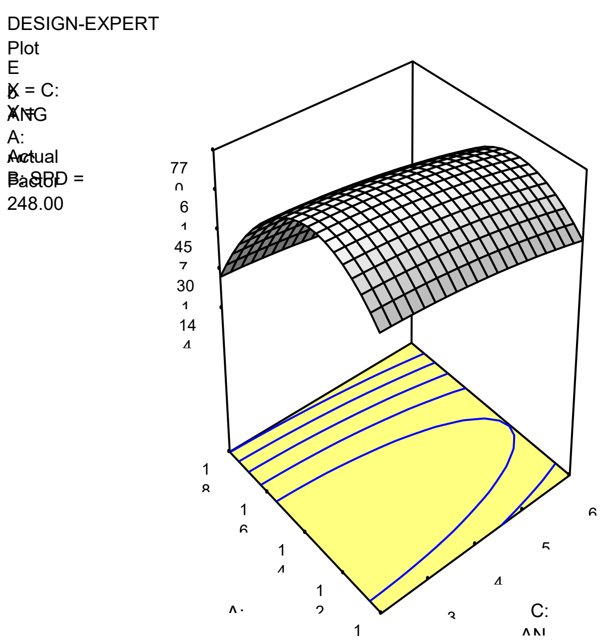

Figure 3.4: Effect of moisture content and tilt angle on the efficiency of separation of materials other than grain

Table 3.2: ANOVA Table for Effect of Process Variables on the Efficiency of Separation of Materials Other than Grains.

Source	Sum of Square	DF	Mean Square	Value	F Prob > F	
Model	16094.41	9	1788.276.93		< 0.0001	significant
A	*6602.87*	*1*	*6602.8725.59*		*< 0.0001*	
B	*999.62*	*1*	*999.62*	*3.87*	*0.0570*	
C	*34.62*	*1*	*34.62*	*0.13*	*0.7164*	
A2	*7599.22*	*1*	*7599.2229.45*		*< 0.0001*	
B2	*57.26*	*1*	*57.26*	*0.22*	*0.6405*	
C2	*9.89*	*1*	*9.89*	*0.038*	*0.8459*	
AB	*5.18*	*1*	*5.18*	*0.020*	*0.8882*	
AC	*436.86*	*1*	*436.86*	*1.69*	*0.2017*	
BC	*2.03*	*1*	*2.03*	*7.872E-003*	*0.9298*	
Residual	9031.42		35	258.04		
Cor Total		1	25125.83		44	

Where A, B and C remain as earlier stated

3.3 Optimization of the Process Variables

The result of the optimization technique revealed that the best cleaning performance would be obtained if the machine is operated at peripheral speed of 252.66 rev/min and tilt angle of 3.52° with moisture content of 12.88% d.b. Under these conditions, the value of efficiency of separation of whole grain would be 93.80%.

4. Conclusions and Recommendations

4.1 *Conclusions*

The highest efficiency of separation of whole grain was 91% at a moisture content of 12% db, 286 rpm of fan speed and 4° angle of inclination of intermediate sieve while the lowest efficiency of 50.355% was recorded at an angle of 6° and 18% moisture. Moisture content, fan speed and tilt angle has significant effects on the performance of the rice cleaning machine. The optimal operating conditions for the cleaning machine were 12.88% d.b. for the moisture content of the grains, a peripheral speed of 252.66 rev/min and tilt angle of 3.52° while the efficiency is 93.80%.

The machine is energy saving, efficient, accessible and requires lesser man power for its operation. Hence, if the cleaning machine is made available to small and medium scale farmers, more rice will be produced of good quality standards to match the quality of imported ones with less drudgery in less time.

4.2 *Recommendations*

i. Investigation should be carried out on the use of the machine as pre cleaner before milling of paddy.

ii. Incorporation of magnets to trap any metallic contaminants.

iii. Investigation should be made on the use of the machine as a cleaner for other grains with provision of appropriate sieves.

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OPTIMIZATION OF AIR INLET AREA OF AN ACTIVE INDIRECT MODE SOLAR DRYER USING RESPONSE SURFACE METHODOLOGY

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Abstract
Air flow into a solar drying system has effect on the drying process. The study was aimed at optimizing air flow features of an active indirect mode solar dryer using a central composite rotatable design (CCRD) of response surface methodology (RSM) technique. The independent factors considered for the experiment were: air inlet area and size of product. The experimental design adopted was a two factor, five levels experiment which gave a total of 13 experimental runs. The air inlet area was selected on four orientations namely: square, rectangular, circular and triangular. Each shape orientation was considered separately, which gave a combined 52 experiments for each experimental run. The desired responses were: air flow rate and drag force. The response surface plots showed that there was positive interaction between the air inlet area and air flow rate, as well as the drag force. The size of the product has no significant effect on the responses. The optimum values for the air flow rate and drag force were obtained as 0.0275 m^3/s and 0.0476N respectively. The corresponding optimal conditions which gave the optimum responses were 100cm^2 (square shape air inlet) and 80 cm^2 (rectangular air inlet area) for air flow rate and drag force respectively. The models used in predicting the responses were adequate enough, as showed desirability of 0.992 and 0.95 respectively. The optimum responses were validated by applying the optimal conditions in the field, and a variation of less than 8% was observed.

Keywords: Solar Dryer, Air Inlet Area, Air Flow Rate, Drag Force, Optimization.

1. Introduction

The air flow into a solar drying system has direct impact on the amount of free water molecules removed from the cell and surface of the product at the initial stage of drying (Alamu *et al.* (2010); Oguntola *et al.*(2010). There is need for development and optimization of solar drying systems that will recommend appropriate air inlet spacing, to achieve more efficient drying of crops. Such innovation will stimulate interest in usage of solar drying systems for agricultural products.

The air inlet area of solar drying systems is most times not given prior attention, as most persons depend on literature and sometimes assumption, to arrive at size and shape of the air inlet of dryers. Itodo *et al.* (2004) had recommended that the air inlet area of solar dryers be optimized, to give room for analysis of variation in shapes and sizes of air inlet of dryers.

Many have deployed response surface approach in optimizing solar drying systems: Erbay and Icier (2009); Majdi *et al.* (2019); Adefemi and Ilesanmi (2018); Zhanyong *et al*. (2015); Mohammed *et al.* (2014); Madamba (2007); Sarimenseli and Yaldiz (2016); Abano *et al.* (2012); Patil *et al*. (2014); Surki *et al.* (2010) and Gupta *et al.* (2013). In developing optimum operating conditions for quality attributes in deep-fat frying of dodo produced from plantain, Adeyanju *et al*. (2016), deployed response surface methodology and concluded that the estimated response surface model could be used to optimize the frying process of dodo fried from plantain. Smitabhindu *et al*. [20] optimized solar assisted dying system for drying bananas.

In optimizing the drying parameters of Moringa seed in a tray dryer using Box-Behnken Technique of Response Surface Methodology, Omofoyewa *et al.* (2017), observed that the models developed models had the capacity to predict to about 70% of the responses. Salvatierra *et al*. [19] posited that the nature of which air flows into a solar dryer can influence the uniformity of air flow in the dryer and its performance. Their study revealed that optimizing air flow and distribution into the dryer and can influence the performance of a dryer.

Ikrang and Umani (2019) used response surface methodology to optimize process conditions for drying catfish, and observed that the method was effective in optimizing the drying process for the drying of different sizes of the product. Sunil *et al.* [23] reviewed optimization techniques used in solar drying. Ikrang and Umani (2019) reported that deployment of RSM for optimization processes, aids in reduction of experimental runs, which could also be economical on the part of researchers.

The study aimed at using a central composite rotatable design (CCRD) of response surface methodology as medium for optimization of air flow rate and force of drag of an active indirect mode solar dryer, to obtain optimum air inlet area for the solar dryer.

2. Materials and Methods

The methodology involved development and computation of air inlet area using relevant equations, measurement and optimization of air flow rate into the dryer and force of drag.

2.1 *Air Inlet Area*

The air inlet area was considered for four different shapes namely: square, rectangular, circular and triangular.

The area of the square inlet shape was computed from the equation:

$$A_s = L \times B \quad (1)$$

Where A_s is the area of the square shaped air inlet (cm^2), L is the length of the inlet(cm)and B is the breath of the inlet(cm).

The area of the rectangular inlet shape was computed from the equation:

$$A_r = L \times W \quad (2)$$

Where A_r is the area of the rectangular shaped air inlet (cm^2), L is the length of the inlet (cm) and W is the height of the inlet (cm).

The area of the circular inlet shape was computed from the equation:

$$A_c = \pi r^2 \quad (3)$$

Where A_c is the area of the circular shaped air inlet (cm^2) and r is the radius of the inlet(cm).

The area of the triangular inlet shape was computed from the equation:

$$A_t = \frac{1}{2} B \times H \quad (4)$$

Where A_r is the area of the triangular shaped air inlet (cm^2), B is the base of the inlet (cm) and H is the height of the inlet(cm).

2.2 *Volumetric Air Flow Rate*

The volumetric air flow rate of the dryer was computed from equation below:

$$\text{Air flow rate, } Q = AV \left(\frac{m^3}{s}\right) \quad (5)$$

Where$Q$ is Volumetric air flow rate, $A$is the area of inlet (m^2) and V is Velocity of air flow at the point of inlet (m/s).

2.3 *Drag Force*

The drag force of the dryer was computed from equation below:

$$F_D = 0.5\rho V^2 A C_d \,(N) \quad (6)$$

Where F_D is Drag force (N) is, ρ is Density of Air (1.225 kg/m^3), $V$is Velocity of air at the point of inlet (m/s), A is Air flow rate andC_d is Coefficient of drag (Dimensionless).

2.4 *Experimental Design and Statistical Analysis*

The levels of the experiment were selected based on preliminary analysis and literatures. The independent factors considered for the experiment were air inlet area and size of product on the dryer. The five levels selected for the product sizes were; P_1(4mm); P_2 (8mm); P_3 (12mm); P_4 (16mm); P_5 (20mm). The four inlet shapes were considered: square, rectangular; circular and triangular. For the square shaped inlet dryers, the levels (areas) selected were: S_1 (4 cm^2); S_2(16 cm^2), S_3(36 cm^2); S_4 (64 cm^2); S_5 (100 cm^2). The rectangular shaped inlet also had five levels (areas) selected as R_1(8cm^2); R_2(24cm^2); R_3 (48cm^2); R_4(80cm^2) and R_5 (40cm^2). The circular shaped inlet dryers had the following levels (areas): C_1 (3.142cm^2); C_2 (12.568cm^2); C_3 (28.278cm^2); C4 (50.272cm^2) and C_5 (78.55cm^2). T_1 (8cm^2); T_2 (16cm^2); T_3 (24cm^2); T_4(32cm^2); T_5 (40cm^2) were chosen as levels (areas) for the triangular shaped inlet dryers.

The experimental design adopted 2 factors, 5 levels, factorial Central Composite Rotatable Design (CCRD) of Response Surface Methodology, as used by Taheri-Garavand*et al.* (2017), while optimizing the drying process of banana. The experimental design gave a total of 52 experiments, 13 each for the four inlet shapes considered (square, rectangular, circular and triangular). The experiment was repeated three times (three batches of drying). The average obtained from the three batches of drying was used as the reference value for computation.

Central Composite Rotatable Design is comprised of three types of design points namely factorial points (n_c), axial points (n_a) and central points (n_c) and the total number of treatment combinations were obtained from the equation below:

$$n = 2^k \left(n_f\right) + 2k(n_a) + k(n_c) \quad (7)$$

where ‘k’ is the number of independent variables and n is the number of repetitions of experiment at the center point, n_a, n_c and n_f are the axial points, central points and factorial points respectively. The total number of design points was obtained using the equation:

$$N = 2^k + 2k + (n_o). \quad (8)$$

The CCRD involved 13 experiments consisting of 2^2 factorial CCD, with 8 axial points (α = 2) and 5 replications at the center points.

$$Codedvalue = \frac{Naturalvalue - Baselevel\ (level\ 0)}{Intervalofvariation} \quad (9)$$

The relationship between the coded and natural values in the response surface methodology (RSM) design for the experiment is as given in equation 10:

$$A_2 = \frac{(PS-12)}{4} \quad (10)$$

A_2 = Coded value for product size

PS = Natural value for product size

The coded values of the independent variables (-2, -1, 0, 1, 2) were used; where -2, 0 and 2 represent the lowest, medium and highest levels respectively. The coded and actual values for square, rectangular, circular and triangular shaped air inlet were as captured in Tables1 to 4.

Table1: Levels, Codes and Intervals of Independent Variables for square shaped air inlet

Factors	**Codes**	**Level**				
		-2	**-1**	**0**	**1**	**2**
Air Inlet area (cm^2)	A_1	4	16	36	64	100
Product size (mm)	A_2	4	8	12	16	20

Table 2: Levels, Codes and Intervals of Independent Variables for rectangular shaped air inlet

Factors	Codes	Level				
		-2	**-1**	**0**	**1**	**2**
Air Inlet area (cm^2)	A_1	8	24	48	80	40
Product size (mm)	A_2	4	8	12	16	20

Table 3: Levels, Codes and Intervals of Independent Variables for circular shaped air inlet

Factors	Codes	Level				
		-2	**-1**	**0**	**1**	**2**
Air Inlet area (cm^2)	A_1	3.142	12.568	28.278	50.272	78.55
Product size (mm)	A_2	4	8	12	16	20

Table 4: Levels, Codes and Intervals of Independent Variables for triangular shaped air inlet

Factors	Codes	Level				
		-2	**-1**	**0**	**1**	**2**
Air Inlet area (cm^2)	A_1	8	16	24	32	40
Product size (mm)	A_2	4	8	12	16	20

The response surface function Y was obtained using a second order polynomial model as below:

$$Y = \beta_0 + \sum_{i=1}^{2} \beta_i X_i + \sum_{i=1}^{2} \beta_{ii} X^2{}_i + \sum_{i=1}^{2} \sum_{j=i+1}^{2} \beta_{ij} X_i X_j \quad (11)$$

Where: Y is the Response (Air Flow Rate, Drag Force, Moisture Content, Drying Rate, Drying Efficiency of Dryer; β_0 is the constant coefficient; $\sum_{i=1}^{2} \beta_i$ is the summation of coefficient of linear terms; $\sum_{i=1}^{2} \beta_{ii}$ is the summation of quadratic terms; $\sum_{i=1}^{2} \sum_{j=i+1}^{2} \beta_{ij}$ is the summation of coefficient of interaction terms; $X_i X_j$ are the independent variables.

Analysis of Variance (ANOVA) was used to determine the significance and fitness of the model as well as the effect of significant individual terms and their interaction on the desired responses. The *p*-value (probability of error value) was used as a tool to check the significance of respective regression coeffiecient which also indicated the interaction effect. Data obtained were statistically analyzed to determine the significant difference in the responses and their interactions at 5% probability level. Response surface plots were also generated with the help of a Design Expert (version 10.0.10) software package for design of experiments was used. In order to correlate the response variable to the independent variables, multiple regression equations were used to fit the coefficient of the polynomial model of the response.

2.5 *Experimental Procedure and Data Collection*

The dryers developed were subjected to test at different levels, according to the factors combination of the experiments, as shown in Table 5 to 8. A Lutron 4 in 1 digital meter (LM-8100), with a measurement rage of 0.4 to 30.0m/s, was used to measure velocity of air flow into the dyers on a two hourly interval. The data obtained was used to compute the air flow rate, while the air flow rate was used to calculate the drag of individual dyers air inlet. The experiment was replicated three times. The experiment was replicated three times using an active indirect mode solar dryer designed and constructed by Etim et al. (2020)

Table 5: Result for air flow rate and drag force of the dryer using square shaped air inlet area and product size

un Order	ir Inlet Area (cm^2)	roduct Size (mm)	ir Flow Rate (m^3/s)	rag Force (N)
	-2	0	0.0028	0.0008
	-1	-1	0.0059	0.0092
	-1	1	0.0053	0.0109
	0	-2	0.0091	0.0142
	0	0	0.0111	0.0213
	0	0	0.0130	0.0286
	0	0	0.0116	0.0231
	0	0	0.0118	0.0235
	0	0	0.0117	0.0212
)	0	2	0.0119	0.0241
l	1	-1	0.0181	0.0315
2	1	1	0.0202	0.0394
3	2	0	0.0240	0.0353

Table 6: Result for air flow rate and drag force of the dryer using rectangular shaped air inlet area and product size

un Order	ir Inlet Area (cm^2)	roduct Size (mm)	ir Flow Rate (m^3/s)	rag Force (N)
	-2	0	0.0023	0.0041
	-1	-1	0.0064	0.0106
	-1	1	0.0058	0.0087
	0	-2	0.0142	0.0158
	0	0	0.0158	0.0322
	0	0	0.0152	0.0296
	0	0	0.0168	0.0362
	0	0	0.0160	0.0327

	0	0	0.0149	0.0285
)	0	2	0.0134	0.0230
l	1	-1	0.0235	0.0422
2	1	1	0.0256	0.0502
3	2	0	0.0097	0.0145

Table 7: Result for air flow rate and drag force of the dryer using circular shaped air inlet area and product size

un Order	ir Inlet Area (cm^2)	roduct Size (mm)	ir Flow Rate (m^3/s)	rag Force (N)
	-2	0	0.0006	0.0007
	-1	-1	0.0029	0.0040
	-1	1	0.0037	0.0065
	0	-2	0.0076	0.0126
	0	0	0.0077	0.0127
	0	0	0.0094	0.0098
	0	0	0.0094	0.0194
	0	0	0.0076	0.0147
	0	0	0.0079	0.0130
)	0	2	0.0101	0.0222
l	1	-1	0.0158	0.0303
2	1	1	0.0146	0.0260
3	2	0	0.0144	0.0259

Table 8: Result for air flow rate and drag force of the dryer using triangular shaped air inlet area and product size

un Order	ir Inlet Area (cm^2)	roduct Size (mm)	ir Flow Rate (m^3/s)	rag Force (N)
	-2	0	0.0016	0.0021

	-1	-1	0.0050	0.0097
	-1	1	0.0047	0.0063
	0	-2	0.0063	0.0103
	0	0	0.0056	0.0081
	0	0	0.0065	0.0108
	0	0	0.0082	0.0181
	0	0	0.0064	0.0105
	0	0	0.0061	0.0095
)	0	2	0.0063	0.0103
l	1	-1	0.0080	0.0123
2	1	1	0.0065	0.0081
3	2	0	0.0123	0.0230

2.6 *Optimization*

Numerical and graphical optimization methods were deployed for the independent variables (air inlet are and product size) to obtain the optimum values for the air flow rate and drag force of the dryer, using design expert software (10.0). Response surface plots of the response variables were used to select the optimum combination of the independent variables, to produce a model capable of predicting the desired responses. The range and optimization goals for the independent and dependent factors were as on Table 9.

Table 9: Ranges and response goals for RSM optimization of the air flow properties

Response	Unit	Optimization Goal (Objective Function)	Relative Importance
Air Flow Rate	m^3/s	Maximize	Very important
Drag Force	N	Maximize	Very important

3.0 Results and Discussions

3.1 *Effect of Air Inlet Area and Product Size on Air Flow Rate*

The air inlet area had significant effect on the air flow rate, but the effect of the product size was minimal. It was observed that circulation of air within the dryer for the process of drying was dependent on the inlet area.

Figures 1 to 4 gave insight to the relationship between air inlet areas, product sizes and air flow rates. It was observed that the air flow rate within the dryer increased as air inlet area increased, and vice-versa.

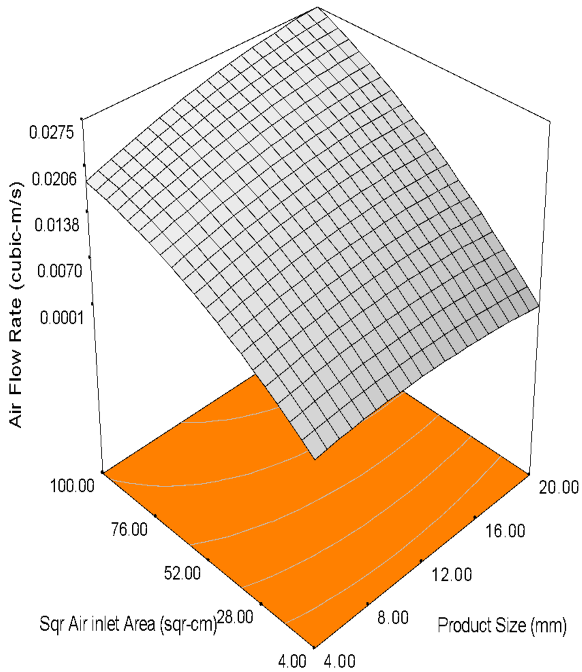

Figure 1: Response Surface plot of air inlet area, air flow rate and product size for square air inlet

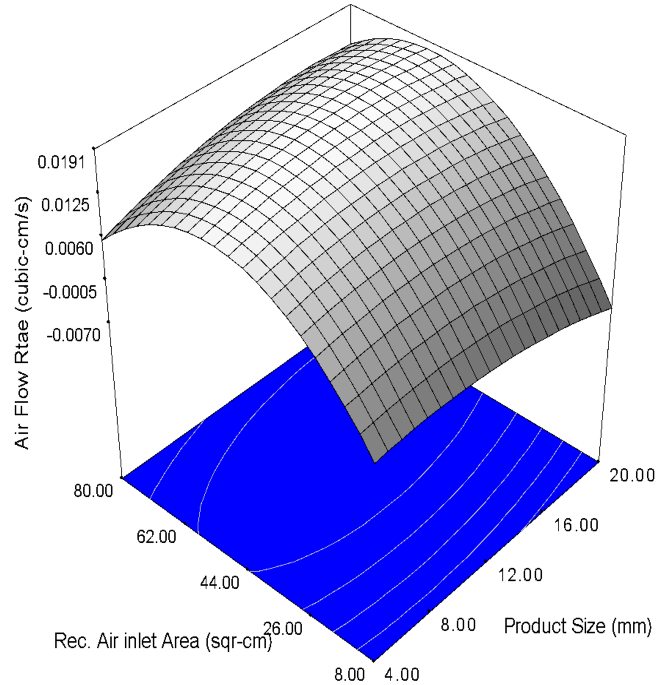

Figure 2: Response Surface plot of air inlet area, air flow rate and product size for rectangular air inlet

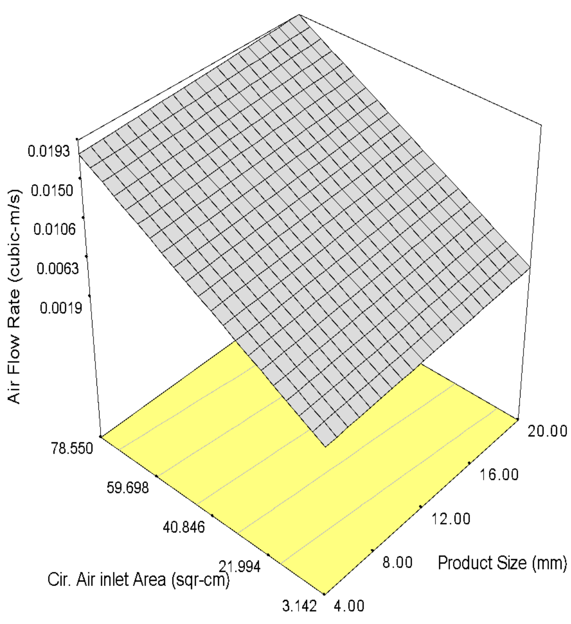

Figure 3: Response Surface plot of air inlet area, air flow rate and product size for circular air inlet

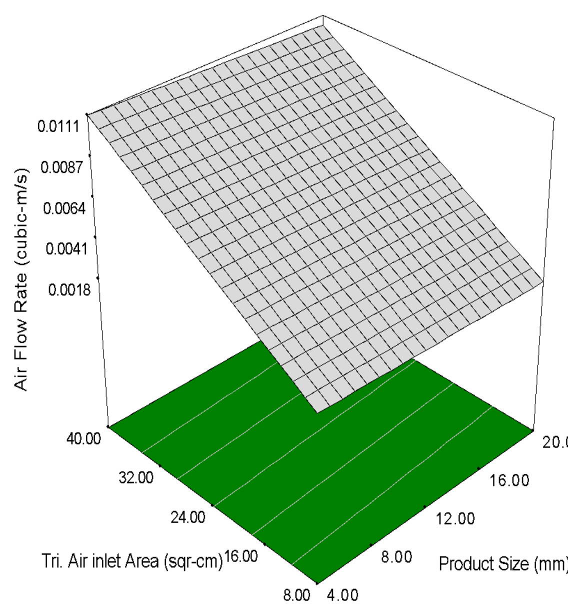

Figure 4: Response Surface plot of air inlet area, air flow rate and product size for triangular air inlet

3.2 Effect of Air Inlet Area and Product Size on Drag Force

The response surface plots in Figure 5 to 8, shows the relationship between air inlet areas, product sizes and drag force variation. The drag force was dependent on the air inlet area. This trend was similar to what was obtainable in the air flow rate.

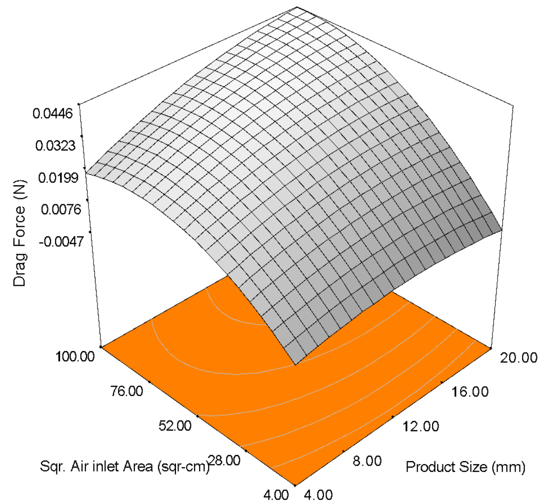

Figure 5: Response Surface plot of air drag force, air flow rate and product size for square air inlet

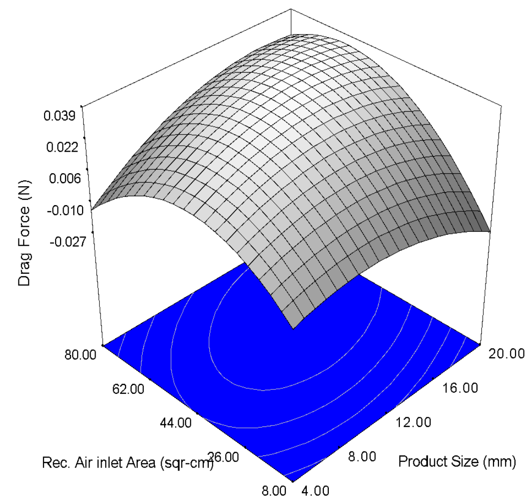

Figure 6: Response Surface plot of air drag force, air flow rate and product size for rectangular air inlet

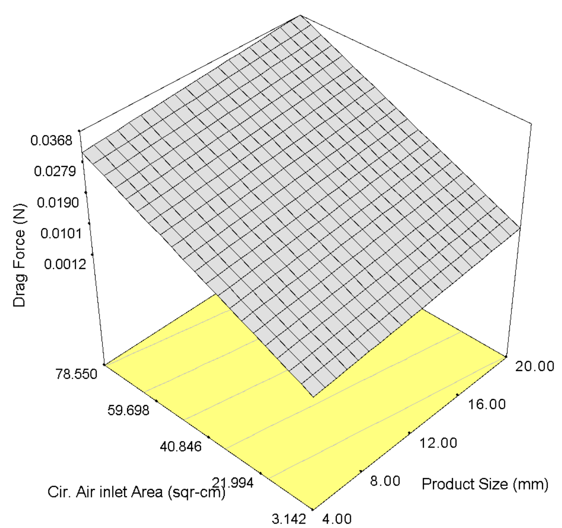

Figure 7: Response Surface plot of air drag force, air flow rate and product size for circular air inlet

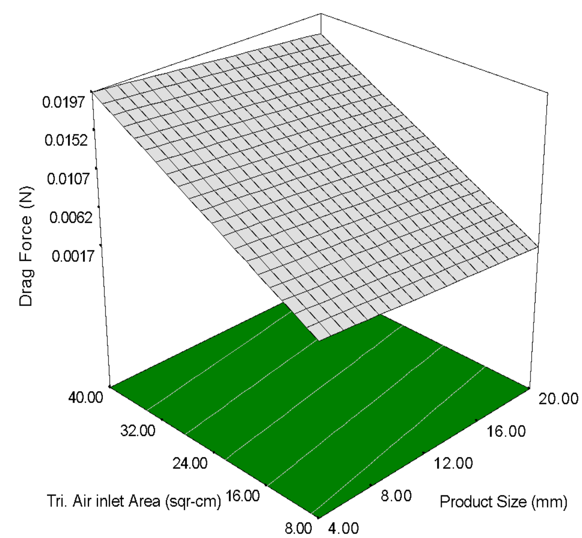

Figure 8: Response Surface plot of air drag force, air flow rate and product size for triangular air inlet

3.3 *Model Selection for Optimization of Air Flow Rate (AFR) of an Active Indirect Mode Solar Dryer for Drying Cooking Banana*

For the optimization process, the following models were selected: linear (square shaped air inlet); quadratic (rectangular shaped air inlet); linear (circular shaped air inlet) and linear (triangular shaped air inlet). The regression equations for air flow rate of the dryer with square, rectangular, circular and triangular inlet dryers were as obtained in equations 12 to 15.

$$AFR_{SQ} = -1.37 \times 10^{-3} + 2.84 \times 10^{-4} S_a + 4.34 \times 10^{-4} P_s - 1.24 \times 10^{-6} {S_a}^2 - 2.20 \times 10^{-5}\, 6.47 \times 10^{-6} S_a P_s \quad (12)$$

$$AFR_{RE} = 9.51 \times 10^{-4} + 2.84 \times 10^{-4} R_a + 2.47 \times 10^{-4} P_s - 3.68 \times 10^{-7} {R_a}^2 - 2.38 \times 10^{-5} {P_s}^2 + 6.51 \times 10^{-6} R_a P_s \quad (13)$$

$$AFR_{CR} = -5.41 \times 10^{-4} + 4.29 \times 10^{-3} C_a + 9.40 \times 10^{-5} P_s \quad (14)$$

$$AFR_{TR} = 3.47 \times 10^{-4} + 2.72 \times 10^{-4} T_a - 3.60 \times 10^{-3} P_s \quad (15)$$

Where AFR_{SQ}, AFR_{RE}, AFR_{CR} and AFR_{TR} are the air flow rate in the square, rectangular, circular and triangular air inlet configurations, respectively, m^3/s; S_a, R_a, C_a and T_a are the square, rectangular, circular and triangular air inlet dimension, respectively (cm^2); P_s is the product size, mm.

For the square shaped unit dryers the model p – value of < 0.0001 was less than the chosen level of significance (0.05). This indicated that the model was significant. The lack of fit p – value of 0.0915, was higher than the level of the significance, as shown in Table 10.

Table 10: Regression analysis of response surface quadratic model for air flow rate and drag force

egression Terms	ir Flow Rate (Quadratic Model)	rag Force (Quadratic Model)
:andard Deviation	0.0001.441	0.0036
'ean	0.012	0.022
oefficient of Variation	11.97	16.32
'edicted Sum of Squares	0.00003779	0.00056
officient of Determination (R^2)	0.9463	0.9376
djusted R^2	0.9414	0.8930
'edicted R^2	0.9112	0.6064
dequate precision	40.99	16.53

The p – value for the square shape air inlet dimensions had a p – value (Prob. > F) of 0.0001, which was lower than the desired level of significance (0.05), while the p – value of the product sizes was 0.107, which was higher than the desired level of significance. This meant that the inlet area had significant effect on the air flow rate of the square shaped inlet dryers, while the product size had no significant effect. The model gave high coefficient of determination ($R^2 = 0.9474$). The high R^2 value indicated that model could account for 94.74 % of the total viability in the response, and that there was high correlation between the independent variables.

The linear positive terms of equations 13 and 15 meant that the air flow rate increased as the air inlet area increased. The positive interaction terms suggested that increase in the levels of the independent factors correspondingly increased the response.

To ascertain the combined effect of the independent variables on the air flow rate, the response plots in Figures 1 to 4, were generated for the model of best fit, as a function of the factors, while the response was kept at its central point.

The air flow rate increased with increase in air inlet area. The product size was observed to have had no significant effect on the air flow into the dryer, as it was largely responsible for the duration of the drying process. Hedge *et al.* (2015); Khaldi *et al.* (2018); and Etim *et al.* (2019) reported that increase in air inlet area of a solar dryer; enhances air flow into the dryer and better the efficiency.

3.4 *Model selection for optimization of drag force (DF) of an active indirect mode solar dryer for drying cooking banana*

The models that were best fit for optimization of drag force were: quadratic (square shaped air inlet); quadratic (rectangular shaped air inlet); linear (circular shaped air inlet) and linear (triangular shaped air inlet). The regression equations for drag force of the dryer with respect to square, rectangular, circular and triangular inlet dryers were as given in equations 16, 17, 18, and 19.

$$DF_{SQ} = -0.01 + 7.79 \times 10^{-4} S_a + 1.68 \times 10^{-3} P_s - 5.74 \times 10^{-6} {S_a}^2 - 6.90 \times 10^{-5} {P_s}^2 + 1.58 S_a P_s \quad (16)$$

$$DF_{RE} = -0.02 + 4.91 \times 10^{-4} R_a + 3.41 \times 10^{-3} P_s - 9.94 \times 10^{-7} {R_a}^2 - 1.69 \times 10^{-4} {P_s}^2 + 2.16 \times 10^{-5} R_a P_s \quad (17)$$

$$DF_{CR} = -0.01 + 8.02 \times 10^{-3} C_a + 3.62 \times 10^{-4} P_s \quad (18)$$

$$DF_{TR} = 9.77 \times 10^{-4} + 3.83 \times 10^{-4} T_a - 1.56 P_s \quad (19)$$

Where DF_{SQ}, DF_{RE}, DF_{CR} and DF_{TR} are drag force in the square, rectangular, circular and triangular air inlet configurations, respectively, N; S_a, R_a, C_a and T_a are square, rectangular, circular and triangular air inlet dimension, respectively (cm^2); P_s= product size, mm

Table 11 shows the ANOVA for the quadratic model for the square shaped air inlet dryer, which had the highest coefficient of determination and least standard deviation.

Table 11: ANOVA for response surface quadratic model for air flow rate of square shapes air inlet dryer

ɔurce of Variation	um of Squares	f	lean Square	-Value	rob> F
lodel	0004170		00008340	3.18	0.0001

AI	0004027		00040272	29.24	0.0001
S	0000042		00000418	42	1070
AI^2	0000036		00000357	92	1313
S^2	0000024		00000241	97	2036
AI×PS	0000018		00000179	46	2655
esidual	0000086		00000122		
ack of Fit	0000066		00000220	46	0915
ıre Error	0000020		00000049		
or Total	0004256	2			

Where SAI represents Square Air Inlet, PS represents Product Size

Table 12: ANOVA for response surface Quadratic Model for drag force of square shapes air inlet dryer

ource of Variation	um of Squares	f	lean Square	-Value	rob> F
lodel	001329		0002659	1.04	0004
AI	001195		0011947	4.54	0.0001
S	000072		0000720	70	0484
AI^2	000041		0000412	26	1141
S^2	000026		0000262	07	1934
AI×PS	000010		0000096	76	4114
esidual	000088		0000126		
ack of Fit	000052		0000174	92	2684
ıre Error	000036		0000091		
or Total	001418	2			

Where SAI represents Square Air Inlet, PS represents Product Size.

For the square shaped inlet dryers, the model *p* – value of 0.0004 was lower than the desired level of significant. The lack of fit *p* – value of 0.2684, was higher than the 5% level of significance. The model terms *p* – values were less than the desired level of significance as shown in Table 12. This meant that the model terms had significant effect on the drag force. A high coefficient of determination ($R^2 = 0.9376$) was also observed, which meant that there was positive correlation between the independent variable. The response model was responsible for 93.76% of the total viability in the response.

The linear positive term in equation 19 meant that the drag force increased as air inlet area increased. The positive interaction terms in equations 16 and 17 established that increase in the independent factors had corresponding increasing effect on the response (drag force).

To ascertain the combined effect of the independent factors on the drag force, the response plots in Figures 5 to 8 were generated for the models of best fit, as a function of the factors, while the response was kept constant. The drag force increased with increase in air inlet area. The product size had no significant effect on the drag force. Etim *et al.* (2019) reported that the drag force of an active indirect mode solar dryer is greatly influenced by the air flow into the dryer.

3.5 *Optimization Goals*

The desired goals for each drying parameter for square, rectangular, circular and triangular air inlet configurations are as shown in Table 13, 14, 15 and 16 respectively. To optimize the air flow rate and drag force by numerical optimization, equal importance of '3' was given to the independent factors (air inlet area and product size) and the responses: air flow rate and drag force.

Table 13: Criteria and output for numerical optimization of solar drying process parameters of cooking banana in an active indirect mode solar dryer using square shape inlet.

Drying criteria	Unit	Lower limit limit	Upper	Optimization Goal	Relative Importance	Output
Sqr air inlet dim.	cm^2	4.00	100.00	Range	3	100.00
Product size	mm	4.00	20.00	Range	3	20.00
Air Flow Rate	m^3/s	0.00277	0.024	Maximize	3	0.0275
Drag Force	N	0.000827	0.0394	Maximize	3	0.0445
Desirability						0.992

Table 14: Criteria and output for numerical optimization of solar drying process parameters of cooking banana in an active indirect mode solar dryer using rectangular shaped inlet

Drying criteria	Unit	Lower limit limit	Upper	Optimization Goal	Relative Importance	Output
Rec. air inlet dim.	cm^2	8.00	80.00	Range	3	80.00
Product size	mm	4.00	20.00	Range	3	20.00
Air Flow Rate	m^3/s	0.00232	0.0256	Maximize	3	0.0250
Drag Force	N	0.00412	0.0502	Maximize	3	0.0476
Desirability						0.950

Table 15: Criteria and output for numerical optimization of solar drying process parameters of cooking banana in an active indirect mode solar dryer using circular shaped inlet

Drying criteria	Unit	Lower limit limit	Upper	Optimization Goal	Relative Importance	Output
Cir. air inlet dim.	cm^2	3.142	78.55	Range	3	78.55

Product size	mm	4.00	20.00	Range	3	19.94
Air Flow Rate	m^3/s	0.000577	0.0158	Maximize	3	0.0179
Drag Force	N	0.000653	0.0303	Maximize	3	0.0341
Desirability						1.000

Table 16: Criteria and output for numerical optimization of solar drying process parameters of cooking banana in an active indirect mode solar dryer using triangular shaped inlet

Drying criteria	Unit	Lower limit limit	Upper	Optimization Goal	Relative Importance	Output
Tri. air inlet dim.	cm^2	8.00	40.00	Range	3	40.00
Product size	mm	4.00	20.00	Range	3	20.00
Air Flow Rate	m^3/s	0.00163	0.0123	Maximize	3	0.0105
Drag Force	N	0.00206	0.023	Maximize	3	0.0172
Desirability						0.895

The summary of the optimal inlet area and product size and predicted optimum values for air flow rate and drag force were obtained as in Table 17.

Table 17: Optimal air inlet area and product size with optimum predicted responses

Air inlet shape	Drying process parameters		Optimum predicted responses		Desirability
	Air inlet area (cm^2)	PS(mm)	AFR (m^3/s)	DF (N)	
Square	100.00	20.00	0.0275	0.0445	0.992
Rectangular	80.00	20.00	0.0250	0.0476	0.950
Circular	78.55	20.00	0.0179	0.0341	1.000
Triangular	40.00	20.00	0.0105	0.0172	0.895

Note: PS is the Product Size, AFR is the Air Flow Rate, while DF is the Drag Force.

3.6 *Optimization and Validation of Air Flow Rate of an Active Indirect Mode Solar Dryer for Drying Cooking Banana*

The optimization process the optimum value of the air flow rate of an active indirect mode solar dryer for drying cooking banana was performed and the summary of the result is shown in Table 17. The optimal values of 0.0275, 0.0250, 0.0179 and 0.0105 m^3/s were obtained for square, rectangular, circular and triangular shaped air inlet dryers that corresponded to air inlet area of 100 cm^2, 80 cm^2, 78.55 cm^2 and 40 cm^2 respectively. The corresponding optimal product size was 20 mm. The optimum air flow rate desirability was 0.992, 0.950, 1.000 and 0.895 for the respective air inlet shapes. Optimum values of 100 cm^2 (square air inlet) and 20 mm (product size) gave the maximum optimum air flow rate of 0.0275 m^3/s and a desirability of 99.2 %.

A test run under the optimal drying conditions of 100cm^2 and 20 mm for air inlet and product size was carried out to validate the linear model of air flow rate for square air inlet dryers; an experimental air flow rate of 0.029 m^3/s was obtained. The variation between the predicted value and the validated data obtained from the field after the test run was 0.0015 (5.17 %) as in Table 18.

Table 18: Deviation in validation of optimum responses

Response	Optimum Value	Field Experiment	Deviation
Air Flow Rate (m^3/s)	0.0275	0.029	0.0015 (5.17 %)
Drag Force (N)	0.0476	0.0441	0.0035 (7.94 %)

In comparison, the predicted and experimental results for the optimum air flow rate for the square air inlet dryers, showed that there was an excellent agreement between the experimental and predicted values for the air flow rate (Figure 9). The deviation between the predicted and the experimental value was relatively, which suggested that model has the capacity to predict the air flow rate of an active indirect mode solar dryer for drying of cooking banana.

3.7 Optimization and Validation of Drag Force of an Active Indirect Mode Solar Dryer for Drying Cooking Banana

The optimization process for the optimum values of the drag force of an active indirect mode solar dryer for drying cooking banana was performed and the summary of the result is shown in Table 17. Optimal values of 0.0445, 0.0476, 0.0341 and 0.0172 N were obtained for square, rectangular, circular and triangular shaped air inlet dryers that corresponded to air inlet area of 100 cm^2, 80 cm^2, 78.55 cm^2 and 40 cm^2 respectively. The product size that gave the optimum condition was 20 mm. The optimum drag force (0.0476N) was obtained from a rectangular inlet area of 80 cm^2, with product size of 20mm at a desirability of 95%.

A test run under the optimal drying conditions of 80 cm^2 and 20 mm for air inlet area and product size was carried out in order to validate the quadratic model of drag force. An experimental value of 0.0441 N was obtained. The result obtained from the field and that of the predicted value showed a deviation of less than 8% as shown in Figure 9.

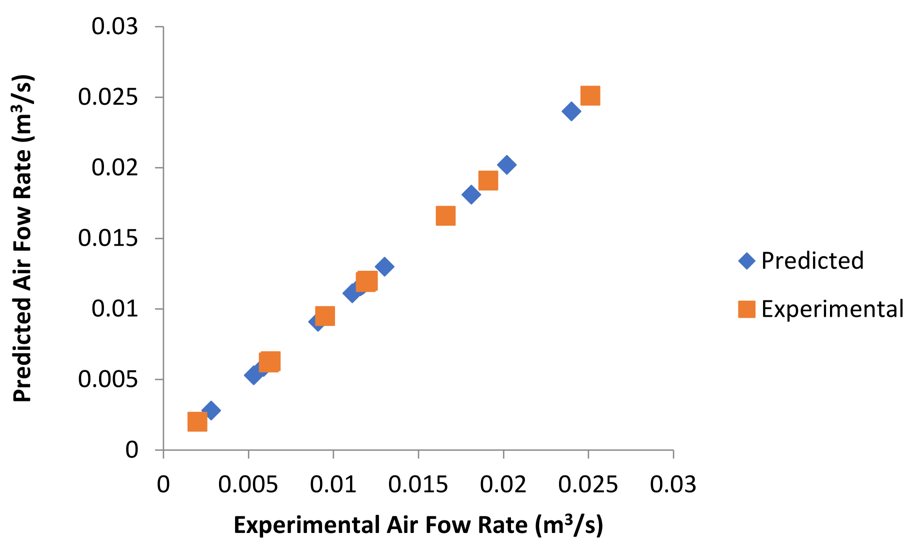

Figure 9: Predicted v Experimental: Air flow rate

The predicted and experimental result for the optimum drag force showed that there was a strong agreement between the experimental and predicted values for the air flow rate (Figure 10). The lower deviation between the experimental and the predicted value suggested that the model generated has capacity to predict the drag force of an active indirect mode solar dryer for the given conditions.

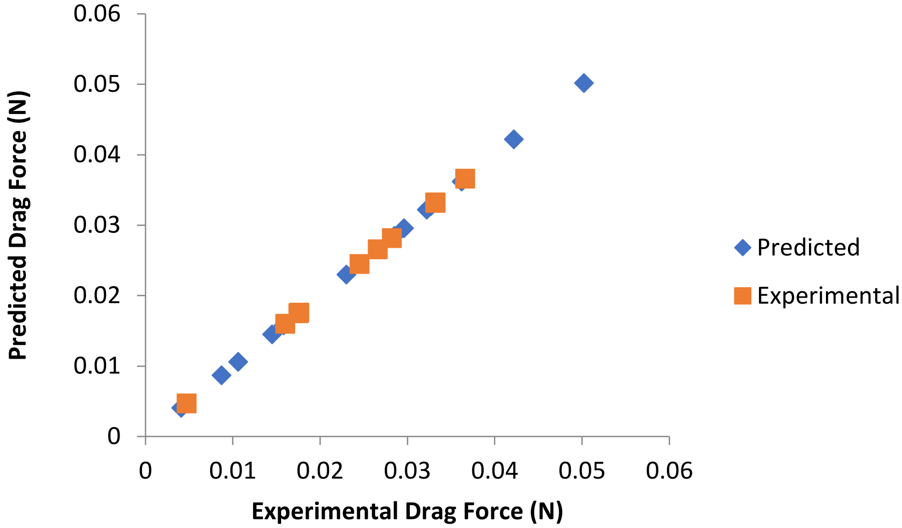

Figure 10: Predicted v Experimental: Drag Force

4.0 Conclusions and Recommendations

The response surface plot used to determine the relationship between air inlet area, product size of cooking banana and the desired optimization responses, showed there was there was positive relationship between the air inlet area, air flow rate and drag force. The models selected were capable of predicting the responses. The optimum responses obtained were 0.0275 m^3/s and 0.0476 N, for air flow rate and drag force respectively. The corresponding dryers that gave the optimum responses were: square (100 cm^2 air inlet area) and rectangular (80 cm^2 air inlet area), which were recommended for optimal air flow into an active indirect mode solar dryer. The air outlet area, which was kept constant during the experiment, should be optimized using the optimal conditions obtained from the experiment. The desirability of the responses were 99.2 and 95% for air flow rate and drag force respectively.

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Declaration of Interest Statement

The author declares no competing interest.

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PERFORMANCE EVALUATION OF A MULTI-GRAIN CLEANING MACHINE

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Abstract

The cleanliness of small sized grains such as sorghum and millet, is usually challenging after threshing operations. A grain cleaning machine was developed using locally available materials and based on detailed engineering design. The machine was used to clean sorghum and millet. It was evaluated using output capacity, cleaning efficiency, and percentage grain scatter loss as the performance parameters, while feed rate, air speed and crank amplitudes were used as the experimental factors. Results from the machine evaluation, indicates that the output capacity ranged between 620.83 to 1088.5 kg/hr. and 620.50 to 1097.83 kg/hr. for sorghum and millet, respectively, while the cleaning efficiency ranged between 98.04 to 98.66 % and 97.30 to 98.05 % for sorghum and millet, respectively. The scatter loss was obtained within ranges of 0.83 - 1.27 % and 1.31 - 2.12 % for millet and sorghum, respectively. The best performance of the machine was obtained at air speed and crank amplitude of 4.5 m/s and 25 mm, respectively for both crops, and feed rates of 1400 kg/hr. for sorghum and 1200 kg/hr. for millet. The research however, achieved the best cleaning efficiencies of 98.64 and 98.05 %, for sorghum and millet, respectively.

Keywords: Grain cleaning, , cleaning efficiency, output capacity, grain scatter loss.

1.Introduction

Sorghum and millet are cereal crops that are grown in large quantities in Nigeria as staple food. They have excellent storage stability and nutritional values, making them the most desired foods for holding in reserves. Sorghum (*Sorghum bicolor (L) Moench*) is the fifth most important cereal after rice, wheat, maize, and barley (FSD, 1999). It constitutes the main food grain for over 750 million people who live in the semi-arid tropics of Africa, Asia, and Latin America. The largest group of producers are small-scale subsistence farmers with minimal access to production inputs. It is also a major source of raw material to many agro-based industries. Sorghum is grown mostly in the Guinea and Sudan savannah zones, in Nigeria. Millet (*Pennisetum glaucum*) is however, a security crop that can be grown where other cereals like maize or wheat would not survive. It is the sixth most important cereal after sorghum, cultivated annually as rain fed crop in arid and semi-arid areas of Africa and the Indian sub-continent (Kajuna, 2001). In Nigeria, the annual yield of sorghum is reported to be in excess of 7 million tons, while millet is estimated at about 5 million tons (FAOSTAT, 2014). The FAO estimates in 2003 put the annual production of millet at over 18 million tons in Sub-Saharan Africa. Sorghum and millet are important sources of dietary protein, carbohydrates, the B complex of vitamins, vitamin E, iron and trace minerals. There has been an increasing demand of the crops for use in the production of food; feed products; alcoholic and non-alcoholic beverages. However, the traditional consumption of the crops still utilizes 98 % of the annual production.

Cleaning is a post-harvest operation undertaken to remove foreign and undesirable materials from threshed seeds/grains thereby leaving the produce clean for storage, planting or further processing. It is a material separation process. Cereal and leguminous crops need to be threshed and detached from their cops, panicles or pods before the process of cleaning. Grain cleaning is done to: reduce requirement for drying and cost; remove materials that could cause deterioration during storage; remove materials that could damage the conveying and milling machinery; remove materials that cause a reduction in the grade (thus reducing the value of the grain); and reduce storage requirements. There are a number of factors that affects the cleanliness and loss of grains during cleaning operations. According to Simonyan (2006), the physical parameters that affect grain cleaning processes are broadly grouped into; crop characteristics and machine parameters. The crop factors are; crop variety, maturity stage, grain moisture content, straw moisture content, bulk density of grain, bulk density of straw, stalk length, and equivalent grain diameter, while the machine factors are; velocity of air, air stream pressure, air density, angle of air direction and terminal velocity of particles (both grain and other materials). Other scholars and researchers have also reported on factors such as feed rate, amount of wind or air velocity, shaker frequency, sieve tilt angle, dimension of sieve opening, crop variety and moisture content (Awady *et al*., 2003; Ebaid, 2005; Sahay and Singh, 2008; Salwa *et al*., 2010, Muhammad *et al*., 2013).

In Northern Nigeria, cleaning or winnowing is usually done by women in an open space when there is free flow of natural wind using a woven circular tray of average diameter of 500 mm made from the back of sorghum stalk or the stalk of certain grass species. Muhammad *et al*. (2013) reported that it takes between seven to twelve minutes to clean a batch of 1 kilogram of uncleaned grains, depending on the winnower's skill, the required cleanliness, grain/non-grain ratio, amount and stability of the natural air current and other environmental factors. The traditional or manual method is arduous, time and labour consuming operations on the persons performing the operations. The natural wind condition may not also be favourable for the operation and may therefore, result to increased time of operation and drudgery. The long hours associated with the traditional method results in fatigue, loss of concentration and consequently, reduction in separation quality.

The average farmer finds it more economical to thresh crops manually but requires extremely high labour and time to clean the grains using the manual method (Muhammad *et al*., 2013). The farmers oftentimes become exhausted to continue with cleaning operations after threshing and as a result keeps the grain-foreign material mixture over long or short periods before cleaning. These practices usually result to mold and insect infestation and possibly damage and destruction to the grains. The presence of foreign matter in grains also increases the weight and bulk volume and resulting increase in the cost of handling, transportation and storage. Over the years, little or no effort has been applied in developing units of cleaning machines with high cleaning efficiencies, most of them are produced as integral parts of threshers, shellers, de-huskers, decorticator or combines. The output of some of these machines like the thresher, are low due to the presence of the threshing units whose threshing capacities are not significantly higher than manual threshing using sticks. Muhammad *et al*. (2013) reported that the threshing units also convey long straw onto the shaker which results in increase grain loss. The high cost of thresher–cleaner machine is due to the additional cost of the threshing component which is not needed by an average farmer. Therefore, it is imperative to develop a grain cleaner capable of relieving farmers and processors of the hard spent energy, time, labour, and resources in manual cleaning operations.

This research aims to develop a prototype cleaning machine for major cereal crops that can clean at-least one ton of the grains in an hour, thereby reducing the drudgery in post-harvest processing. The development of the prototype machine would be of importance to cereal and seed producers, as it will improve the cleanliness of their products and increase the market value.

2. Materials and Methods

2.1 *Construction of Grain Cleaning Machine*

A prototype grain cleaning machine was designed and constructed in the metal and fabricating workshop of the Department of Agricultural and Bio-Environmental Engineering Technology, Nuhu Bamalli Polytechnic, Zaria, Kaduna State. The major components of the prototype machine are shown in Fig. 1 and Table 1 gives a description of the machine. Figure 2(a and b) present the pictorial views of the machine. The main parts of the cleaner include the following:

i. the frame which serves as the skeletal support and means of coupling and holding other component parts together.

ii. the hopper which is trapezoidal in shape with the base inclined at an angle of 30^0 for discharge and even distribution of grains over the first screen; The shaft diameter was determined using Equation 1, as expressed by Khurmi and Gupta (2007), while the size of the driven pulley was determined using Equation 2, as given by Hannah and Stephen (1984). The blower has three blades enclosed in the casing to deliver air current over the reciprocating screens. The sieve compartment consists of the casing, two outlets, and three round screens (6.0, 4.5 and 2.0 mm) made with mild steel, selected based on determined physical properties of the grains. All screens are replaceable and adjustable between 0 and 12^0. The screen compartment oscillates with the aid of a connecting rod attached to the main shaft and an adjustable crank which helps to achieve various levels reciprocating amplitude.

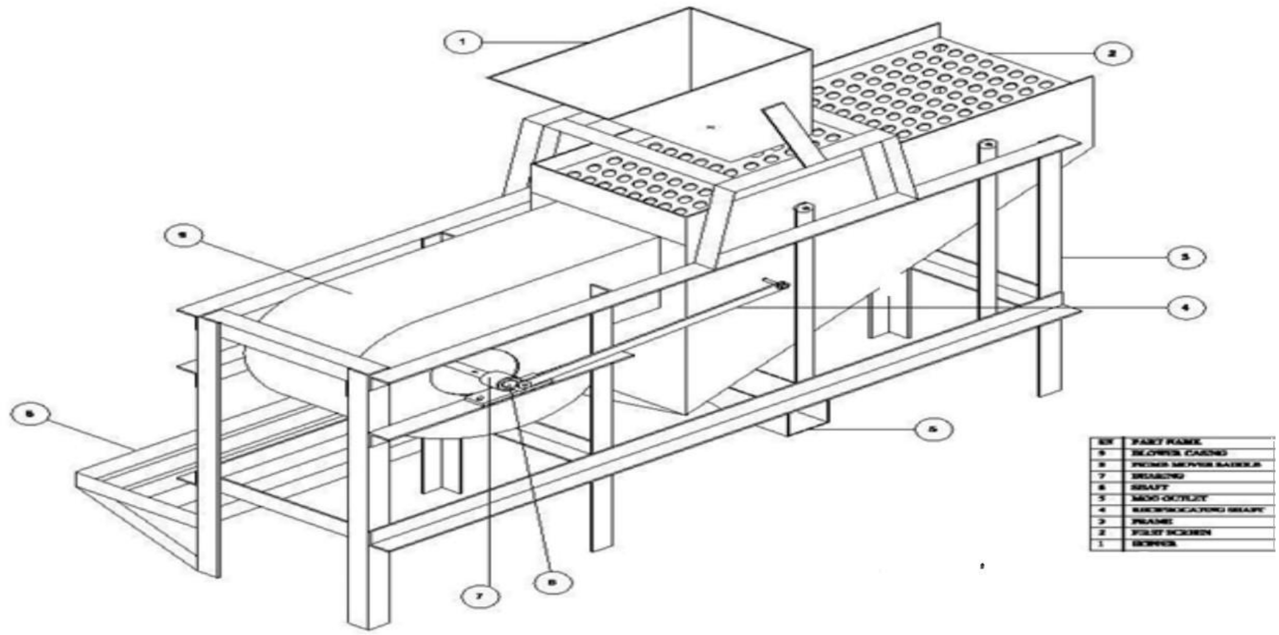

Fig. 1. Isometric view of the machine showing the major component

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (1)$$

where:
d=Shaft diameter (mm),
K_b = Combine shock and fatigue factors for bending moment,
K_t = Combine shock and fatigue factors for torsional moment,
M_b = Maximum bending moment (Nm),
M_t = Torsional moments (Nm),
S_s = Maximum allowable shear stress (N/m^2)

$$N_1 D_1 = N_2 D_2 \quad (2)$$

where:
N_1 = speed of driving pulley (rpm).
D_1 = diameter of driving pulley (m), and
D_2 = diameter of driven pulley (m)
N_2 speed of driven pulley (rpm)

Table 1. Description of Construction Materials

S/No	Material Description	Quantity	Material
1	Frame (25 × 25 × 5mm - Angle iron)	1	M.S - Angle iron
2	Hopper (1.5mm)	1	M.S – Sheet (Gauge 18)
3	Shaft (Ø 25mm)	1	M.S - Rod
4	Connecting rod (Ø 16 mm)	1	M.S - Rod
5	Pulley (150 diameter)		M.S

6	V-Belt	1	Leather
7	Sieve compartment (3mm)	1	M.S – Sheet (Gauge 18)
8	Sieves (2.0, 4.5 & 6.0 mm hole diameter)	3	M.S – Sheet (Gauge 18)
9	Flexible support for sieve compartment (5mm)	4	M.S – Flat bar
10	Fan housing (1.5mm)	1	M.S – Sheet (Gauge 18)
11	Fan blades (5 mm)	3	M.S – Sheet (Gauge 18)
12	Outlets	2	M.S – Sheet (Gauge 18)
13	Pillow Bearing	2	
14	Prime mover (Petrol Engine - 3.5hp)	1	

Scale - 1:5

All dimensions in mm

2.2 *Operation of the Prototype Machine*

A batch of unclean threshed grains is fed through the hopper to flow by gravity over the first screen which is inclined at an angle of 6^0. The second screen is inclined at 9^0 in the same orientation as the first while the third sieve is inclined at 12^0 at the reverse direction. The first screen initiates the separation by size when the sieve chamber oscillates. As the grains and chaff mixture flow between the screens, they pass across an air stream from the blower which performs the separation based on the aerodynamic properties of the mixture. The cleaned grains roll over the third screen and are collected at one of the outlets, while broken grains, stalk and other smaller particles passe through the screen are collected at the other outlet. The machine is powered by a small 3.5 hp petrol engine.

(a). Side view of the machine *(b). Front view of machine*

Fig. 2(a and b). Different views of the constructed machine

2.3 ***Machine Evaluation***

SAMSORG 43 variety of sorghum and EX BORNO variety of pearl millet were sourced and used for the experiment. Feed rate, air speed and crank amplitude were used as the independent variables in evaluating the performance of the machine. Four levels of feed-rate (800kg/hr., 1000kg/hr., 1200kg/hr. and 1400kg/hr.), four levels of air speed (2.5 m/s, 4.5 m/s, 6.0 m/s, and 8.0 m/s) and three levels of crank amplitude (10 mm, 25 mm and 40 mm), were used for the experiment. Machine output capacity, cleaning efficiency and percentage grain loss were determined as the performance indices of the machine. The expression in Equation 3 was used as given by Simonyan *et al* (2006) to determine the cleaning efficiency of the grains while the grain scatter loss was obtained using Equation 4 as given by Ndirika (1994). The combination of experimental factors in three replications produced a total of 144 treatments. Grain samples of both grains were analyzed manually before the experiment and the result showed that the millet sample consist of 84 % pure grains and 16 % impurities (chaff, straw, dust, small immature seeds), while the sorghum sample on the other hand consist 87 % pure grains and 13 % impurities.

$$\eta = \frac{G_o}{G_o + C_{cg}} . 100 \quad (3)$$

where:

η =cleaning efficiency, %

G_o = weight of pure grain at the outlet, kg

C_{cg} = weight of foreign materials in pure grains, kg

$$S_c = \frac{Q_l}{Q_t} \quad (4)$$

Where:

S_c = percentage of scatter loss, %

Q_l = quantity of grains scattered around the machine, kg

Q_t = summation of grains trapped within the machine and those scattered around, kg

3. Results and Discussions

3.1 *Effect Feed Rate on Machine Performance*

The effect of feed rate on cleaning efficiency of the machine in cleaning sorghum and millet is expressed in Figures 3. The regression analysis shows a polynomial relationship of feed rate with cleaning efficiency for millet and a high negative linear correlation of feed rate with cleaning efficiency for sorghum. The coefficient of determination for the effect feed rate on the cleaning efficiency for sorghum and millet is 0.9182 and 0.7174, respectively. Simonyan *et al.* (2006), Salwa *et al.* (2010), Muhammed *et al.* (2013) and Afolabi (2015) have reported similar trends of decreasing cleaning efficiency with increasing feed rates. The effect of decreasing cleaning efficiency with increasing feed rates may be attributed to the increasing load intensity on the sieve and multiple particles acting as obstructions to the air flow. As the feed rate is increased the material flowing across the air current forms a thicker blanket making it increasingly more difficult for air current to penetrate and flush out the unwanted materials.

The effect of feed rate on grain scatter loss is expressed in Figure 4. The regression analysis showed a positive linear correlation between feed rate and scatter loss for sorghum and a polynomial relationship for millet. Grain scatter loss increased with corresponding increase in feed rate. Muhammad *et al.* (2013) reported a polynomial relationship between scatter loss and feed rate for sorghum and millet grains. The coefficients of determination for the relationship is 0.9996 and 0.9566 for sorghum and millet, respectively. The increase in grain scattering with feed rate could be explained due to the fact that as the feed rate increase gradually, the material that flow across the air current allows air to flush out some of the grains alongside the unwanted material. Figure 5 express the effect of feed rate on output (throughput) capacity of the machine. The output capacity for both grains increased with increase in the feed rate.

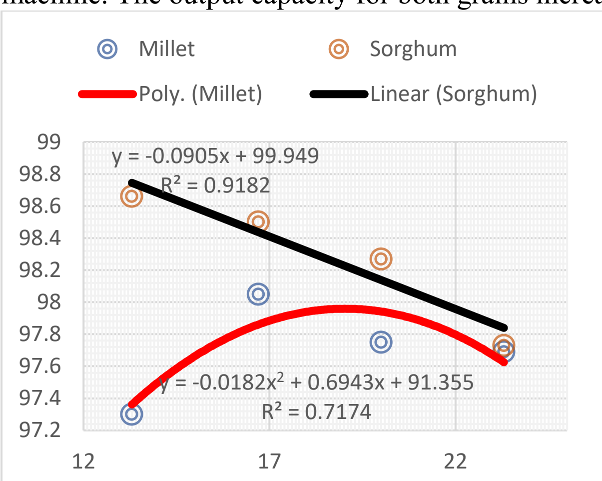

Figure 3. Effect of feed rates (kg/min) on cleaning efficiency (%) of the machine

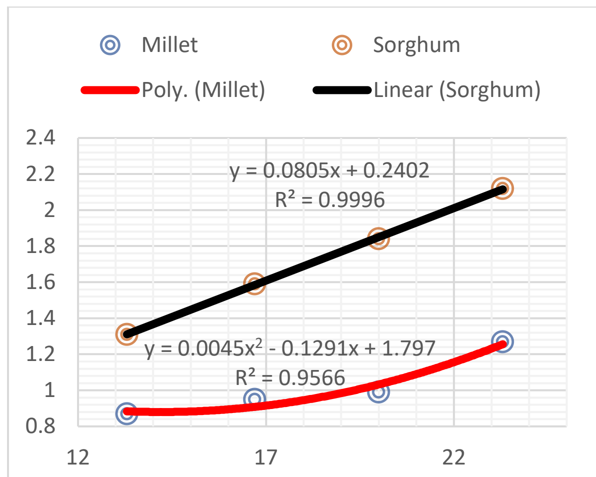

Figure 4. feed rates (kg/min) on scatter losses (%)

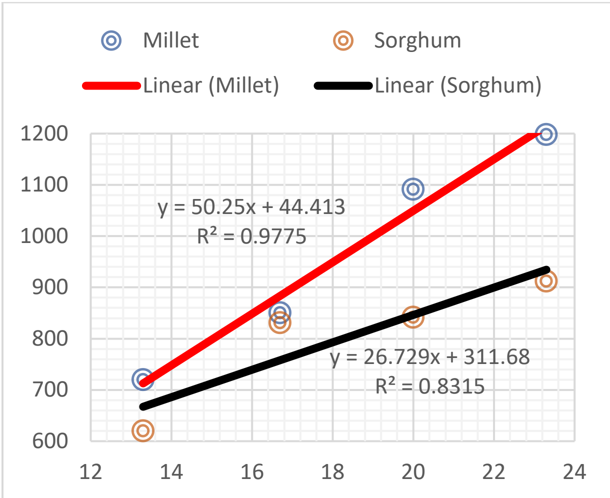

Figure 5. Effect of feed rates (kg/min) on output capacity (throughput) (kg/hr)

3.2 *Effect of Air Speed on Machine Performance*

The effect of air speed on the cleaning efficiency of the machine is expressed in Figure 6. The regression analysis shows a polynomial relationship between air speed and cleaning efficiency for both grains. The cleaning efficiency increased from the air speed of 2.5m/s to a peak value at 4.5m/s and decreases afterward. The coefficient of determination for the relationship is 0.9347 for sorghum and 0.6984 for millet. Simonyan *et al.* (2006) reported a decrease cleaning efficiency with increase in air speed for sorghum. These phenomena may be attributed to the reduction in the resident time of flight of materials to be cleaned within the air stream. When the resident time is longer, it positively affects the efficiency of separation, as there is greater likelihood for lighter particles being displaced in the air stream (Simonyan *et al.,* 2006).

The effect of air speed on scatter loss for millet and sorghum is expressed in Figure 7. Grain scatter loss shows a positive linear correlation with air speed, for both grains. More grain losses were recorded as the air speed progressively increase from 2.5, 4.6, 6.0 to 8,0m/s. The behaviour may be attributed to a state where the increasing air speed overcomes the terminal velocity of the grains and some particles get then blown off together with the chaff. Mohammad *et al.* (2013) reported a polynomial relationship between fan speed and grain scatter loss for both sorghum and millet. They reported that the grain scatter loss for both grains increased with further decrease or increase in fan speed.

The effect of air speed on output (throughput) capacity is shown in Figure 8. The output capacity of the two grains increases with increase in air speed. 0.9963 and 0.7939 are the coefficients of determination for millet and sorghum, respectively, as machine output increased with increase in air speed. Increasing the feed rate increases the effect of the blanket formed across the air stream and a substantial quantity of the grains is collected at the outlet. A reduction in the air strength that would initiate the separation process may cause more grains roll over the sieve, to be collected together with the chaff. An increase in the load intensity across the air stream causes turbulence while a decrease lowers the free stream turbulence intensity which causes the drag coefficient to decrease.

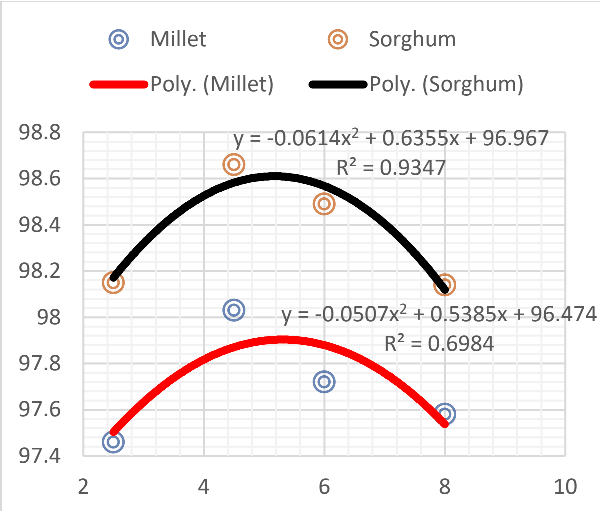

Figure 6. Effect of air speed (m/s) on cleaning efficiency (%) of the machine

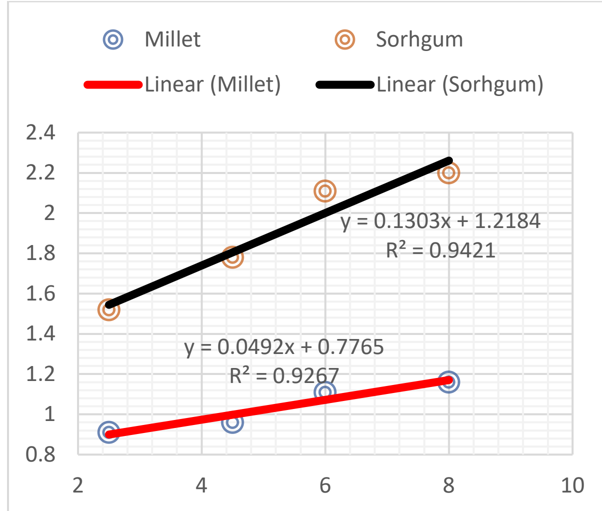

Figure 7. Effect of air speed (m/s) on scatter loss (%)

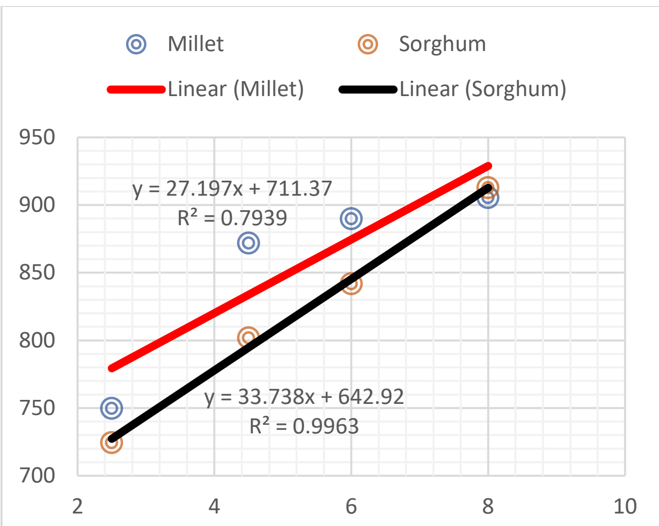

Figure 8. Effect of Air speed (m/s) on output capacity (Kg/hr) of machine

3.3 Effect of Crank Amplitude on Machine Performance

The effect of crank amplitude on the cleaning efficiency of the machine for the millet and sorghum is expressed in Figure 9. Both grains exhibited a polynomial relationship with regards to the effect of crank amplitude on cleaning efficiency. The percentage cleaning efficiency for the two grains increases or decreases with further increase in the crank amplitude. The transport of particles along an oscillating sieve is a function of the oscillation frequency. Increasing agitation is to allow more materials to pass through the sieve holes. It affects the frequency of the process and affects the metering of particulate substances along the sieve. These trend of increase or decrease in the cleaning efficiency with further increase in sieve oscillation may be due to less resident time of the materials to be separated on the sieve. The increasing load intensity of materials may also be the reason for the decrease in cleaning efficiency. The results obtained for the effect of crank amplitude on cleaning efficiency are similar to the findings of Salwa *et al.* (2010), who reported that the cleaning efficiency obtained in cleaning fennel seed increased from 15 to 20 mm amplitude and later decreased from 20 to 30 mm amplitude.

The effects of crank amplitude on grain scatter loss is expressed in Figure 10. The regression analysis showed a high positive correlation of crank amplitude with grain scatter loss for sorghum and millet. Scatter loss for both millet and sorghum increases with increase in crank amplitude. The coefficient of determination for sorghum and millet are 0.8596 and 0.9735, respectively. Simonyan *et al.* (2006) reported that frequency of oscillation has a greater effect the passage of particles through the sieves.

The relationship between the crank amplitude and output capacity of the machine in cleaning millet and sorghum is represented in Figure 11. The relationship followed a polynomial pattern for both grains. The output increases with increase in crank amplitude to a peak amplitude and decreases afterward. The coefficient of determination (R^2) for the two grains is 1.

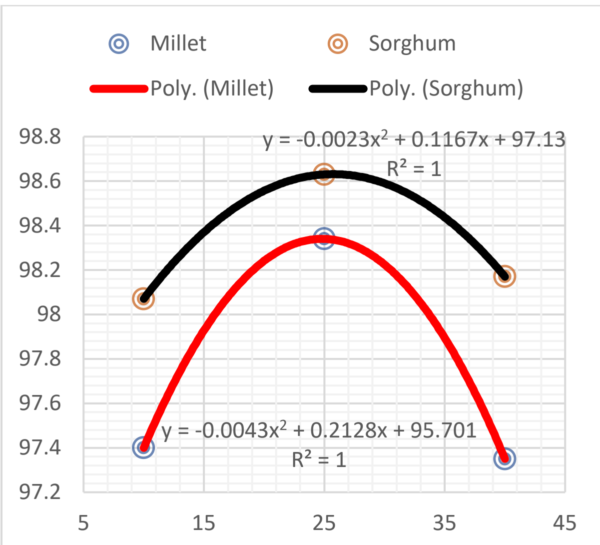

Figure 9. Effect of crank amplitude (mm) on cleaning efficiency (%)

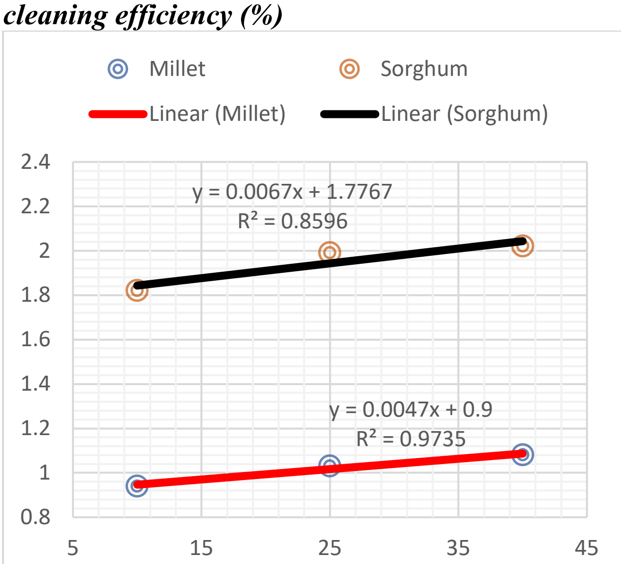

Figure 10. Effect of crank amplitude (mm) on grain scatter losses (%)

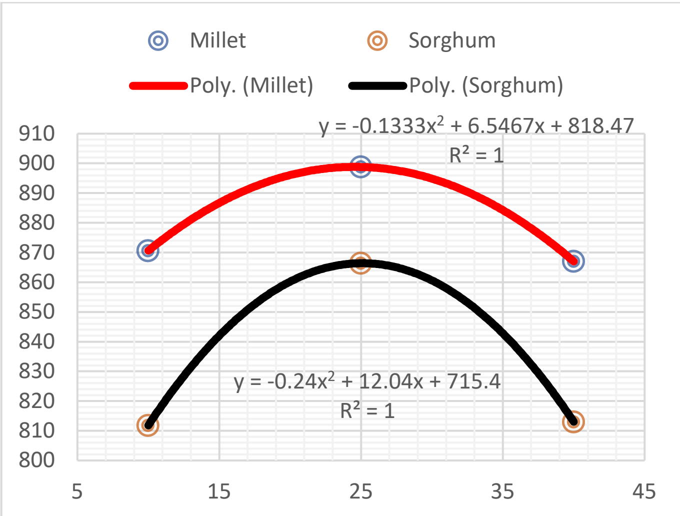

Figure 11. Effect of crank amplitude (mm) on output of machine (Kg/hr)

4. Conclusion

A multi-crop cleaning machine was developed based detailed design and it was found to be very efficient in the separation process of grains from the associated foreign matter. Samples of sorghum (SAMSORG 43) and millet (Ex BORNO) at moisture levels suitable for storage were sourced locally and used as the test crops. The machine was tested and the output capacity ranged between 620.83 to 1088.5 kg/hr and 620.50 to 1097.83 kg/hr for sorghum and millet, respectively, while 98.04 to 98.66 % and 97.30 to 98.05 % are the respective ranges for cleaning efficiency of sorghum and millet. The scatter loss was obtained within ranges of 0.83 - 1.27 % and 1.31 - 2.12 % for millet and sorghum, respectively. Cleaning efficiency of 98.05% at 0.89% grain loss was obtained as the best in cleaning millet, while the corresponding value for sorghum is 98.64% at 1.59%. The optimum cleaning efficiencies were obtained at air speed of 4.5m/s, crank amplitude of 25mm, and feed rates of 1400kg/hr and 1200kg/hr for sorghum and millet, respectively.

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APPROPRIATE ENGINEERING AND TECHNOLOGY: A SIMULATING TRANSFORMER FOR SOCIO-ECONOMIC DEVELOPMENT AND POST-HARVEST LOSSES REDUCTION IN THE AGRICULTURAL VALUE CHAINS

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Abstract

This study examines the appropriate engineering and technology as a stimulating factor in enhancing socio-economic development and post-harvest losses reduction in Agricultural value chains in Nigeria. The issues and challenges bedeviling the appropriate engineering and technology were reviewed vis-à-vis socio-economic development; and minimizing post-harvest losses in agricultural value chains for optimal outputs. The paper went further to x-ray issues affecting the Agricultural sector and its post-harvest outputs. Consequently, the paper suggested the 3-I cyclic model as a suitable method of modernizing Nigeria engineering and technology vis-à-vis Agricultural post-harvest outputs and socio-economic development.

Keywords: Agricultural value chains, appropriate engineering and technology, outputs, post-harvest losses, simulating transformer

1.0 Introduction

Engineering and technology are considered to be the key factors for simulating national development (Akpojedje, et al. 2017). According to Onipede (2010) who opined that engineering and technological development are generally regarded as catalyst for national development because they offer among other things the necessary support for change in all the major sectors of the economy, most especially in agricultural and industrial sectors. Before the modern age, every region or part of the country has a peculiar and informal way of proffering solution to their peculiar problems both in production of goods & services and development of tools for agriculture, building construction, ammunitions, etc. which is term local or indigenous engineering and technology or skills. Thus, indigenous engineering and technology are localized techniques or skills practiced by the people of a locality to proffer solution to their peculiar indigenous problems (Akpojedje and Agbeboaye, 2020). The need to transform this existing indigenous engineering and technology into appropriate (suitable) engineering and technology for a better productivity of goods and services (Akpojedje and Mormah, 2017) is of a paramount importance because appropriate engineering and technology are unarguably the prime source of change, that is, of innovations and improvement of production methods needed to propel growths and development of any nation's economy (Onipede, 2010). "The use of appropriate indigenous engineering and technologically based economy are viable alternatives to transform key sectors of the economy for wealth creation and development in the third world countries. Developing key components, resourceful and skillful manpower that can add value to the engineering and technological development cannot be overemphasized" (Adeolu, et al., 2015) in any nation's economic building and sustainability. Hence, the concept of appropriate indigenous engineering and technological inventions if prudently exploited will minimize waste, poverty and maximize values in critical sectors (Adeolu, et al., 2015) of the economy especially in the agricultural value chains for the African socio-economic drive and sustainability. Consequently, the need to critically review term appropriate engineering and technology as a stimulating transformer for socio-economic development and post-harvest losses reduction in the agricultural value chains.

2.0 Definition of Terms

a. **Engineering:** is the application of mathematics and scientific, economic, social and practical knowledge in order to invent, innovate, design, build, maintain, research and improve structures, machines, tools, systems, components, materials, processes and organizations (The Free Encyclopedia, 2020). Engineering is the field or discipline, practice, profession and art that relates to the development, acquisition and application of technical, scientific and mathematical knowledge about the understanding, design, development, invention, innovation and use of materials, machines, structures, systems and processes for specific purpose (UNESCO REPORT, 2016). A scientist that is involved in the art of engineering (building or repairing engine, machines, tools, roads, bridges) is known as an Engineer. There exist linkage between a country's indigenous engineering capacity and its economic development (UNESCO REPORT, 2016). Consequently, we can say that engineering is the application of scientific knowledge in order to meet the various needs of man. Essentially, the engineering profession is indispensable in the socio-economic and political transformation of any nation. Therefore, "the engineering profession does not only play a major role in the growth and development of a nation's economy but also improving standard of living of its people (UNESCO REPORT, 2016).

b. **Technology:** Abdulkareem (2013) defined technology as the "art and science of applying man's knowledge in human endeavours so as to satisfy man's needs. Technology development and management are considered to be the key driving force in the development of any economy (Park, et al., 2011). The International Technology Education Association (2002) defined technology as the "use of knowledge, skills and resources to meet people's needs and wants by developing practical solutions to problems, taking social and environmental factors into consideration. The economic growth of both developed and developing countries depend on it (Park, et al., 2011). According to Akpojedje, et al. (2017) "the concept of technology as a stimulating transformer for national development is jaded if not considered as a critical factor or element to be tackled by stakeholders in any nation. In addition, technology is defined as the "systematic knowledge and action usually of industrial process but applicable to any recurrent activity (Ibeanu and Okonkwo, 2014). "In complementing this, they went further that "technology is a scientific knowledge aimed at satisfying the basic man's needs. In their submission, they classified technology into three broad categories" (Ibeanu and Okonkwo, 2014):
   i. The human-embodied technology such as skills, knowledge and experience;
   ii. The capital-embodied technology such as machines, equipment and tools, and
   iii. The disembodied technology, which includes blue-prints, products and products specification.

Technology can be accepted as putting human knowledge, acquired skills, experiences, philosophy and resources to meet people's or communities' needs and wants (Akpojedje and Abu, 2016).

c. **Appropriate:** is the suitability of a thing at a giving conditions, place and time. Also, it is right, apt, proper, correct, apposite, suitable and applicable of a thing in an optimal manner.
d. **Socio-economic:** is defined as the social sciences that study how economic activity affect and is shaped by social process. In other words, it is refers broadly to the use of economics in the study of society (Eatwell, et al., 1987).
e. **Trades:** is a basic economic concept that involves the exchange of goods and services for financial gain from the seller to buyer. It can also be defined as a bilateral economy between producers and consumers.
f. **Industries:** is a section or sector that create methods and applied the same for the production of goods or related services in the economy.
g. **Agricultural Value Chains:** it encapsulates the flow of agricultural products, knowledge and information between smallholder of farms and consumers. In other words, it involves adding value at each stage of the production, marketing and consumption process of agricultural produce. Additionally, an agricultural value chain is defined as the people and activities that bring a basic agricultural product such as cassava or cotton from obtaining inputs and production in the field to the consumer, through stages such as processing, packaging, and distribution.
h. **Post-Harvest Losses:** is defined as agricultural output(s) that loose economic value after harvest. In other words, agricultural product(s) that are damaged after harvest and cannot be sold for a reasonable profit margin. In other words, Postharvest loss can be defined as the degradation in both quantity and quality of a food production from harvest to consumption.
i. **Indigenous Engineering and Technology:** the term indigenous basically refers to native or home-grown; while technology is the art and science of applying knowledge to meet human needs (Okorafor, 2014).

Therefore, indigenous engineering and technology is defined as the localized techniques or skills practiced by the people of a locality to proffer solution to their peculiar indigenous problems.

3.0 Contemporary State of Indigenous Engineering and Technology in Nigeria

In spite of Nigeria and her counterpart African countries being blessed with abundant human and material resources, its populace continues to face series of developmental challenges. One of the dominant challenges is the poor state of its indigenous engineering and technology. Africa contributes only 2% of the total industrial output of the world's market economies (Okorafor, 2014). In Nigeria, this is essentially a reflection of the poor level of technology in terms of the obsolete nature of tools used in most of its farming, mining and other productive activities. It is regrettable that despite the number of research institutions (universities, polytechnics, etc.) in the country, it still heavily depends on imported machines, spare parts, and other technical needs. A nation is technologically backward and in bad shape if (Ake, 1985):

i. It is unable to produce her own military hardware with which to defend herself, if the need arise;
ii. It depends on other countries for the supply of spare parts for industrial machineries;
iii. It is unable to explore and export her natural resources except with the help of expatriates (foreigners);
iv. It cannot produce capital goods such as tractors, lathe machines, milling machines, drillings, cars, trains and other earth moving equipment; and
v. It exports her raw materials to other nations as against finished product.

According to Akpojedje, et al. (2016) Nigeria at present is a consuming nation and not a producing nation. It has been turned to a dumping ground where all manner of engineering and technological production are being dumped for usage. Ever since the existence of the country, it heavily relies on foreign technological inputs to drive its economy. The country still depends on the machines and some consumables that are manufactured in the developed and industrialized nations. The dependent on foreign engineering and technology was much felt in Nigeria at the beginning of the Corona Virus 2019 (COVID-19) pandemic, when it was still regarded as an epidemic in China by the World Health Organization (W.H.O) there was a distortion in the supply of finished commodities from China. Consequently, the prices of most capital goods (mostly machines and its spare parts) went up in Nigeria. Besides, when the COVID-19 was declared a pandemic by the W.H.O it resulted to a stoppage in the supply of machines, spare parts and other consumables from the industrialized nations; mostly China to Nigeria. This was accentuated in the COVID-19 pandemic where drugs, surgical face mask, medical ventilator among others were inadequate in the country because there was a halt in their production in the developed nations. The state of indigenous engineering and technology has become worrisome as are being undertaken by the Chinese engineering and technology. Consequently, the Nigerian technology and economy survival are still subject to foreign dictates. "There is no shortcut to maturity and in my view, Africa should be recolonized because Africans are still under slavery" (Trump, 2016). In totality, all these make Nigeria to still be facing a debacle syndrome of "technological colonization."

4.0 Current State of African Trades and Industries

The current state of African trades and industrial involvement is very weak presently. It is on record that Africa contributes only 2% of total industrial outputs of the world's market economies (Okorafor, 2014). This scenario played out vividly when this global pandemic called Corona Virus 2019 (COVID-2019) that is confronting the entire world health security today. The chains of production of goods and services were halted and manufacturing industries shutdown. This led to shortage of vital goods and services especially pharmaceutical equipment and materials. Consequently, the weakness of African trades and industrial involvement in the continent was openly displayed, especially Nigeria as a country, trades and industries involvement was badly halted. COVID-19 has impacted China's global trade for several months now; since China is Africa's biggest trading partner, the effects of COVID-19 are already being felt in Africa, especially Nigeria. With China having shut down its manufacturing centre and closed its ports, there has been a resultant decrease in demand for African commodities.

During COVID-19 pandemic, production and manufacturing all over the world were being shutdown in different parts of the world where and when the pandemic it was at its peak. Thus, breaking the chain or link in the supply of manufactured goods mostly from the developed world to that of the developing world, like Africa. There was also a break in the supply of raw materials from the developing world to the developed world. Before the COVID-19 Pandemic, the Nigerian economy like that of other Africa economy is structurally weak and unstable, as Nigeria runs a mono-cultural economy based mainly on proceeds realized from the production and sales of crude petroleum oil (Esokpunwu, 2018). Its economy in most cases is mono-cultural and depends on the export of primary products and commodities whose prices are subject to the vagaries of market forces in the international market (Aliu, 2010). In this situation, the nation has no economic insurance in a situation where there is often incessant drastic fall in the price of crude oil in the international market. For example, in the current 2020 national budget that was already signed into law later faced series of amendment due to the prices of crude oil and the quality of crude oil production (barrel) per day. It is most unfortunate that where every country is taking advantage of contemporary world of globalization, Nigeria is still faced with the paucity of capital, infrastructure, technology and technical know-how that are essential to its socio-economic and infrastructural development as regards its populace.

The Nigerian trades and industrial doldrums began with the Organization of Petroleum Exporting Countries (OPEC) crisis of the early 1970's, the Iranian revolution of 1979 and the Iraq-Iran war that began in 1980 as well as other global circumstances that have brought about the "oil boom" at different times in the nation's history. All these led to significant changes in the world oil market as the price of crude oil sky-rocketed. With this, various successive regime in Nigeria began to concentrate on the export of crude oil as its major source of foreign exchange of earning, abandoning agriculture that was hitherto the main stay of its economy. Thus, making the nation to be a mono-economy. The mono-economy nature of the economy has resulted to a lot of structural weakness and challenges which the country is passing through at present as a dependent economy. One of the major fall-out of the mono-economy status of Nigeria multi-various dependency. According to the dependency theory, "the dependence of less developed countries (LDCs) on developed countries (DCs) is the main cause for the underdevelopment of the former (Jhingan, 2005). According to Ake (1985) dependency is grossly responsible for the inability for Nigeria and other third world nations to diversify their economies. Despite the large sum made in the different "oil boom," the various administration failed to manage the enormous wealth brought by it. Rather than invest in the productive sector and technological advancement of indigenous engineering and technology, they were involved in profligate spending on stupendous salary and allowance for political public office holders and unnecessary importation. The government began to think of what the country can import and consume to the negligence of what it can produce locally for export and domestic consumption. These brought in the re-occurring syndrome of high cost of governance in the nation's polity. At present in the country, the different state governors have the sum being given to them as security votes and such money are used at the governors' discretions without being accounted for. This has often led to poor infrastructure, poor legitimacy and poor governance. The overall effect of the oil boom was therefore to discourage expansion of productive capacity and underdevelopment of indigenous engineering & technology (Osaghae, 2002).

Essentially, the country did not make concrete effort to boost or improve the socioeconomic life of its people. Many of its economic policies were merely cosmetics (Abah and Osezua, 2008).

The economic dependency and mono-economy have made the government to put less interest in the agricultural and mining sectors. The mining sector is no longer given much interest to the extent that most mining site of solid mineral resources have been taken over by illegal mining activities. It has even taken a worrisome dimension where some top politicians conspire with some foreigners to engage in this illegal mining. Primary products (mineral resources and agricultural produce) including crude oil are exported from Nigeria to the developed world; mostly China and are exported from the developed countries as finished products. The prices of finished products are high compared to primary commodities that are very low in the international market. Such relationship created due to economic dependency and mono-cultural economy create more industries and employment for the developed economy, while unemployment is deepened for the Nigerian economy. All these produce a dangerous equation that reproduces Nigeria old relationship with colonial powers with a renewed neo-colonialism. It becomes a case of who plays the piper, dictates the tune. For example, China endless growing demand for Nigeria natural resources (primary commodities or raw materials) is to consolidate its own version of industrial revolution. It is noteworthy that the bulk of Africa's export to China are raw materials (Femi, 2010).

Basically, despite inadequacy in the manufacturing sector, the few ones available are faced with the adverse challenge of fluctuation of exchange rate and power cut. This is true because this sector in the country is highly dependent on the importation of factor inputs and capital good from the industrialized countries. Thus, depending on the external sector for the import of non-labour inputs. This was obviously manifested in the COVID-19 pandemic, where the manufacturing sector in the country was negatively affected as a result of the break in the supply of non-labour factor inputs from the industrialized world. Nigeria obtains majority of its non-labour inputs such as machines and their spare parts, chemical raw materials as well as power that is got indirectly. All has led to the weakening of the formal sector over the informal sector in the economy. Thus, due to the COVID-19 pandemic that obstructed the importation of non-labour factor (capital input) from the industrialized countries, there became an increase in the prices of finished commodities in the Nigerian market. Besides, there are other numerous problems in the country such as shortage in surgical face mask, medical equipment and other finished commodities that are produced externally but are marketed in Nigeria. India for example stopped the marketing and supply of its manufactured drugs to other countries, where Nigeria was badly affected. It is sad that in this twenty first century, Nigeria is used as a dumping ground for obsolete technology of the West and undesirable machines from the East. This further reduces the impetus for the formal sector to grow and developed in relation to the informal sector. The inability of the formal sector to provide employment for rapidly growing labour force has led to the existence and growth of a large informal (refuge) sector (Iyoha, 2004).

5.0 Factors Affecting African Trades and Industrial Transformation

The global pandemic has further deepened the openness of the weakness of African trades and industrialization. The COVID-19 pandemic has halted mass production and supply chains disrupted due to closures of borders in various part of the world. This has cause global ripple effects across all socio-economic sectors in a rare "twin supply – demand shock." Especially, the Africa continent has begun to feel the full impact of the 'partial' and 'total' lockdown because of the contemporary structurally weak trades and industrialization.

The Africa as a continent must quickly evaluate and review the factors militating against the African trades and industrial transformation because African trades heavily dependent on exportation of natural resources and any reduction in demand, the negative impacts on socio-economic of the most of the continent is high. Nigeria as the giant of the Africa is not exempted from the structurally weak socio-economic system where primary materials are export and finished goods are imported like her counterpart in the Africa continent. Therefore, the Africa continent handlers must constantly review and assessing the factors that are inhibiting the African trades and industrial transformation if the socio-economic development the people are yearning for will be attain soon. The following are some of the factors affecting trades and industrial transformation in the Africa continent:

a. **Inadequate Domestic Investment:** one of the major factors inhibiting Africa trades and industrial transformation is inadequate domestic investment that will drive rapid economic growth which will translate to investment approach compared to some developed countries like China. Africa continent is consumption-intensive oriented far more than commodity oriented. According to Akpojedje, et al. (2017). Nigeria at present is a consuming nation and not a producing nation like her counterpart in the Africa continent. On the contrary, China had maintained very high level of domestic investment averaging 39.8% between 1984 and 2010 against just 20.5% for African countries during the same period (Anyanwu, 2014). This low domestic investment in the Africa continent has impacted the continent trades and industrial transformation negatively which the handlers/managers must quickly and urgently look into if the fortune of the Africa continent must change in respect to trades and industrialization.

b. Inadequate of Structural Transformation of Trades and Industrialization: the structural transformation of African trades and industrialization is inadequate as compared to developed countries such as China. The major key factor fueling China's growth is trade. Chinese export finished and hi-tech products to both developed and developing countries while they import primary and raw materials in which they turn into finished product by adding value, which increase the cost price when imported back to the Africa continent. It is observed that African countries' exports are highly concentrated and less diversified, unlike the developed countries such as China, with many relying on a narrow band of primary materials such as oil and mineral resources as a major export. According to Anyanwu (2014) opined that China's trade openness ratio averaged 43% between 1984 and 2010 against 73% (dominated by imports of consumer goods) for African countries. Also, Lin (2011) narrated that continuous stagnation of export upgrading in African is surprising as Sub-Sahara Africa's share of world manufacturing production and exports had declined over the past three decades from 0.4% and 0.3% in 1980 to 0.3% and 0.2% in 2008 respectively. Nigeria case is worsen off because mono-cultural economy been practiced has structurally weakened the trades and industrialization of the country.

c. **Lack of Adaptation of Technological Advancement:** the heavily reliance of the Africa continent on foreign hi-tech finished products imported to various Africa countries has made the continent handlers/managers to jettison the development of the indigenous engineering and technology.
One of the efficient method of developing and changing indigenous technology is to adopt the foreign hi-tech and mix it with indigenous technology to form suitable or appropriate technology that will drive the economy of the continent. According to Akpojedje and Abu (2016) "the concept of indigenous engineering and technology transformation in Nigeria and her counterpart nation in Sub-Saharan Africa is inevitable, if the fortune of the region must change for its nations' economy building, development and its sustainability. The transformation of indigenous engineering and technology through adaptation of the foreign hi-technology is the way to go but the Africa continent is a consuming continent except few countries like South Africa, the handlers have not encourage the adaptation of the foreign hi-technology that would have develop our local technology. Countries like China developed their local technology through adaptation of foreign hi-technology from America, UK, etc.

d. **Limited Technological Progress:** technological changes are regarded as the most important factor in the process of economic growth (Aliu, 2010). There are five (5) factors that are present in the growth of technology in modern economic growth: a scientific discovery or an addition to technical knowledge, an invention, an innovation, an improvement and the spread of invention usually accompanied by improvements (Kuznets, 1995). However, the economic dependency and the mono-cultural nature of the economy has instilled limitation on technological uplift that ought to be a veritable factor in the process of economic growth that would have transform trades and industrialization of the Africa continent, especially Nigeria as a country. Crude oil and other primary products are exported to the industrialized countries, where technologies are abound and are imported back to Nigeria as finished commodities. Hence, this limits the technological growth and changes in the methods of production and further be a clog in the wheel of new techniques of research or innovation in production method. Nigeria as a country lack information concerning the availability of appropriate technologies. And this has led to the exploitation of the country due to its weak bargaining power. This is even compounded by the presence of Multi-National Companies (MNCs) that have led to the economic and political distortion in the country. For example, the technologies being transferred to Nigeria by the MNCs do not give the right to the country to use, change or transfer according to the nation's discretion or requirements. When the COVID-19 pandemic was predominantly present in the industrialized world, there was a break in the chain of supply of manufactured goods imported into the country accentuated some of the effects of the nation's economic dependency which were numerous. There were shortages of surgical face mask and some essential medical equipment, prices of spare parts of vehicles/machines and drugs went up as well as that of other imported consumables. Essentially, manufacturing in the economy is highly characterized by high average cost of production, high labour output and capital-output ratio as well as deficiency of capital equipment. Insufficient capital limits the process of eradicating the old techniques and the installation of modern techniques.

e. **Foreign Trade Orientation:** the mono-economy of the Nigeria economy is reflected in the export of primary products and importation of consumer goods and machinery (Akpojedje and Ighodaro, 2019). All these are possible because the government major source of revenue is the export of crude oil where the foreign exchange derived from it is used for the importation of consumer goods and machinery. The concentration on the export of primary commodities has led to the neglect of the other sectors of the economy. Consequently, the economy becomes particularly susceptible to volatility and fluctuations of prices of export commodities in the international market. For example, the Nigeria national budget for the year 2020 that had already being signed into law was rejiggered by the Federal Government as a result of the drastic fall in the price of crude oil in the international market. The problem of over dependent on foreign technologies constitutes a serious threat and set-back to the development of local technology

(Manabete and Umar, 2014). Besides, foreign trade orientation also has a ripple effect in the Nigerian economy with the use of Multi-National Corporations (MNCs) from the developed countries where they spread all over Nigeria as a developing economy. The MNCs, also known as foreign companies are involved in manufacturing, export oriented plantations, petroleum and mining sectors in the country to maximize their gains at the expense of the Nigerian economy.

f. **Slow Growth Rate of Agricultural Sector:** there is slow growth rate in the sector because the government sees the export of crude oil as its main source of foreign exchange and revenue. Earnings from crude oil and gas accounted for 93.8% of Nigeria total export for the year 2019. The growth rate of the agricultural sector is at a low pace despite the abundant arable soil, weather, and human resources in the country. Consequently, there is limited export of primary commodities, insufficient output of food items and raw materials that may be required by the few available manufacturing industries. The mono-economy nature of the country has made the agricultural sector to contribute negligible foreign exchange and earnings to the Nigerian economy and its government. Agricultural labour force and raw materials for agro-based industries, stimulate domestic demand for industrial goods, increased savings and tax revenue to be utilized for further development; earn more foreign exchange to finance imports of capital, intermediate goods and raw materials for industrialization (Ake, 1985). However, in Nigeria, more people are engaged in agriculture for subsistence purpose rather than for commercial, industrial and other sectors of the economy.

g. **Foreign Capital Orientation:** Nigerian economy highly depend on the developed economies for foreign capital (in the form of semi-manufacture or industrial goods) as factor inputs that are used to convert primary goods into finished goods. Besides, the primary goods that are exported from Nigeria to the industrialized economies at very low prices are given added value as finished products and imported back to the country at high prices. Consequently, foreign investors often dictate the pricing and supply of equipment, core technical know-how, personnel and the choice of projects in the country. For instance, in terms of oil exploration, China National Offshore Oil Company (CNOOC) and Sinopec, feature prominently (Okorafor, 2014). Essentially, the Chinese state-owned enterprises are the main instruments the Chinese government deploys to concretize agreements earlier entered into with African government in the energy and mining sectors (Femi, 2010). Thereby weakening the trades and industrial transformation of the Africa continent.

6.0 Post-Harvest Losses in Agricultural Value Chains

A value chain is simply a useful way of understanding how the world is producing, buying and selling produce, while post-harvest losses (PHL) is the reduction of the economic value of agricultural produce due to damage of the product after harvest. Therefore, post-harvest losses in agricultural value chains are the reduction of the economic value of agricultural produce between the farmer (producer) and the buyer (consumer). The annual agricultural value chains losses have been estimated around 1.3 billion tones around the world (FAO, 2011). The concept of agricultural losses is defined differently in different region. For developed countries, agricultural losses arise at the consumer stage and the concerns agricultural produce which is processed and ready to eat while in developing countries like Nigeria, agricultural produce losses occur at the post-harvest stages, during marketing and processing (FAO, 2015). This is as a result of limited engineering and technology advancement in the country. Post-harvest losses magnitude varies along the entire value chain depending on the produce and the region the losses occur.

Post-harvest losses in produce destined for the domestic market are comparably greater than in produce destined for export market (FAO, 2015). This marked difference, is primarily due to post-harvest practices implemented by market (FAO and APO, 2005). Therefore, "losses occur in the local market as a result of inappropriate of post-harvest handling and due to market surplus, particularly during peak seasons. Due to poor postharvest handling practices, in both domestic and export supply chains, farmer suffered from quantitative and qualitative postharvest losses (FAO, 2015). For example, the losses in cassava during harvesting, processing and marketing stages is presented in Figure 1.

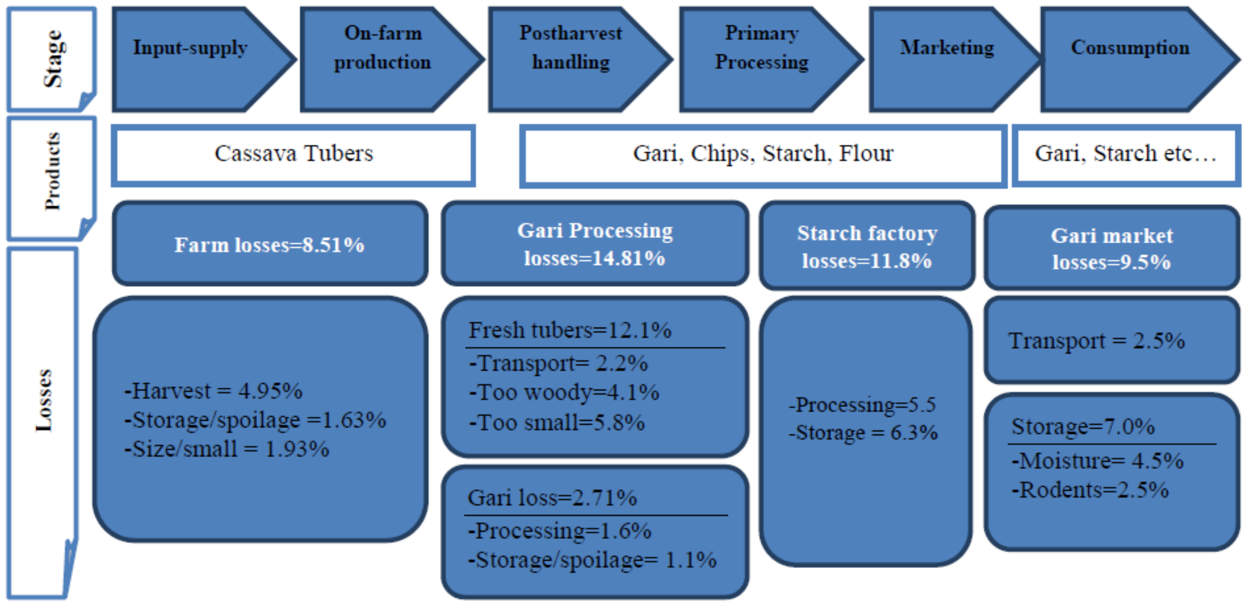

Figure 1: Post-harvest Losses in Cassava Value Chain (Oguntade, 2013).

According to Food and Agricultural Organization of the United Nations [FAO] (2015) provided a survey's information collected from farmers (200), markers (30) and processors (55) of cassava in Nigeria and the postharvest losses in the value chains is depicted in Figure 1, while Table 1 showed the postharvest horticultural losses along a commercial tomato supply chain in Fiji. The causes and impact of poor post-harvest handling and losses were highlighted as follows:

a. poor postharvest handling
b. poor packing and packaging
c. poor education and postharvest research and development (R&D)
d. poor infrastructures and connectivity
e. poor cold chain, transport and climate control
f. poor storage facilities
g. poor marketing information and pricing
h. poor processing capacity
i. poor investment capacity and credit access
j. poor quality standards and control
k. unsustainable food supply and value chains
l. decrease in produce's shelf-life
m. poor quality produce

Table 1: Postharvest Horticultural Losses along a Commercial Tomato Supply Chain in Fiji (FAO, 2015)

	ocation	rocess	osses%	escription

Time				
Day1 to Day4	Farm	Ripening	8.8%	Due to rots during ripening
Day 5	Farm pack-house	Packaging in plastic boxes	9%	Failed to ripen at the time of packing
Day 5	Transport	Transporting	0.13%	Distance 121.19km/ transported in truck
ay 6	Market	Selling	6.4%	Thrown away by vendor due to over ripe or rots
Total losses from (farm to vendor)			**32.93 %**	
POST MARKET LOSSES/WASTAGE				
ay 7	Market		8.26 %	In inappropriate storage facilities and if case of not consume in 3days (72 hours)
ay 8	**larket**		6.19 %	
ay 9	**larket**		13.4 %	
Total postharvest losses			**60.78%**	

7.0 Factors Affecting Post-Harvest Outputs in Agricultural Value Chains

Postharvest losses vary greatly among commodities and production areas and seasons (FAO, 2015). In the postharvest agricultural chains various factors affect the quality of the produce in the entire agricultural value chains. These factors can be classified into the following:

7.1 *Internal Factors*

The internal factors are factors that affect the postharvest produce from the moment of harvesting, handling, storage, processing and marketing. Therefore, the internal factors are:

i. **Harvesting:** the major factor that affect the agricultural outputs are the inability of establishing maturity index of the commodities or lack of maturity index for local export market.
ii. **Pre – Cooling:** the "loss at this stage is due to high cost and lack of availability of pre – cooling facilities, inadequate human capacity on pre-cooling technology at the commercial scale level (FAO, 2015).
iii. **Transportation:** the primary challenge at the transportation stage of the value chains include poor infrastructure such as roads, bridge, mobility, etc., and lack of appropriate transport systems. The transportation system in most developing countries is extremely poor and inadequate to convey the agricultural produce. Also, the roads network is totally disrupted and disjointed along the agricultural value chains.
iv. **Storage:** the storage facilities if is not properly manage with advance technology, pest and diseases can attack agricultural produce stored in the storage facilities. Storage facilities and technology, hygiene, and proper monitoring if not adhere to adequately, long-term storage may be a waste
v. **Grading:** proper packing and advance packaging technologies are critical in order to reduce mechanical injury to the agricultural produce in the value chains during the movement of the produce from the farmer (producer) to buyer (consumer).
vi. **Packaging and Labelling:** the process of packaging and labelling the agricultural produce, if adequate and advance technologies are not employed, it may cause damage to the packaging which injure the agricultural product been packaged.
vii. **Secondary Processing:** the major cause of postharvest losses at this stage is inadequate availability of appropriate varieties of processing techniques, lack of appropriate processing technologies and lack of basic infrastructure to carry out proper processing of agricultural produce especially in the developing countries like Nigeria.
viii. **Biological Degradation:** biological processes cause deterioration in the agricultural produce in the postharvest stages, it includes respiration rate, ethylene production and action, rates of compositional changes, mechanical injuries, water stress, sprouting and rooting, physiological disorders, and pathological breakdown. The factors that enhance biological degradation are: humidity, temperature, etc.

7.2 *External Factors*

1. The factors that affect agricultural produce during postharvest outside the value chains can cause great postharvest losses. Therefore, these factors can be further group into: i. Environmental factors and ii. Socioeconomic factors.

7.2.1 Environmental Factors

The climatic conditions affect the quality and quantity of harvest in agricultural sector, such as:

i. **Temperature:** generally, the higher the temperature the shorter the storage life of horticultural commodities which translate to greater amount of losses within a given period of time.
ii. **Humidity:** the movement of water vapour between stored agricultural produce and its surrounding atmosphere can cause damage, the most agricultural produce will give up moisture to the air, while the dry ones will absorb moisture from the atmosphere. This increase the biological degradation of the agricultural produce, thereby increasing the amount of losses in the commodities.
iii. **Time:** the longer the period in which agricultural commodities are stored, the greater is the deterioration in quality and the greater is the chances of damage to the commodities stored and also, greater losses incurred.

7.2.2 Socio-economic Factors

The social trend such as urbanization has driven more people from rural area to urban area, which is resulting in a higher demand for agricultural commodities at the urban area. Hence, the need to move the agricultural produce from the rural to the urban centre which cause increase in postharvest losses along the supply chains.

8.0 Appropriate Engineering and Technology as a Stimulating Transformer

The importance of appropriate engineering and technology (AET) to national development and socioeconomic well-being cannot be overemphasize for nation's growth (Akpojedje, et al., 2017). Hence, it is important to say here that engineering and technology are the stimulating transformer for socio-economic development (Akpojedje, et al., 2017).

According to Akpojedje and Abu (2016), "Engineering and Technology" is the major key player for transformation of any nation development. The fusion of the relevant indigenous and foreign technologies is what is popularly referred to as "appropriate technology" (Essien, 2011). Hence, we can say the fusion of relevant indigenous and foreign engineering and technology is what is called "Appropriate Engineering and Technology". According to Essien (2011), "appropriate engineering and technology" stresses the socio-cultural and environmental importance of both indigenous and foreign technologies. Consequently, "appropriate engineering and technology is the application of engineering and technology at the simplest level that can effectively achieve the intended purpose in a given locality or nation" (Akpojedje, et al., 2017). The development of any nation's economy is always linked with the application of appropriate engineering and technology (Akpojedje, et al., 2017).

"Appropriate engineering and technology development" can be generally regarded as a catalyst for nation's economic and national development, because it offers among other things the necessary support for change in all the major sectors of the economy, most especially in agricultural and industrial sectors (Onipede, 2010). Therefore "Appropriate Engineering and Technology Development" is unarguably the prime source of change; that is, of innovations and adaptations required for improving production methods needed to propel growth and development (Onipede, 2010) in the agricultural value chains that will in turn reduce post-harvest losses in developing countries like Nigeria. This will transform the economic sector of the country. It is a well-known fact that technological advancement divorced from it cultural context, is destined to grow without a soul (Essien, 2011). Then, we can say, "Appropriate Engineering and Technology Development" divorced from it cultural context, is destined to advance without soul and spirit. And any living body without a soul and spirit is dead alive. In fact, the best appropriate engineering and technology is the combination of indigenous and imported (foreign) engineering and technology knowledge to build human capacity for progressive (Akpojedje, et al., 2017) economic growth and sustainability.

"There is an apparent dearth of engineering and technology entrepreneurship and capital in Africa especially Nigeria; a situation that has led to the near non-existent of productive capacity of the continent, with very minimal potentials for value addition" (Adeolu, et al., 2015). "The result of the foregoing scenario is low capacity building for wealth creation and increasing level of unemployment; since knowledge and innovation are the two key drivers for sustaining economic growth in the 21st century" (Adeolu, et al., 2015). Then, African countries should be keyed into harnessing its strong indigenous engineering and technologies fused with foreign technologies to form appropriate engineering and technology for foundational ecosystem to industrialize relevant sectors and research with a strong focus on commercialization, and to extend the ecosystem to facilitate innovation and enterprise (Adeolu, et al., 2015) for nations' economic growth and sustainability.

9.0 Present State of Appropriate Engineering and Technology in Nigeria

The present state of engineering and technology in Nigeria is regrettable because over decades of existence of Nigeria as a country, she still largely depends on foreign or imported machines, goods and technological needs. In the midst of numerous and abundance of natural resources and human capital, Nigeria still wallows in a state of quagmire in engineering and technological sector as seen today. It is bothersome and worrisome that Nigeria as a giant of Africa as they say; cannot produce its required goods and services through indigenous engineering and technology; all machineries and equipment used today are imported. There is no modus of operandi to come up with a model in Nigeria that will mix the cultural context with foreign hi-tech to form appropriate technology that will transform into meaningful economic development and sustainability. As it is today, all manner of technologies are been dumped in Africa, Nigeria is not an exception without proper harnessing them for economic transformation that will lead to wealth creation and development of the nation. According to Akpojedje et al. (2017). "Nigeria as at today is a consuming nation and not a producing nation. Nigeria has been turned to a dumping site where all manner of engineering and technological productions are been dumped for usage."

Appropriate engineering and technology is a veritable tool because it harnesses the transformation of natural resources (endowment) into goods and services that will cause economic revolution both in the industrial and agricultural sectors. There is no gain saying that over decades of existence of Africa nations they still largely depend on foreign technological service to sustain their technological needs that will drive the continent economy. The present state of appropriate engineering and technology in Nigeria is regrettable because over decades of existence of Nigeria as nation, she still largely depend on foreign (borrowed) or imported machines, goods and technological needs (Akpojedje, et al., 2017). "Technologically wise, Nigeria as acountry, can be said to be technological backward and in bad shape (Akpojedje and Abu, 2016). "Consequently, we can say as at today, despite the enormous availability of natural resources and indigenous knowledge, the appropriate engineering and technological development in Nigeria particularly is grossly low and inadequate in terms of her technological development, advancement and productivity (Akpojedje and Abu, 2016).

10. Enhancing Appropriate Engineering and Technology in Nigeria Through 3-I Cyclic Model

The stimulation of indigenous engineering and technology through appropriate engineering and technological transformation and support is made up of primary and secondary sections in this paper. The primary section considers the role of government (stakeholders) in supporting the transformation of indigenous engineering and technology to meet local needs as well as global standards for sustainable economic growth in Nigeria. Conversely, the secondary section adopts the technological imitation, improvement and innovation (3-I model) pattern strategy of local engineering and technological development and transformation proposed by Park *et al*. (2011).

10.1 *Role Of Government (Handlers/Managers) in Supporting the Transformation of Indigenous Engineering And Technology*

In order to transform the nation's indigenous engineering and technology, and social infrastructure through appropriate engineering and technological development to meet global standards, the Nigerian government should put the following into consideration:

(a) Technical oriented policy: There should be an urgent need by the Nigerian government to always promulgate social, economic policies that are technically oriented. Besides the government, other stakeholders should make policies that are technologically drive and abstain from any form of policy that will retrogress technological development.

(b) Giving more attention to technical education*:* The government and stakeholders should prioritise technical education in the country. This can be complemented by updating and stocking of the technical laboratories with better and more advance tools and equipment to work with; while the use of obsolete ones should be discouraged

(c) Adequate funding of research and development: The government should adequately fund and encourage a bilateral relationship between industries and technical institutions in the country.

(d) Commercialization of research and development: There should not be a disconnection between the results obtained through research and development (R & D) in institutions and industries. In addition, any relevant output from R & D should be practically put into use by industries in order to encourage novelty and discovering in the country's technological development and advancement.

(e) Strengthening capacity building: It is important for the Nigerian government to strengthen the capacity building of science and technology in the country; as well as the basic technical skills, which are also a prerequisite for future development.

10.2 *Adoption of the Technological Imitation, Improvement and Innovation (3-I) Model of Development and Transformation*

The secondary section of the technological transformation is the adoption of foreign (imported)_technology through the 3-I model of technological advancement strategy; as such 3-I model is the best option for many developing countries like Nigeria to start the spiral process of technological advancement (Park *et al.*, 2011). Nigeria can emulate countries like China, Japan, Korea and other contemporary developed countries, which adopts the 3-I model of technological advancement strategy in order to have the same result. Nevertheless, the government is an indispensable entity in the 3-I model of technological development as shown in Figure 1.

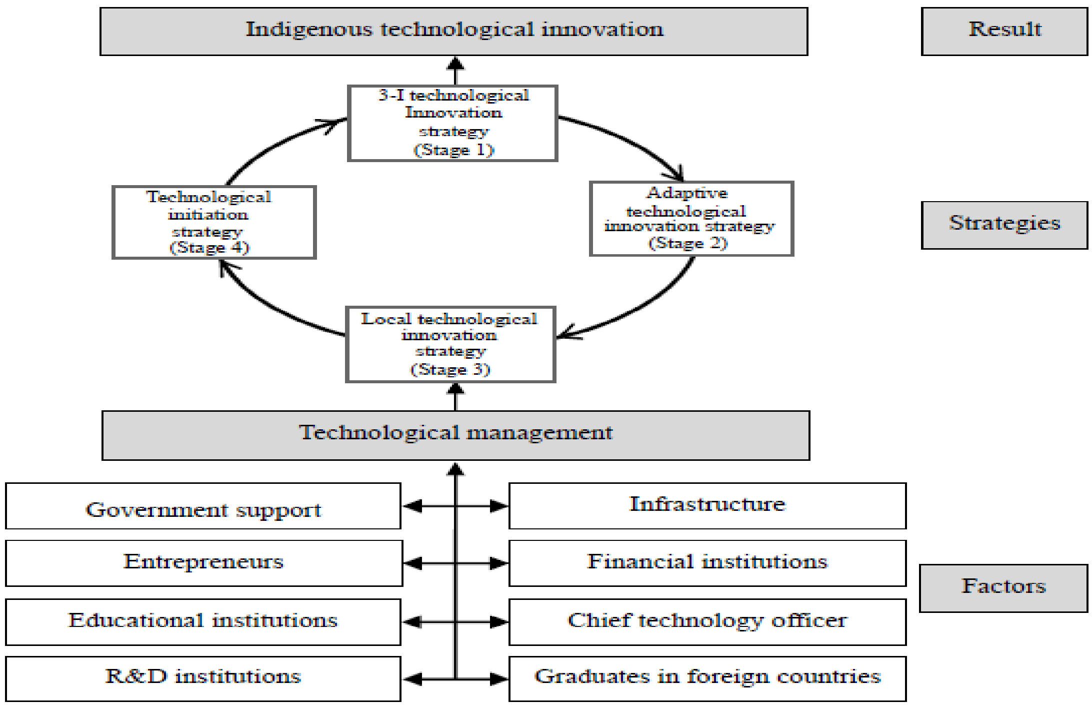

Figure 1. Building Model of Indigenous Technology Development (Park et al., 2011).

Indigenous engineering and technological innovations can be commercialized successfully as entrepreneurs that will benefit the users, which will lead to the prosperity of the society as shown in the cyclic model for indigenous technological advancement in Figure 2.

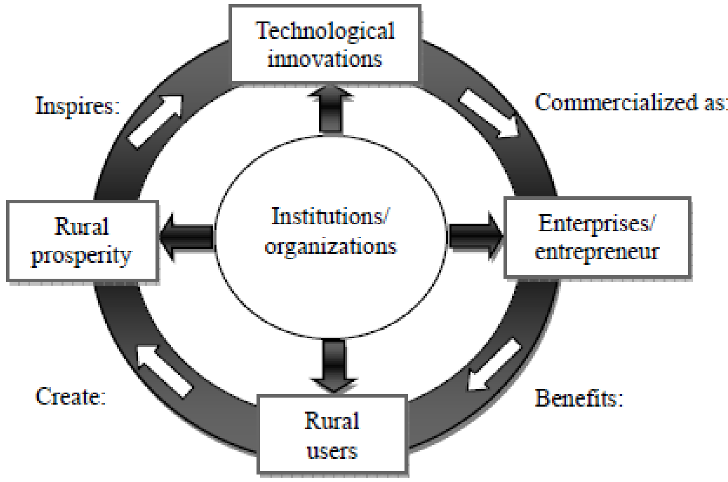

Figure 2. Cyclic Model for Indigenous Technological Advancement (Park et al., 2011).

A deep look and examination of Figure 2 shows an in-depth bilateral relationship between industries and research institutions in Nigeria. This will lead to inspirations of indigenous technological innovation as entrepreneur/enterprise that will assist rural users and generate affluence, thereby developing the indigenous content of the country. Nigeria can become industrialized like her counterpart in the technological advanced countries if the models proposed in this paper are adequately implemented.

11. Conclusions

In this paper we have provided a comprehensive study of impact of the appropriate engineering and technology as a panacea to post-harvest losses (PHL) reduction in the agricultural value chains. Engineering and technology are key factor for economic and agricultural sector transformation if religiously adapted and implemented as outlined in this research work. In true terms, "Appropriate Engineering and Technology Development" is unarguably the prime source of change; that is, of innovations and adaptations required for improving agricultural production and methods needed to propel growth and development in the agricultural value chains (Onipede, 2010). So, Appropriate Engineering and Technology Development" divorced of it cultural context, is destined to advance without a soul and spirit; and any living body without a soul and spirit is dead alive (Akpojedje and Mormah, 2017).

12. Recommendations

Nigeria at present is facing a looming compounded and severe economy challenge amidst the COVID-19 pandemic. Its long mono-economy has been a bane to the socio-economic development of the country. The revolution of its indigenous engineering and technology to appropriate engineering and technology can take it out of the contemporary looming socio-economic quagmire. Hence, the following are recommended to be adopted firmly by the government and the country's handlers to revolutionize its agricultural value chains that will minimize post-harvest losses which will in turn increase market value:

i. **Improvement on Farm Post-harvest Practices:** the country's handlers should improve on the indigenous engineering and technology that will in turn enhance post-harvest products and packaging practices, sorting, storages, infrastructural development and help producers in value adding activities.
ii. **Strengthen Research and Development Institutions:** the country's managers should strengthen research and development institutions especially agricultural sector. Appropriate research and recommendations for agricultural inputs that will increase quality produce should be encourage in the country. Researches that improve farmers' friendly maturity indices and suitable harvest tools/methods should be focused on. Also, establishes good grading, sorting and packaging protocols for various commodities in the agricultural value chains. Arrived researches that will enhance temperature usage, humidity and environmental factors for multiple agricultural products in post-harvest storages should be welcome and commercialized adequately.

iii. **Improve Access to Information and Capacity Building**: information that will encourage capacity building should be accessible to farmers and also, working directly with farmers, traders and other agricultural value chains' stakeholders to accept and promote improved post-harvest practices/methods. The agricultural sector's handlers should encourage simple agro-processing methods in the interior villages and establish regional post-harvest management. Additionally, post-harvest losses reduction information networking and systems should be put in place through appropriate engineering and technology.

iv. **Technical Oriented Policy Formulation for Post-harvest Losses Reduction:** the agricultural sector's handlers/managers should formulate technically oriented policies that will support the development and adaptation of appropriate post-harvest management technologies and its enhancement. This suitable engineering and technological policies when implemented, it will monitor post-harvest management standard such as: safety, maturity, grading and sorting in the domestic and export market. Strong synergy among producers, government's agencies, researchers and donor agencies for establishing priority projects and also, increase public campaigns awareness on how to reduce post-harvest losses in the agricultural value chains should be done. These technological oriented policies are economical when its approach is used for socio-economic and political transformation of the society for optimal human and food security.

v. **Increase of Investment on Infrastructural Development:** the government and stakeholders in the country should build more collection centers in the rural areas of the country near production places and equipped it with good sorting techniques, grading, packaging, sanitation system and storage facilities. Also, link every collection centers with good roads for easy transportation of produce to market. More processing factories with modern technologies and enhance the existing ones with suitable processing technology, packaging, good sanitation system, food safety and quality standard practices.

vi. **Commercialization of Research and Development of Institutions:** the results of R & D should not be left to rot away on the shelves of institutions. But the government should ensure that it encourage adequate R & D in various tertiary institutions and ensure that a tight relationship is created between them and industries. For example, giving out incentives and scholarship.

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DURABILITY OF CUBED HARD AND SOFT FERMENTED LOCUST BEANS SEED (PARKIA BIGLOBOSA) CONDIMENTS

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Abstract

Plant proteins is one of the cheap safe sources of proteins for human consumption. Locust beans are the mature seeds that come from the parkia pods. The pods are harvested and processed into the fermented product. It makes a concentrated food with high protein content (40%), high vitamin, moderate fat content (35%), carbohydrate and macronutrients such as potassium, sodium, magnesium, calcium, nitrogen, and phosphorus. There are two popular forms of the condiment in Nigeria, namely: 'Iru Woro' (Hard fermented) and 'Iru Pete' (Soft fermented). The need for alternative method of preservation other than refrigeration and salting brought about the idea of drying before converting into condiments using edible starch (cassava and corn) as binding agents. 400 g of the ground dried locust beans was mixed with 80g of the binding agent and diced in a 3 x 3 cm cubing machine; the products were dried in an electric utility dryer for 10-12 hours and final moisture contents were recorded. The products were then subjected to durability test using a tumbling apparatus. Cubes made from Iru Woro with cassava starch had the highest average durability index of 99.91 % and lowest average friability of 0.09 % at final moisture content of 9.34 w.b while for corn starch, it had an average durability index of 99.56 % and friability of 0.44 % at moisture content of 11.58 % w.b. Cubes from Iru Pete with cassava starch had an average durability index of 99.77 % and 0.23 % friability at moisture content of 11.24 % w.b. while the average durability index for corn starch was 99.81 % and 0.19 % average friability at final moisture content of 9.80 % w.b. This implies that the cubes from both binder type can withstand destructive loads during handling, transportation, and storage.

Keywords: Binding agents, Condiments, Durability, Locust beans and Product varieties.

1. Introduction

An improved human nutrition through affordable balanced diet would enhance healthy living. Plant proteins is one of the cheap safe sources of proteins for human consumption; African locust bean (*Parkia biglobosa*) is a tree legume that belongs to the family *Mimosoideae,* it is commonly found in Tropical Africa and the Mediterranean and not usually cultivated but grows abundantly in grass land. It is produced in large quantity in Nigeria (Odunfa, 1982). The locust beans are the mature seeds that come from the *parkia* pods. The pods are harvested and processed into the fermented product (Figure 1) known as: '*Iru*', *'Dawa dawa'* and '*Ogiri'* in the Yoruba, Hausa and Igbo Languages respectively; more than 100 million people in West Africa use *'iru'* as food stuff (Sadiku, 2010; Odunfa, 1982).

Figure 1. Locust beans

Locust beans make a concentrated food with high protein content (40%), high vitamin, moderate fat content (35%), carbohydrate and macronutrients such as potassium, sodium, magnesium, calcium, nitrogen and phosphorus (Klanjcar *et al*., 2002). Lysine makes up about 7 percent of the protein, a level similar to that in whole egg, one of the gold standards of proteinaceous foods. The fat is of the unsaturated kind, the major fatty acid being linoleic—a nutritionally useful ingredient often deficient in the diets of the poor (NRC, 2006).

There are two popular forms (Figure 2) of the condiment in Nigeria, namely: *'Iru Woro'* (Hard fermented) and *'Iru Pete'* (Soft fermented). Fermentation improves the flavour and digestibility of many foods; increases nutritional values; provides important living enzymes and beneficial microorganisms to our diet. There is a breakdown of certain constituents, reduction of anti-nutritional factors in grains and the synthesis of B-vitamins during fermentation. The physical, chemical and nutritional characteristics of the locust beans seeds improve when fermented (Amoa-Awu *et al*., 2005; Omosebi and Otunola, 2013).

Figure 2. (a) Had fermented (*Woro*) (b) Soft fermented Processed Locust beans (*Pete*)

Drying is a method of food preservation by removing moisture from the food to avoid the growth of bacteria, yeasts, and moulds. This helps in slowing down the action of enzymes. Drying is one of the oldest methods of food preservation; it entails subjecting foods to an atmosphere of low vapour pressure and providing the necessary heat to vaporize moisture in raw foods. Longer shelf-life, product diversity and substantial volume reduction are some justifications for the popularity of dried agricultural products (Olalusi *et al.,* 2019).

The daily demand for this condiment is on the rise because of its nutritive and medicinal benefits. The need for alternative method of preservation other than refrigeration and salting brought about the idea of drying before converting into condiments using edible starch as binding agents.

Effective drying of locust beans would enhance its taste, flavour and increase utilization in soups. It would enhance conversion into cubed form and make the condiment available all year round, improve palatability, appearance, packaging and storage, handling, and usage. Thereby complementing other protein sources like fish, egg and meat in local diets and contribute to its acceptance to the end users. Hence, reduce excessive dependence on chemical base condiments.

This research work evaluates the shelf life of cubed locust beans (*Parkia biglobosa*) condiments for the purpose of handling, transportation, and storage.

2. Materials and Methods

2.1. *Experimental Design*

The Experimental Design for the purpose of this test was conducted using Randomized Complete Block Design (RCBD) with a total number of 432 observations for the stage 1 (2 forms x 3 temperatures x 3 Quantities x 8 hours drying time x 3 replications). For the second stage, 2 varieties x binder x 10 hours minimum drying time x 3 replications x 1 die given a total of 120 replications. However, the effects of the replications were not felt because in the computations for analysis of Variance (ANOVA) mean values were used instead.

2.2. *Experimental Procedure*

2.2.1. Sample Preparation (First Stage)

The locust bean condiments of two forms ere produced by a local processor in Ilorin.
The condiment *Iru Woro,* V_1 and *Iru Pete,* V_2 were weighed into different sizes for categorization and to effectively dry the condiment.
Group 1 = 200 g (Weight of fermented sample)
Group 2 = 300g (Weight of fermented sample)
Group 3 = 400g (Weight of fermented sample)
Also, this was considered to investigate the effect of weight on the drying characteristics of the condiment.

2.2.2. *Preparation of Binding Agent*

The types of binding agent considered in this study were corn starch and cassava starch. 80 g each of the binding agent were weighed and mixed into 50 ml of boiled water at 95 $\pm$ 5 ^{0}C, the mixture was stirred thoroughly until homogenous paste was obtained for each binder type.

2.2.3. *Preparation of Sample for Cubing*

The materials required for this part include; Tachometer to measure the machine speed of the cubing machine, Tumbling Apparatus to determine the durability of the product in cube form, Sensitive Scale to measure the quantity for both binding agent and locust beans, clean water for mixing the binding agent (Cassava Starch and Corn Starch) and cubing machine.
According to the study by Food and Nutrition Department, University of Ilorin (2012), the ratio of the binding agent to the dried milled fermented locust beans seeds is 1:5. The fermented products (dried *Iru Woro* and *Iru Pete*) were then milled into fine particle size.
400 g each of dried and milled *Iru Woro* and *Iru Pete* were weighed respectively into separate bowls and 80 g of cassava starch and corn starch were used as binding agent in each case and for each fermented locust beans. The samples were mixed thoroughly with a stirrer to allow for uniform distribution of the binding agent to produce desired texture. The mixture was converted into cube form using a cubing machine constructed in the Department of Agricultural and Biosystems Engineering, University of Ilorin. The die size 3 cm by 3 cm and speed 350 rpm were used. The strength characteristic of the product was determined by durability index of the product.

2.2.4 *Drying Procedures*

2.2.4.1 *First Stage (Conversion of Wet Fermented Beans into dried form)*

The dryer was pre-heated for 30 minutes in order to establish steady state conditions to the desire temperature of 45 ^{0}C using the temperature controller while the samples were prepared accordingly (*Iru Woro,* V_1 and *Iru Pete,* V_2). Labels were randomly placed on trays with tags of the two treatments, Sw 1- 3 for *Iru Woro,* Sp 1-3 for Iru Pete, Qw1-3 for weight of the *Iru Woro* and Qp1 - 3 for weight of *Iru Pete*. The freshly fermented Locust beans were spread on the trays and inserted into the dryer. Thereafter, the fan was switched on and set to a velocity of 0.5 m/s using the fan regulator. A digital anemometer was used to measure the speed of the fan and immediately after loading, the initial condition of the environment and the drying chamber was determined.

The weight was checked every one hour using an electronic weighing balance throughout the drying period. Temperature of the exhaust air was determined and recorded using a thermocouple with a probe and mercury in-bulb thermometer was used to calibrate the temperature on the different tray. The procedure was repeated at 50 ^{0}C and 55 ^{0}C temperature respectively. Figure 3 shows the arrangement of the locust beans in the dryer.

Figure 3. Arrangement of Locust beans in the Dryer

2.2.4.2. ***Second Stage (Conversion of dried and milled fermented locust beans into cube form)***

The dryer was pre-heated to the desire temperature of 50 ^{0}C using the temperature controller while the samples were prepared accordingly (*Iru Woro* and *Iru Pete)* mixed with binding agent. Trays were labeled with tags of the two treatments, Bw1-2 for *Iru Woro* with binder and Bp1-2 for *Iru Pete* with binder. This was done using die size 3 cm by 3 cm for the cubing. The cubed locust beans samples were randomly arranged on the tray before drying.

Fan was switched on and set to a velocity of 0.5 m/s using the fan regulator and a digital anemometer was used to measure the speed of the fan. The product was dried for storage (Figure 4).

Figure 4. Dried Cubed Locust Beans Seed Condiments: (a) *Iru Woro* (b) *Iru Pete*.

2.3. ***Measurement of Parameters***

2.3.1 ***Drying rate***

This is the calculation that involves in the design and analysis of dryers and also requires the knowledge of the length of time needed to dry a product from initial moisture content m_i to final moisture content m_f and the rate at which drying is taking place.

Weights of samples at regular interval of 1 hour were measured until the desired moisture level was reached in order to monitor the reduction in moisture during the drying process. At interval of 1 hour, the samples were brought out of the dryer for weighing and replaced back after measurement.

The drying rate is calculated using equation by Adejumo (2007) as expressed:

$$R = \left(\frac{dM}{dt}\right) = \frac{m_i - m_f}{t} \qquad (1)$$

Where, R is the drying rate in g/h; dM is the change in mass g; d_t is the change in time h; t is the total time h; m_i is the initial mass of locust beans samples, g and m_f is the final mass of locust beans samples in g.

The drying rate at interval can be calculated in order to monitor the trend in the drying rate as the drying progresses. The relationship below was used.

$$\frac{w_t - w(t + \Delta t)}{\Delta t} \qquad (2)$$

Where, W_t is the weight of fermented locust beans at time W (t + Δt) is the weight of fermented locust beans at time t + Δt is the time interval for sampling.

2.3.2. *Determination of Durability Index*

Durability Index of the cube produced was determined by using a tumbling apparatus (Figure 5) designed and constructed as specified by the ASAE S269.2 rotating at 60 rpm for 120s. Initial weight of a set of 5 cubes placed in the tumbling apparatus was recorded as M_{cbt} and the machine operated through rigorous shaking after which their final weight M_{cat} was recorded. The durability (D_p) and friability (F_p) were calculated using equations by Adejumo, 2007:

$$D_p(\%) = \frac{M_{cat}}{M_{cbt}} \times 100 \qquad (4)$$

$$F_p(\%) = 100 - D_p \qquad (5)$$

Where,

D_p is Durability of cubes in %; F_p is Friability of cubes in %; M_{cat} is weight of cube after tumbling in gram (g) and M_{cbt} is weight of cube before tumbling in gram (g).

Figure 5. Tumbling Apparatus

3. Results and Discussions

3.1. *Effect of Binder Type on the Drying Rates and Drying Time of Fermented and Cubed Locust Beans.*

The average drying time for fermented and cubed locust beans condiments with cassava starch was 10 hours which shows that it dries faster than the one with corn starch of 12 hrs. The drying rates for the two binding agents as related to the different varieties are shown in Table 1. From the table, cubes with cassava starch have mean drying rates of 53.26 g/hr – 69.39 g/hr for *Iru Woro* and 56.00 g/hr – 106.26 g/hr for *Iru Pete* while cubes made with corn starch have 48.88 g/hr – 62.22 g/hr for *Iru Woro* and 36.66 g/hr – 74.08 g/hr for *Iru Pete*.

Table 1. Duncan's New Multiple Range Test for Means of Drying Rates and Drying Temperature on Processed Cubed Fermented Products

Cubes with Cassava Starch

ariety	rying Temperature ^{0}C	rying Rates g/hr
u Woro	5	3.26^b
	)	1.43^a
	5	).39^c
u Pete	5	5.00^a
	)	).05^b
	5	)6.26^c

. Cubes with Corn Starch

ariety	rying Temperature ^{0}C	rying Rates g/hr
u Woro	5	3.88^a
	)	1.69^b
	5	2.22^c
u Pete	5	5.66^a
	)	4.08^c
	5	7.60^b

Values with the same letter are not significantly different at ($P<0.05$)

3.2. *Pellet Durability Index for Locust beans Cube*

Durability is the ability of cubes to withstand destructive loads and forces during transportation. Result of the percentage durability is as shown in Tables 2 and 3. Cubes made from *Iru Woro* with cassava starch had the highest average durability index of 99.91 % and lowest average friability of 0.09 % at final moisture content of 9.34 w.b while for corn starch, it had an average durability index of 99.56 % and friability of 0.44 % at moisture content of 11.58 % w.b.

Cubes made from *Iru Pete w*ith cassava starch had an average durability index of 99.77 % and 0.23 % friability at moisture content of 11.24 % w.b. while the average durability index for corn starch was 99.81 % and 0.19 %

average friability at final moisture content of 9.80 % w.b. This implies that the cubes from both binder type can withstand destructive loads during handling, transportation, and storage.

It is noted that the *Iru Woro* with corn starch and higher moisture content as related to weight has cubes of lower durability index compared with *Iru Pete* combined with corn starch. This is in support of the statement made by Jennifer *et al.,* (2004) that "*Increase in moisture content reduces durability"*. This might be because of weakness in the binding force that occurs as moisture content increases thereby reducing the durability of pellets produced (Adejumo, 2007).

Table 2. Percentage Composition of Durability and Friability From the two Product Varieties Using Cassava Starch.

Iru Woro			*Iru Pete*	
S/N	Durability (%)	Friability (%)	Durability (%)	Friability (%)
1	99.91	0.09	99.77	0.23
2	99.92	0.08	99.77	0.23
3	99.91	0.09	99.75	0.25
Mean	**99.91**	**0.09**	**99.77**	**0.23**

Table 3. Percentage of the Durability and Friability from the two Product Types Using Corn Starch.

Iru Woro			*Iru Pete*	
S/N	Durability (%)	Friability (%)	Durability (%)	Friability (%)
1	99.56	0.44	99.81	0.19
2	99.56	0.44	99.81	0.19
3	99.55	0.45	99.80	0.20
Mean	**99.56**	**0.44**	**99.81**	**0.19**

4. Conclusion

Cassava and corn starch are both suitable to produce durable locust beans seed condiments though moisture content of the final product has a significant role to play in the durability for the purpose of handling, transportation, and storage.

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THIN LAYER DRYING KINETICS OF AFRICAN GIANT SNAIL (*ACHATINA ACHATINA*)

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Abstract

African Giant Snail (Achatina Achatina) is eaten after eviscerating the flesh from the shell and separating the edible part from the other viscera in a dried or semi-dried state, in the coastal area where they are predominately available. Drying is a veritable technology for its storage beyond immediate consumption. This study thus, studied the Thin Layer Drying Kinetics of African Giant Snail (Achatina Achatina). A laboratory convective oven dryer was used as the heating source, on temperature range of 60 – 100℃ applied in a varying manner on multiples of 10℃. The layer thickness was about 0.013-m. The drying profile showed a typical falling rate period with no distinct constant rate period for all the temperature levels used in this work. Moisture loss (diffusion) data obtained from the experiments were fitted to three popular semi-empirical thin-layer models of ANN, Page, Lewis, and Henderson-Pabis, respectively, and their suitability was validated using statistical parameters (of R^2, RMSE and χ^2). This was done to select thin-layer model that would suitably describe the drying kinetics of the samples over the range of temperature levels chosen in this work. Consequently, the ANN and that of Henderson-Pabis respectively were taken to have reliably predicted the drying behaviour of the samples at the chosen temperature levels. The effective diffusivity and the temperature-related activation energy values ranged from 2.191×10^{-10} m^2/min- 8.219×10^{-11}-m^2/min and 22.5kJ/mol, respectively. Drying rates along with characterizing drying constants and curves also showed an exponential increase with temperature.

Keywords: African Giant Snail, thin layer drying kinetics, drying curves, effective diffusivity, activation energy.

1.0 Introduction

African Giant Snail (*Achatina Achatina*) serve as delicacies in tropic areas. In Africa snails serves as relatively cheaper and alternatively to portentous sources see plate 1. Snails' meat is highly proteineous about 80.9% - 89.92% of dry dry basis having low fat and cholesterol (Emelve ey al.,2013; Engmann et al.,2012) and very good to those with health consciousness. The snail meat is characteristically tender and having a pliable or springy texture when chewed, with a sui generis, nice floral-like, mushroom-like flavour when cooked. Snails has it limitation because of it perishability and seasonality (Tetty et al., 1997; Onwubude et al., 1997). Researchers show that snails' meat hardly last a day before deterioration started. Land snails are easily prone to rapid damage due to unprotection to several kids of microbes and contaminants as they creep or crawl on the soil (Onwubuche et al., 2019). In other to reduced this limitation, they are traditionally smoked-dried and sale by table-top traders. Nevertheless, the smoke-dried snails though have good market value locally but does not meet international standard to earn foreign exchange in the country. Snails population are high during the wet season where they are harvested in large amount by the rural communities, they are very cheap, but became scarce and very expensive during the dry season reasons because they are difficult to find (Ahmed and raut 2008; Asibery 1986; Rahman and Raut, 2010; Wilson 2007). Snails suffer great loss and reduction because of biological snail predators and therefore, snail farming is highly encouraged (Appiah et al., 2009; Hadfield 1986).

Many researchers has done works in Giant Africa snail and has focused on the proximate composition of the various species (Ademolu et al, 2004;Fagbuaro et al; 2006).

Locally, in Nigeria Bayelsa State to be precise snail meat are eaten and preserved by eviscerating the flesh from the shell and separating the edible part from the other viscera for further processing, the edible portion is then parboiled incubated with seasonings to individual taste of organleptic properties which is then sold in the market by table-top trader.

Snail feeds on varieties of dead plant materials, decaying organic matters as well as artificial diets. Locally snail hunters used droplets of deteriorated crab as a trap and they are captured while eating on the decomposed crab especially in the night.

Drying does not deplete but would retain required flavour, colour and nutritive value, and also influence physicochemical and quality characteristic of products (Masken et al, 2002). The report of (Doymaz et al., 2002) takes drying as an industrial preservation technique in which moisture content and water activity of bio-materials are reduced by motive heated air. This definition thus, excludes drying methods such as sun-drying and freeze-drying where drying is achieved without a significant presence of convective air. Large scale commercial dry keeping would thus, employ industrial and a better mechanized process of drying. Appropriate technologies designed for such mechanized drying are rife in technical literature. Many mathematical models have however, been used to describe the thin-layer drying process of several of such food products, and these also serves as tools for process control and in drying simulation studies, and for predicting the suitable drying conditions (Doymaz et al., 2002; Vega et al., 2007;Unal and Sacilik, 2011) Therefore, in this work, the drying behaviour of the African Giant Snail (*Achachatina Achatina*) was investigated on thin-layers and the emanating experimental data was fitted to the selected thin-layer drying models to characterize the drying kinetics of the African Giant Snail (*Achachatina Achatina*). This would also create a good data base for improved equipment design of the drying processes.

Plate 1: An African Giant Snail (Achachatina Achatina)

2. Theoretical Framework

Thin-layer drying as applied to high systemic moisture biomaterials is a complicated process with simultaneous heat and mass transfer. Thin layer as a concept refers to a layer of a product that can be described as sufficiently small in thickness whereon air characteristics everywhere in the layer could be considered identically uniform with no observable variations. Then in thin-layer drying it is expected that all individual particles of the material are fully exposed to the drying air. The conditions of thin layer drying are often divided into two periods of drying which are the constant rates and the falling rate periods (Ikrang 2014). In this work, thin-layer drying was done in batches of single beds or layers split to different small but uniform thickness each. It is usual to place or arrange the different splits in vertical series such that hot air in a forced convective stream could be made to pass over them. The hot air stream can then be seen to absorb moisture from the first split through the others, such that the exhaust from one split becoming input air to the subsequent split, and on through the final or terminal split. Passing through a number of thin splits in this manner, it is evident that the moisture pick-up ability of the air stream declines one over the next layer. For the success of such simulation work therefore, the splits (now to be referred to as thin-layers), be made infinitesimally thin and arranged in such a manner that the inlet hot air stream simply exhausts through the layers undiminished in its moisture carrying capacity. Drying would then become achieved in all the splits, each batch characterized by different drying rates at the different temperature levels applied (Zibokere and Egbe 2019). Literature reports show that most drying activities of biomaterials generally omit the constant rate period but do so largely in the falling rate period (Brenan et al., 1969; Toledo, 2000; Earle, 2006). The entire rate period of the drying process is known to be a diffusion (molecular transport) phenomenon through a continuum of interface slits and generally governed by Fick's second law (moisture flux proportional to the moisture gradient) given as (Bird et l., 2005; Suarez et al., 1980).

$$\frac{dM}{dt} = D_e\left(\frac{d^2M}{dr^2}\right) \quad \ldots \quad 1$$

where

M = moisture content at time t, kg_{H_2O}/kg_{solid}
t = drying time, min.
r = radius of an equivalent sphere (distance from the core to the surface), mm
D_e = effective diffusivity, mm^2/min.

The moisture ratio (MR) prevalent in the drying system can be expressed as (Sahey and Singh 2005)

$$MR = \frac{M - M_e}{M_o - M_e} \quad \ldots \quad 2$$

where

M_e = equilibrium moisture content (emc), kg_{H_2O}/kg_{solid}
M_o = initial moisture content, kg_{H_2O}/kg_{solid}

and M is as previously defined

2.1 Estimating Effective Diffusivity, D_e

Effective diffusivity (D_e) is a temperature and moisture content dependent diffusion parameter that describes and drives the moisture transport process in the condition of any diffusion mechanism during drying of any visco-elastic material. Of the three stages in the drying profile namely, the free stage, the constant rate period and the falling rate period, the effectiveness of moisture transport is observable more in the third - the falling rate period during drying (Dincer and Dost, 1995; Touil et al., 2014). The mathematical expression for effective diffusivity, D_e as derived for a material of cylindrical geometry at the falling rate period during drying is (Zibokere and Egbe 2020; Guine et al., 2011; Crank, 1975).

$$MR = \frac{M - M_e}{M_o - M_e} = \frac{6}{\pi^2}\int_{n=1}^{\infty} \frac{1}{(2n-1)^2} e^{-(2n-1)^2\frac{\pi^2 D_e t}{L^2}} \quad \ldots \quad 3$$

for n = number of cylindrical surfaces placed in slits (thin-layers)

Taking

$(2n - 1)^2 = \varepsilon_n$ recognized as the root of a related Bessel function, and for a material of cylindrical geometry,

L = R_c = radius of cylinder,

Then equation 3 will reduce to

$$MR = \frac{M - M_e}{M_o - M_e} = \frac{6}{\pi^2}\int_{n=1}^{\infty} \varepsilon_n{}^{-2} e^{-\varepsilon_n(\frac{\pi^2 D_e t}{R_c{}^2})} \quad \ldots \quad 4$$

Taking only the first term (n = 1) rendering others as negligible, equation 4 would become (Zogzas et al., 1996).

$$MR = \frac{M - M_e}{M_o - M_e} = \frac{6}{\varepsilon_1} e^{-\varepsilon_1(\frac{D_e t}{R_c{}^2})} \quad \ldots \quad 5$$

where

MR = moisture ratio

Taking natural log on both sides, equation 5 will linearize to

$$\ln(MR) = \ln\frac{6}{\varepsilon_1} - \varepsilon_1 D_e(\frac{1}{R_c})^2 t \quad \ldots \quad 6$$

The effective diffusivity, D_e in the drying system can then be obtained from the slope of the plot of ln(MR) versus drying time, t with intercept $\ln\frac{6}{\varepsilon_1}$ (Guine et al., 2011)

$$D_e = \frac{Slope\ of\ plot\ [R_c{}^2]}{\varepsilon_1} \quad \ldots \quad 7$$

And from equation 2, if values of M_e are small in relation to values of M and M_o (assumed to be zero) in (Burubai 2015; Robert et al., 2008), then the equation would reduce to

$$MR = \frac{M}{M_o} \qquad \ldots \qquad 8$$

2,2 *Thin-layer Drying Models*

The use of mathematical models in estimating the behavior of agricultural and other bio-materials during drying is common in technical literature. Several of such thin-layer drying models are listed in Table 1 (the Lewis, the Page and the Henderson-Pabis models respectively) are selected for validation in this work on African Giant Snail (*Achatina Achatina*). From equation 5, taking n = 1 and further simplifying would bring about the thin layer drying equation of

the Lewis model (see Table 1)

$$MR = e^{-kt} \qquad \ldots \qquad 9$$

the Henderson-Pabis model (see Table 1)

$$MR = Ae^{-kt} \qquad \ldots \qquad 10$$

and when n > 1, **the Page model** (see Table 1)

$$MR = e^{-kt^n} \qquad \ldots \qquad 11$$

Equation 9) can further simplify as

$$\ln(MR) = \ln(k) - kt \qquad \ldots \qquad 12$$

or

$$\ln(\frac{M}{M_o}) = \ln(k) - kt \qquad \ldots \qquad 13$$

Wherein k is seen as kinetic (drying) rate constant and a, b, n are model constants.

Then the plot of moisture ratio on natural logarithm axis against drying time of equation 11, the intercept, ln(k) on the moisture ratio axis and slope, - kt, the effective diffusivity, D_e can now be deduced.

Table 1: List of Thin-layer Drying Models with References

S/No.	Title of Model	Model Expression	Reference
1	Lewis	MR = exp(−kt)	‹ingly et al., 2007)
2	Page	MR = exp(−kt^n)	‹age, 1946)
3	Henderson & Pabis	MR = a exp(−kt)	‹ogrul, 2003)

2.3 *Activation Energy, E_a*

This is energy required to initiate the diffusion (the phenomenon of moisture transport) during drying of biological materials. Activation energy, E_a can be estimated from the relationship between Effective diffusivity, D_e and temperature, t which is assumed to be an Arrhenius type function given as (Silva et al., 2015).

$$D_e = D_o(e^{-\frac{E_a}{Rt}}) \qquad \ldots \qquad 14$$

where

E_a = activation energy, kJ/mol
D_e = effective diffusivity at t°K, m^2/s.
D_o = pre-exponential factor of the Arrhenius equation at 0°K, m^2/s.
R = universal gas constant (8.314 x 10^{-3}, kJ/mol.K)
t = air temperature expressed in °K

Simplification of (12) gives

$$\ln D_e = \ln D_o - \frac{E_a}{R}t^{-1} \qquad \ldots \qquad 15$$

or

$$-\frac{E_a}{R}t^{-1} = \ln D_e - \ln D_o \qquad \ldots \qquad 16$$

or

$$\frac{E_a}{Rt} = \ln(\frac{D_o}{D_e}) \quad \ldots \quad 17$$

$$\frac{E_a}{R}t^{-1} = \ln(\frac{D_o}{D_e}) \quad \ldots \quad 18$$

Plotting of $\ln D_e$ as a function of t^{-1} (Fig. 3) will be linear with intercept, $\ln D_o$ and slope, - $\frac{E_a}{R}$; then the activation energy can be estimated as (Navneet et al., 2012)

$$E_a = \text{-ve slope}(R) \quad \ldots \quad 19$$

2.4 ***Obtaining Drying curves***

Drying rates and their control are essential in describing thin-layer drying. Higher drying rates at the different drying temperatures can reduce drying time (Daniel, 2016). However, drying at high temperatures (say above 80 °C) in several drying conditions, could adversely affect the final quality of high body moisture materials (Shi et al., 2008; Chen et al., 2013). The reduction of moisture in the drying process can possibly to relate in say (y) direction in a given split for a given drying temperature to the drying time (t) in a cubic polynomial form as follows (Haydar et al., 2014)

$$y = c_0 + c_1t + c_2t^2 + c_3t^3 + c_4t^4\ldots. \quad \ldots \quad 20$$

Where the c's are constants caring for the intrinsic factors in the drying process. Differentiating equation 20 with respect to time will yield **drying rate** as follows

$$\frac{dy}{dt} = -(c_1 + 2c_2t + 3c_3t^2 + 4c_4t^3 \ldots) \quad \ldots \quad 21$$

The negative sign indicates decay in drying rate with passage of drying time. Considering higher powers of t as negligible, equation 19 can reduce to

$$\text{Drying rate } (\frac{dy}{dt}) = -(c_1 + 2c_2t + 3c_3t^2) \quad \ldots \quad 22$$

Equation 22 is semi-parabolic on a drying rate vs drying time plot, yielding **drying curves** for the different drying temperatures chosen in this work.

3.0 Materials and Method

3.1 ***Sample Preparation***

A large quantity of freshly harvested African Giant Snail (*Achachatina Achatina*) (some 25-kg) was obtained from a local but general market at Ondewari town in Southern Ijaw Local Government Area of Bayelsa state, Nigeria. They were thoroughly washed in fresh water and meat was carefully removed from the shell using sterilize needle and allowed to stabilize in the ambience of the Laboratory. Using a 0.001-cm precision veneer caliper each of the African Giant Snail (Achachatina Achatina) meat to be used in the drying tests was measured of the basic dimensions, stratified into groups of different but equal thickness and length, re-stabilized and stored without any further treatment in refrigerated cabinets in the Food Processing Laboratory, Department of Agricultural and Environmental Engineering of Niger Delta University, Bayelsa State. Identical samples were then drawn from the stratified lot for the drying tests. The samples were then oven dried in a thin-layered form, to a constant final weight using WTC binder oven Model WTCB 1718 at varying temperatures from 60^0C - 100^0C with increments of 10^0C. All weight measurements were done using a laboratory–type top digital balance with 0.01-g precision. The initial and all other moisture content values were taken using the oven method of ASAE standard (ASAE, 2000). The moisture reduction process (i.e. weight loss) for each sample was monitored at specific time intervals (of about 10-min) to point of equilibrium and in a manner as described in the works of (Zibokere and Egbe, 2020) on Spiced Okpokuru *(Oryctes rhinoceros*), and on catfish (Sankat and Mujaffar, 2006). All the drying tests were replicated thrice at each temperature level and average values were recorded. The weight differences before and after drying were used to determine the final moisture content for each replicate, all measured on dry-basis as (Mohsenin, 1986)

$$M = \frac{w_i - w_f}{w_f} \quad \ldots \quad 23$$

where

M = dry basis moisture content, %-db
W_i = initial weight of the specimen, g
W_f = initial weight of the specimen, g.

3.2 Statistics for Goodness of Fit

Thin-layer drying models can normally be evaluated and the quality of fit compared using certain statistical indicators such as coefficient of determination, R^2; the non-parametric reduced chi-square, χ^2, the root mean square error, RMSE and mean bias error MBE. The usual criteria is that an acceptable goodness of fit is said to have occurred in describing the drying curve of a given model if R^2 value is high and the values of other indicators, χ^2, RMSE and MBE are low. In this work, the experimental drying data of the samples obtained at different temperatures were used to fit into the three commonly used thin-layer drying models. The goodness of fit of the selected mathematical models to the experimental data was evaluated using the given criteria (Maydeu etal., 2010; Wang et al., 2006). The statistical parameters used as the indicators were calculated as follows (Ndukwu et al., 2010), (Burubai, 2015)

$$R^2 = 1 - \left[\sum_{i=1}^{n} (MR_{pre,i} - MR_{exp,i})^2\right] \quad \ldots \quad 24$$

$$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (MR_{pre,i} - MR_{exp,i})^2}{n}} \quad \ldots \quad 25$$

$$\chi^2 = \frac{\sum_{i=1}^{n} (MR_{pre,i} - MR_{exp,i})^2}{n - k} \quad \ldots \quad 26$$

$$\text{MBE} = \left[\sum_{i=1}^{n} (MR_{pre,i} - MR_{exp,i})^2\right] \quad \ldots \quad 27$$

where

$MR_{pre.}$ = predicted moisture ratio
$MR_{exp.}$ = experimental moisture ratio
n = number of observations
k is as previously defined.

3.0 Results and Discussion

3.1. Characterizing Drying Kinetics

It was necessary to transform the drying data obtained from the experiments into dimensionless moisture ratios (MR). These MR values were then plotted as a function of drying time for the African Giant Snail (Achachatina Achatina) respectively at the selected temperatures (Fig. 1), while Fig. 2 presents the variations of the moisture ratios given in logarithmic form [ln(MR)] plotted as a function of drying time. This is drawn to enable the estimation of activation energy in the drying system. It is known that activation energy promotes the molecular transport phenomenon (diffusion) that drives the drying process. The moisture ratios are all given in dry basis (db). The plots in the Figures are observed to have followed the general trend of drying curves as reported for many biomaterials. The curves exhibited initial steeper slope, an indication of an initial increased and accelerated moisture loss in drying. This could be due to increased water activity within the samples resulting from a quicker migration of moisture to the surface for evaporation and evacuation, helping to shorten the drying time. The drying process, however, became slower (the curves became flattened) at the later stages, even with increasing temperatures (Fig. 2) as lesser and lesser water become available for evaporation at the surface of the samples.

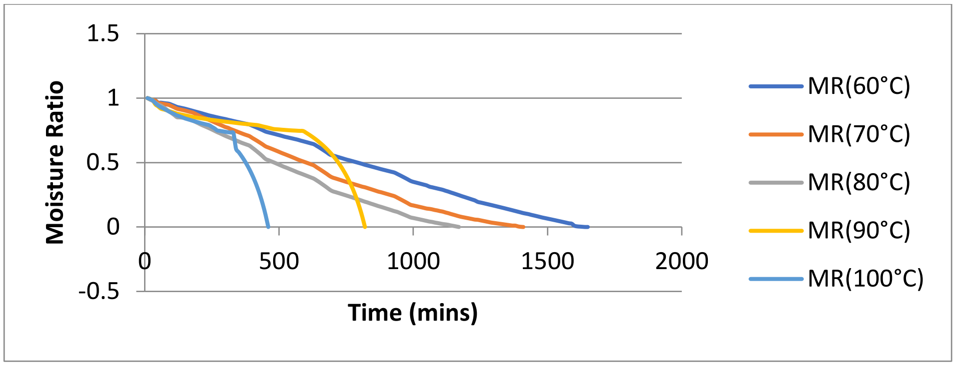

Figure. 1: Moisture ratio versus drying time of African Giant Snail (Achachatina Achatina) at different temperatures

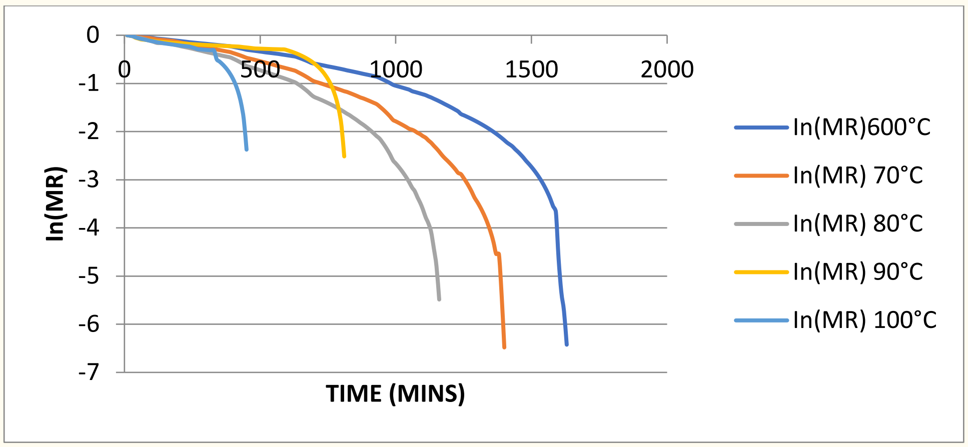

Fig. 2: Drying curves of (Logarithmic moisture ratio vs drying time)

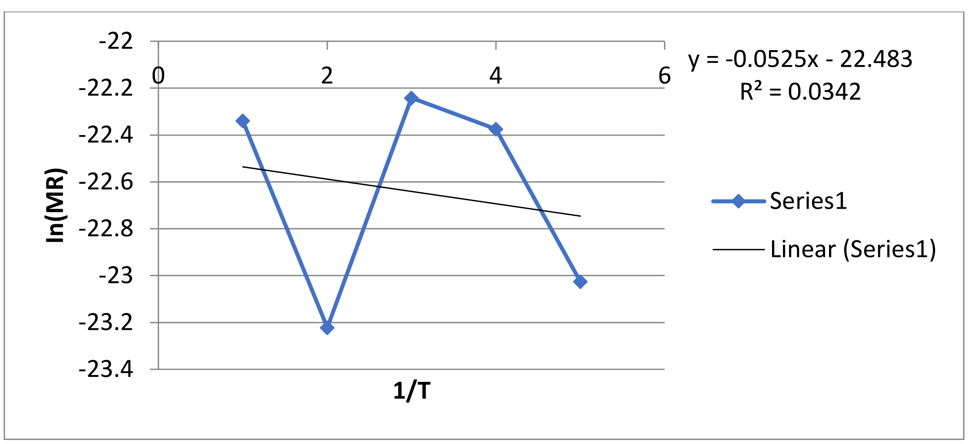

Fig. 3: Estimation of Activation Energy for specimens of African Giant Snail (Achachatina Achatina)

This is rather characteristic of such bio-materials with high constituent moisture mixed with fats/oils and protein which greatly reduce water activity even with increase in drying temperature (Zibokere and Egbe 2019; Davies et al., 2019; Burubai and Bratua, 2015; Jain and Pathare, 2007). The situation is also typical of a falling rate drying period without the feature of case-hardening even on the high temperatures ranges, generally agreeing with reports on thin layer drying works on fresh water clam (Burubai 2015), salted catfish fillets (Sakat and Mujaffar 2006) and fresh fish (Kilic, 2009).

3.2 *Fitting Experimental Data into Thin-Layer Drying Models*

The transformed dimensionless moisture ratios were used to fit to the empirical models of ANN, Lewis, Page, and Henderson and Pabis, respectively, and for all the different drying temperatures chosen in this work. The fitted parameters were subjected to statistical analysis for all the drying conditions (Table 2 and 3). The fitting results in concurrence with the statistical analysis showed that the coefficient of determination, R^2 values were consistently high in the range of 0.8389 – 1.000 for all the models. The indication here is that all the used empirical models could satisfactorily describe the drying behavior of the samples. When tuned further with the other statistical parameters, the model expression of ANN and Henderson- Pabis model followed by that of the Page model had the highest R^2 values and the lowest χ^2 and RMSE values in the temperature range of the work. This showed the suitability of these models in describing the drying kinetics of the samples. It was therefore, satisfactory to selected ANN and Henderson-Pabis model to predict the drying kinetics of the African Giant Snail (Achachatina Achatina) on the drying temperatures applied in this work figure 4 and figure 5.

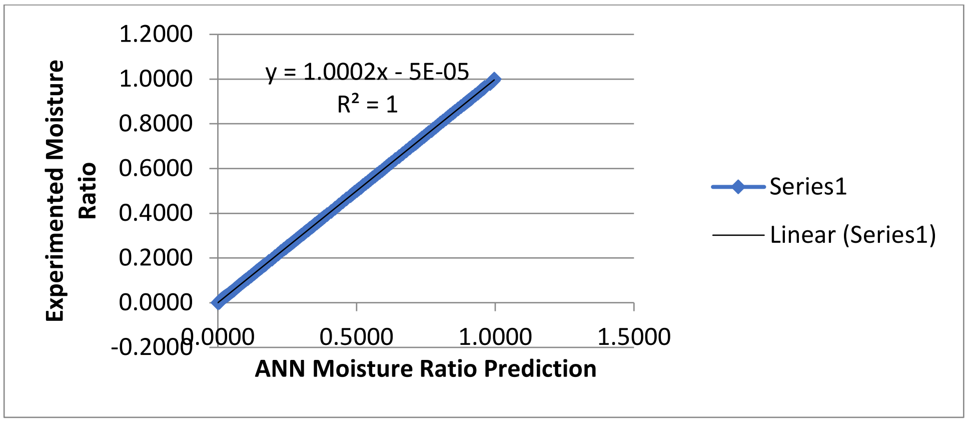

Figure 4. Relationship between Experimented Moisture ratio and ANN Moisture Ratio Prediction at 70°C

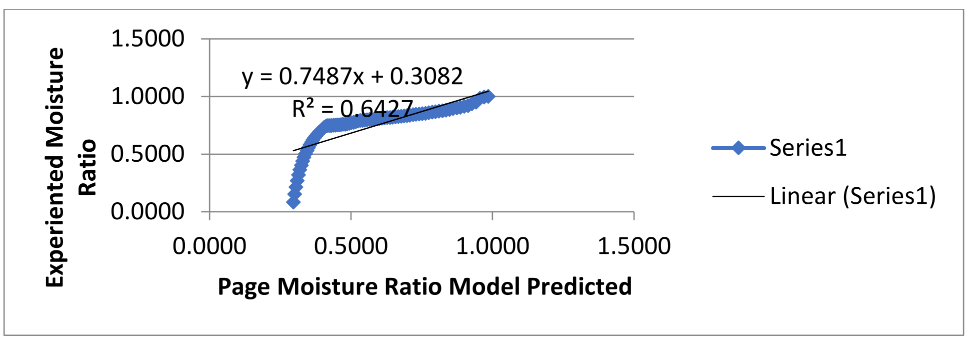

Figure 5. Relationship between Experimented Moisture ratio and Page Model Moisture Ratio Prediction at 70°C

3.3 *Estimation of Effective Moisture Diffusivity and Activation Energy*

Using data obtained from the drying experiments, the logarithmic moisture ratio values, ln(MR) were plotted as a function of drying time, t at the various drying temperatures (Fig. 2). Estimation of the effective moisture diffusivity was then done using the method of slopes, derived from the regression line relating the ln(MR) values and the varying drying times, validated with the corresponding coefficients of determination, R^2 (at 1.000). It is clear from Fig. 2 that effective moisture diffusivity, D_e increased fairly greatly as drying temperatures increased. This is expected because, though, the temperature dependency of moisture retention capacity of a visco-elastic material is a function of the body structure and the presence of void fractions and is known to significantly affect moisture diffusivity, it is shown that less energy was required to remove moisture at the higher drying temperatures as the water molecules obviously become more loosely bound to the body matrix of the samples than at lower drying temperatures (Xiong et el.,1992). In fact, the D_e values ranged from 22.191 x $10^{-10}m^2/min$- 8.219 x 10^{-11}-m^2/min. This observation is similar to that indicated for palm weevil larvae (Zibokere and Egbe, 2019) for shrimps (Prachayawarakorn, 2002).

Table 2: Statistical Parameters of African Giant Snail (Achatina Achatina) on Three Selected Thin-layer Drying Models

		PAGE MODEL		
TEMP	MBE	X^2	RMSE	R^2
60°C	0.03145	0.000192	0.013764	0.9686
70°C	0.0081	0.0000576	0.00759	0.9919
80°C	0.2665	0.001645	0.040389	0.8389
90°C	0.0239	0.00023	0.017004	0.9760
100°C	0.02742	0.00060937	0.024416	0.9726
		LEWIS MODEL		
TEMP	MBE	X^2	RMSE	R^2
60°C	0.0432	0.000264	0.001261	0.9567
70°C	0.03689	0.000262	0.016118	0.9631
80°C	0.03128	0.000267	0.016282	0.9687
90°C	0.00929	0.000113	0.010584	0.9907
100°C	0.02629	0.00056	0.0237	0.937
		HENDERSON MODEL		
TEMP	MBE	X^2	RMSE	R^2
60°C	0.00092	0.00000558	0.0023545	0.999
70°C	0.002556	0.000018253	0.004242	0.9974
80°C	0.001811	0.00001561	0.003918	0.9982
90°C	0.000000863	1.066E-07	0.000322	1
100°C	0.000000514	1.147E-09	0.00003314	1

Table 3. Artificial Neural Network Prediction (ANN) on African Giant Snail (Achatina Achatina)

N	emperature	MSE	2	BE	2
	)°C	0000013907	000000000001934	0000000003191	
	)°C	000002910	0000000000016668	0000000002350	
	)°C	0000063034	00000000003973	000000004649	
	)°C	0000000368	00000000001355	000000001112	
	)0°C	000111	00000001234	000000567805	9999

Table 3. Mosisture diffusivity values of African Giant Snail (Achatina Achatina)

Temperature °C	verage effective moisture diffusivity
)	986 x 10^{-10}
)	219 x 10^{-11}
)	191 x 10^{-10}
)	917 x 10^{-10}
)0	000 x10^{-10}

mud snail meat (Buruba and Bratua 2015). Figure 3 was drawn to linearize Figure 2 to enable the estimation of the process activation energy, E_a using the slope method. It can be observed in the figure 3 that the plot is only slightly negative meeting with the required orientation for the slope method. The evaluated value of the process activation energy, E_a gave 22.5kJ/mol which is seen to be within the literature range of 12.7 - 110-kJ/mol for high moisture biomaterials (Kingly et al., 2007) and 21.6 - 39.03 kJ/mol for fruits and vegetables (Sankat et al., 2006).

4.0 Conclusion

African Giant Snail (*Achachatina Achatina*) was investigated to estimate its drying kinetics on thin layers. In line with other biological materials as reported in several technical literatures drying was observed to follow the falling rate period. In the work, experimental data were fitted to four selected thin-layer models to explore the best for predicting the drying kinetics of the samples. ANN and Henderson-Pabis model followed closely by Page model were observed to present good estimators of the drying behaviour of the Page model the drying temperature so applied. The activation energy value was deduced to be 22.5KJ/mol and falls within the range as in technical literature over the same temperature range in this work. The effective moisture diffusivity values increased with increase of drying temperature.

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NUTRITIONAL COMPOSITION, HEALTH BENEFITS AND UTILIZATION OF FONIO (*Digitaria exili*) GRAINS: A REVIEW

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Abstract

Fonio is a traditional cereal which has often occupied a marginal position among other cereals in most West African countries where it is cultivated; Adequate knowledge on the chemical and nutritional properties, as well as health benefits of fonio is required in its processing and maximum utilization. In this review, the chemical and nutritional characteristics of fonio were identified and compared with those of other major cereals like maize, rice, millet and sorghum. fonio cereals compared favorably well with these other cereals.

Keywords: Cereals, grains

1.0 Introduction

The cereal grains of economic importance are the cool-season crops mainly wheat, barley, oats, and rye and the warm-season cereals like rice, maize, sorghum and millet (Ghatge, 2012). Fonio (Plate 1) is one of the ancient African crops, possibly the oldest West African crop as its cultivation seems to have started about 7,000 years ago (Gari, 2002). The first references to Fonio as food are reported from the mid-14th century (Cruz *et al.,* 2011). Significant cultivation is in West Africa from Chad to Cape Verde, South Mali, in Western Burkina Faso, Eastern Senegal, Northern Guinea, in North-Eastern Nigeria as well as in the South of Niger, where the plant supplies the staple food for several million people.

Fonio is an annual, erect herbaceous plant which reaches heights from 30 to 80 cm. The ears consist of two to five narrow part ears, which are up to 15 cm long. The spikelets comprise a sterile flower and a fertile flower, the latter of which gives rise to the fonio grain. Some varieties can already be harvested 42–56 days after sowing. Other ripen more slowly, usually in 165–180 days (Cruz *et al.,* 2011).

Fonio is additionally referred to as hungry millet or hungry *koos*. In Senegal it is called *fundi*, *findi*, *eboniaye* or *efoleb*. Other local African names include *fonyo*, *fundenyo*, *foinye* (*Fulani*), *Fini* (*Bambara*), *Acha*, *iburu*, *aburo* (Nigerian), *findo* (Gambia), *afio-warun*, *ipoga, ova* (Togo), *Fani, feni*, *foundé* (Mali), *foni* (Burkina Faso), *pende, kpendo, founié, pounié* (Guinea), *podgi* (Benin), *pom, pohin* (Ivory Coast) (Cruz *et al.,* 2011).

This paper aims to provide useful information of fonio (*Digitaria exilisis*) grains about its nutritional composition, health benefits and utilization of fonio grains.

Plate 1: Samples of fonio seed (Source: Irving and Jideani, (1997))

2. Fonio Grains

2.1 *Chemical and Nutritional Composition of Fonio Grains*

The proximate and chemical composition of fonio grain are presented in (Table 2.1). It should be noted that these values refer to the whole or dehusked grains.

2.1.1 *Energy value*

The energy value of fonio grains was not very much studied in literature. Jideani and Akingbala, (1993) reported a value of 19400 KJ/kg (Table 2.1). This result was higher than that reported for other cereals such as rice (18091 KJ/kg), maize (16982 KJ/kg) and sorghum (16245 KJ/kg) by Saldivar (2003).

2.1.2 *Carbohydrates*

The carbohydrates of fonio grains can also have many uses in industrial sector and their contents ranged from 67.1 to 91 % with a mean value of 79.05 % (Table 2.1). Nitrogen-Free Extract (NFE) or method by difference was used by all authors to determine the fonio carbohydrate contents. The lowest carbohydrate content was reported by Saldivar (2003) while the highest value was obtained by Jideani and Akingbala (1993).

2.1.3 *Starch*

Starch is the most abundant carbohydrate in fonio grains as in other cereals and the main provider of calories. Cruz *et al*., (2011) reported a starch content of 68% for fonio grains (Table 2.1). This starch percentage of the fonio grains was lower than that reported for sorghum and rice which was in average of 73.8 and 77.2% respectively. Starch is normally composed of one-quarter amylose, with the remaining three quarters being amylopectin but proportions varied generally according to species. Jideani and Akingbala,(1993) determined amylose content of fonio grains, procured from a local market in Nigeria, by the method described by Robyt and Bemis(1967) and they obtained 28 % of amylase.

2.1.4 *Soluble Sugars*

Soluble sugars were generally in very small quantities in the cereal grains and their concentration varied according to botanical species. The detected sugars in measurable quantities in the cereal grains were mainly saccharose, raffinose, stachyose, glucose and fructose. Some of these sugars, essentially the saccharose, glucose and fructose (Table 2.1), were also identified in fonio grains and their average soluble sugar content was 1% (Cruz *et al*., 2011).

2.1.5 *Fibres*

Fibre constituted of lignin and polysaccharides which are fraction of a consumed food and not degraded in the gut. Crude fibre contents reported for fonio grains were in the range of 0.41-11.3 % with a mean value of 5.85 % (Table 2.1). The lowest value (0.41 %) of crude fibre content was reported by Jideani and Akingbala (1993) while the highest value (11.3 %) was reported by Saldivar (2003). The high variation in the crude fibre contents of fonio grains could also be attributed to environmental influences, geographical location, agronomic and genetic factors on the one hand and to different analytical methods on the other hand.

Table 2.1 Proximate, chemical and nutrient composition of fonio grains

Composition		Fonio		References
	Min	Average	Max	
Energy value (KJ/Kg)		19400		Jideani and Akingbala (1993)
Carbohydrates (%)	67.1	79.05	91	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Starch (%)		68		Cruz et al (2011)
Amylose (%)	22.1	22.05	28	Cruz et al (2011), Jideani and Akingbala (1993), Jideani et al (1996)
Soluble sugar (%)		1		Cruz et al (2011)
Glucose (%)				Cruz et al (2011)
Fructose (%)				Cruz et al (2011)
Saccharose (%)	0.7	0.75	0.8	Cruz et al (2011)
Crude fiber (%)	0.41	5.85	11.3	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Protein (%)	5.1	8.05	11	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004), Jideani et al (1996)
Albumins		3.5		Jideani et al (1994a)
Globulins		1.8		Jideani et al (1994a)
Prolamins		5.5		Jideani et al (1994a)
Glutelins		14		Jideani et al (1994a)
Lipids (%)	1.3	3.25	5.2	Irving and Jideani (1997), Cruz et al., (2011), Jideani and

				Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004), Jideani et al (1996)
Ash (%)	1	3.5	6	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004), Jideani et al (1996)
Vitamins				
Thiamins (mg/100g)	0.3	0.39	0.48	Serna Saldivar (2003), Fliedel et al (2004)
Riboflavin (mg/100g)	0.05	0.07	0.1	Serna Saldivar (2003), Fliedel et al (2004)
Nicotinic acid (mg/100g)		3		Serna Saldivar (2003),

Source: Carbiner *et al*., (1960), Temple and Bassa (1991), Jideani *et al*., (1994b), Fliedel *et al*., (2004), Chukwu and Abdul-Kadir (2008).

2.2 *Proteins and Amino Acids*

The main source of protein for the human diet comes from cereal grains because they constitute the basic food in many developing countries. Protein contents of fonio grains ranged from 5.1 % (Fulcher *et al*., 1981) to 11 % (Fliedel *et al*., 2004) with a mean value of 8.05 % (Table 2.2). Protein content of fonio average was in lower than values reported by Saldivar (2003) for sorghum, millet and rice. Literature is limited on different protein fraction of fonio grains; only Jideani *et al*.,(1994a) investigated the percentage of each protein fraction of fonio grains in various Osborne fractions. Fonio possessed also the four protein fractions, frequent in most cereals, mainly albumin (3.5 %), globulin (1.8 %), prolamin (5.5 %) and glutelin (14%).

2.4 *Vitamins*

Vitamins are essential organic molecules needed in very small amounts for cellular metabolism. Cereals are considered like important sources of B vitamins, except B12 or cobalamin17. Very few authors have studied the vitamin contents of fonio grains (Table 2.1). The fonio grains contained also the B complex vitamins mainly thiamin. The content of which ranged from 0.3 to 0.48 mg/100 g (average: 0.39 mg/100 g) and riboflavin the value of which ranged between 0.05 - 0,1 mg/100 g (average: 0.07 mg/100 g). Nicotinic acid or PP vitamin has been found in concentrations (3 mg/100g) higher than the other vitamins in fonio grains according to the results reported by Serna Saldivar (2003).

Table 2.2 Amino acid composition of Fonio grains

Amino acid (%)		Fonio (g per 16g)		Fonio (Mol %)	Fonio (%)
	Min	Average	Max	Average	Average
Essential					
Phenylalanine	2.34	3.72	5.1	3.1	0.47
Histidine	1.33	1.71	2.1	1.4	0.17
Isoleucine	1.37	2.68	4	3.2	0.28
Leucine	4.4	7.1	9.8	8.8	0.91
Lysine	1.9	2.25	2.6	1.3	0.19
Methionine	2.98	4.3	5.6	3.7	0.34
Threonine	1.89	2.94	4	4.9	0.34
Tryptophan	0.9	0.92	0.95	-	0.16
Valine	2.34	4.07	5.8	6.1	0.52
Non essential					
Aspartic acid	3.5	5	6.5	7.2	0.68
Glutamic acid	6.9	13.55	20.2	18.2	2.16
Alanine	4.2	6.6	9	11.4	1.24
Arginine	1.3	2.55	3.8	2.1	0.93
Cysteine	2.8	2.9	3	2.5	0.07
Glycine	1.9	2.55	3.2	6.5	0.08
Proline	3.2	5.15	7.1	7.2	0.51
Serine	2.1	3.6	5.1	7.9	0.49
Tyrosine	0.91	2.25	3.6	2.2	0.23

Source: Carbiner *et al*., (1960), Temple and Bassa (1991), Jideani *et al*., (1994b), Fliedel *et al*., (2004), Chukwu and Abdul-Kadir (2008).

2.5 *Minerals*

Most of the authors used atomic absorption spectrophotometry to determine the mineral elements contained in the fonio ash. Major mineral elements in the fonio grains were magnesium, phosphorus and potassium. Table 2.3 shows the mineral composition of fonio grains.

Table 2.3: Mineral composition of Fonio grains

Minerals		Fonio		References
	Min	Average	Max	
Macroelements (%)				
Calcium (Ca)	0.0067	0.018	0.03	Irving and Jideani (1997), Cruz et al.,(2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Phosphorus (P)	0.09	0.17	0.25	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Potassium (K)	0.02	0.14	0.26	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Sodium (Na)	0.05	0.017	0.03	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Magnesium (Mg)	0.07	0.46	0.85	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Sulphur (S)		0.16		Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Microelements (ppm)				Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),

Iron (Fe)	36	84.8	133.6	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Copper (Cu)	1.5	8.25	15	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Manganese (Mn)	21.6	25.8	30	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),
Zinc (Zn)	30	36.15	42.3	Irving and Jideani (1997), Cruz et al., (2011), Jideani and Akingbala(1993), Temple and Bassa (1991), Serna Saldiver (2003), Fliedel et al (2004),

Source: Jideani and Akingbala (1993).

Table 2.3 showed that Ca content ranges from 0.0067 to 0.03 %; P content varies between 0.09 and 0.25 %; K value ranges from 0.02 to 0.26 %; Na reported is in the range of 0.005-0.03 %; Mg content varies between 0.07-0.85; S content is in average 0.16 %; Fe level is 36-133.6 ppm; Cu value is 1.5-15 ppm; Mn level is 21.6-30 ppm and Zn content is 30-42.3 ppm.

2.6 *Potential Health Benefits of Fonio*

Fonio is more than just an interesting alternative to the more common grains. The grain is also rich in phytochemicals, including phytic acid, which is believed to lower cholesterol, and phytate, which is associated with reduced cancer risk (Coulibaly *et al*., 2011). These health benefits have been partly attributed to the wide variety of potential chemopreventive substances, called phytochemicals, including antioxidants present in high amounts in foods such as fonio (Izadi *et al*., 2012).

2.7 Utilization of Fonio

Fonio have good grain qualities suitable for processing. Processing of the grain for many end uses involves primary (wetting, dehulling and milling) and secondary (fermentation, malting, extrusion, glaking, popping and roasting) operations. Being a staple and consumed at household levels, processing must be considered at both traditional and industrial levels, involving small, medium and large-scale entrepreneurs (Obilana and Manyasa, 2002; Hamad, 2012).

3.0 Conclusion

Fonio is still the staple food for millions of poor people in Africa and Asia. Like many other cereals, fonio is high in carbohydrate energy content and nutritious, making them useful components of dietary and nutritional balance in foods. Combination of fonio with other sources of protein would compensate the deficiency of certain amino acids such as lysine. Successful improvement of these attributes would be a crucial key to expand the spectrum of utilization of fonio. Future trends should focus on the consumption of fonio cereals due to its abundant nutritional and health benefits.

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FOOD EXTRUSION: A REVIEW

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Abstract

Extrusion technology has witnessed tremendous attention in the dynamics of food processing as a system that utilizes a single screw or a set of screws to force food / feed ingredients under one or several conditions of mixing, heating and shear through an opening or die designed to form and/or puff dry the ingredient and then cut to a specified size by blades. Extrusion-cooking is increasing popularity in the global agro-food processing industry, particularly in the food and feed sectors. It is a high-temperature, short-time process in which moistened, expansive, starchy raw material is used. The entire process is continuous and capable of happening in less than a minute. The most commonly used extruders in the food industry include single-screw and twin-screw systems, with twin-screw systems more widely used because of their flexibility. This paper reviews various techniques/methods adopted by researchers and engineers in analysing the current extrusion technologies.

Keywords: Extrusion, Processing, Die, Food, Feed.

1.0 Introduction

Extrusion is simply the operation of shaping a plastic or dough-like material by forcing it through a restriction or die (Bouvier and Campanella, 2014). A food extruder is a device that expedites the shaping and restructuring process for food ingredients and the mix is known as the extrudate. Extruders can be used to cook, form, mix, texturise and shape food products under conditions that would favour quality retention, high productivity and low cost (Berk, 2009). The principles of operation in extrusion are similar in all types: raw materials are fed into the extruder barrel and the screw(s) then convey the food along it. Further down the barrel, smaller flights restrict the volume and increase the resistance to movement of the food. As a result, it fills the barrel and the spaces between the screw flights and thus becomes compressed. As it moves further along the barrel, the screw kneads the material into a semi-solid, plasticized mass. If the food is heated above 100ºC the process is known as extrusion cooking or hot extrusion (Lakkis, 2007). The food is then passed to the section of the barrel having the smallest flights, where pressure and shearing is further increased. Finally, it is forced through one or more restricted openings (dies) at the discharge end of the barrel as the food emerges under pressure from the die, it expands to the final shape and cools rapidly as moisture is flashed off as steam. A variety of shapes, including rods, spheres, doughnuts, tubes, strips, squirls or shells can be formed. Typical products include a wide variety of low density, expanded snack foods and ready-to-eat (RTE) puffed cereals (Bjorck and Asp, 2003).

In extrusion applications, mainly two different extruder designs are used: the single screw extruder and the twin screw extruder. Within each design, there are various further process design options, including screw size, screw geometry, screw speed, screw rotation (corotating, counterrotating), extruder length, die geometry, barrel geometry, throughput etc. Depending on the processing requirements, extruders can have throughputs ranging from several grams per hour to several tons per hour (Bordolloi and Ganguly, 2014). For most food extrusion applications, corotating twin screw extruders are well-suited and preferred, as they allow extensive variation in thermal and mechanical energy inputs, control of the residence time, and the application of efficient mixing. This uniquely versatile processing nature of extrusion has allowed the technology to develop into widespread industrial applications (Bouvier and Campanella, 2014).

In the case of breakfast cereals and snacks, high temperature and pressure during cooking of starch-based dough and high pressure drop in the extruder die lead to an evaporation of water at the die exit (Studer *et al*.,2004). This evaporation leads to bubble formation (nucleation) and growth inside the dough and is responsible for significant expansion of the product resulting in their specific sensorial properties, i.e., taste, crunchiness, crispiness, and ‘mouth feel’ (Horvat *et al*., 2013). Extrusion processing is a useful tool for handling diverse raw materials and provides a useful means by which unconventional, under-utilized nutrient sources and food processing residues can be incorporated into food systems. Under-utilized cereals, pseudo cereals and food materials which have demonstrated low economic, or processing value have been successfully integrated into consumer markets.

2.0 Methodology

The study adopted an archival research methodology where the focus of the research was on a review of empirical studies on the analysis of different types of food extruders. Thus, the required data for the study were based on secondary sources obtained from academic journals, conference papers, and thesis from both printed and online sources.

3.0 Results and Discussion

Cold extrusion and hot extrusion are the two forms of extrusion methods (Offiah *et al.*, 2019). In hot extrusion process, various types of food products are produced which includes cereal based crispy snacks food, weaning foods from soybean, and sugar based confectionary (Nidhi *et al.*, 2019). In Cold extrusion, the temperature of the food is maintained constant which is used in shaping and mixing of food including meat products and pasta. Temperature less than 100 degree centigrade is used for the low pressure extrusion. Cold extruders are suitable for small scale industry and also for household usage. The main use of cold extruders is in pasta production, although comparable machines are used to frame (Tiwari and Jha, 2017), roll batter (Bhattacharya, 2011) into various shapes.

Hot extrusion process is also known as extrusion cooking. In cold extrusion, mixing and shaping of food is done by the non-cooking method including pasta, biscuit dough. Different types of new food product are formed by extrusion cooking which includes puffed cereals, expanded snack foods etc. There are three forms of extruders used by food manufacturers industries. These are; piston extruders (Doll *et al*., 2019), roller-type extruders (Sevostyanov *et al*., 2019), and screw extruders (Pandey *et al*., 2021). Based on screw design, two forms of extruders are most commonly available: Single-screw extruder and Twin-screw extruder (Gaspar-Cunha *et al.*, 2018).

3.1 *Single-Screw Extruder*

Wesholowski *et al*. (2019) reviewed that single-screw extruder was first used in 1935. It contain a single rotating screw in a metal barrel, and come in varying patterns. The most commonly used single-screws have a constant pitch and it works on a simple and cheap to run operation. Single-screws usually consist of three sections (Feldmann *et al.,* 2016). This type of extruder has three sections in screw-barrel unit: feed zone, compression zone, melting or plasticizing zone and at the end of the barrel, a die is located. Materials flow in forward direction inside the barrel and it fills the barrel and space between the screw flights and gets compressed, causing the increase in shear and frictional forces. The increase in resistance in movement occurred due to screw flights. Melting/plasticizing and degradation of starch molecules occur in the third zone. Further down, the plasticized food material is forced through a restricted opening (die). Puffed, porous structured finished products are the results of rapid expansion of melted material which comes out from die head. This expansion is due to sudden decrease in pressure and immediate vaporisation of moisture (about 40-60%) of melted materials (Ramachandra and Thejaswini, 2015).

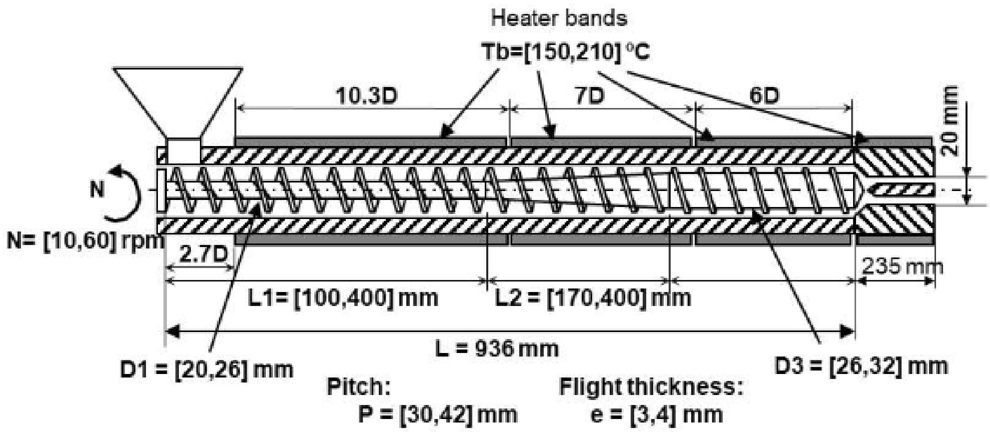

Fig 1: Typical Single Screw Extruder (Riaz, 2016)

3.2 *Twin-Screw Extruders*

Twin screw consists of two parallel screws in a barrel with a figure-eight cross section (Eitzlmayr and Khinast, 2015). The use of twin-screw extruders for food processing started in the 1970s, with an expanding number of applications in the 1980s. Twin-screw extruders are generally one and a half times or more expensive than a single screw machine for the same capacity and the degree of quality control and processing flexibility it offers make them attractive to food industries (Kohlgrüber, 2020). Twin screws produce a more uniform flow of the product through the barrel due to the positive pumping action of the screw flights (Seem *et al.,* 2017). The term 'twin-screw' applies to extruders with two screws of equal length placed inside the same barrel. It consists of two parallel screws in a barrel. It is more complicated than single screw extruders and provides much more flexibility and better control (Thompson, 2015). Twin screws produce a more uniform flow of the product through the barrel due to the positive pumping action of the screw flights (Hejna *et al.*, 2012).

In twin screw extruder, two rotating parallel screw having same dimension is present inside the barrel. Twin screw extruder is entangled than single screw extruders, and yet gives considerably better control and more versatility. The flow of product will be uniform throughout the barrel as a result of positive pumping of screw flights.

The findings of this review proves that the main dissimilarity between single and twin screw extruder is the conveying mechanism (Mount, 2017). In a single screw extruder, the conveying action is the result of the friction effects; the friction between screw and the product and the friction between barrel and product. The single screw extruder needs the barrel wall for the good conveying action, the product may co-rotate along with the screw. Whereas, in a twin screw extruder, the product is enclosed between the intermeshing screws and barrel and is conveyed positively towards the die. Due to such positive displacement action, the product is prevented from co-rotating with the screw. In twin screw extruder the friction at the barrel is of less importance. A single-screw extruder is the simplest food manufacturing device and is very economical to operate. Tiwari and Jha (2009) suggested that single-screw extruders are only suitable for manufacturing of foods that contain less than 4% fat,10% sugar and 30% water (Feldmann et al., 2016). Twin-screw extruders consist of two intermeshing screws either co-rotating or counter-rotating against each other. They have much higher mixing capability than single-screw extruders. One significant advantage of twin-screw extruders is the much extended product range. Food that contain 20% fat, 40% sugar and 65% moisture and can be handled by a twin-screw extruder (Tiwari and Jha, 2009).

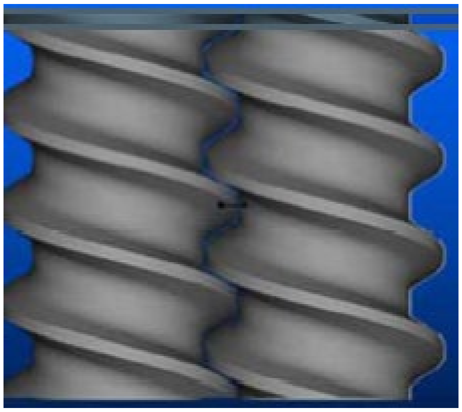

Fig 2: Twin Screw Extruder. Source: (Riaz, 2016)

4. Conclusion

In conclusion, methods that are widely used in the literature of extruders are single screw extruders and Twin-Screw Extruders on either cold or hot extrusion process. The single screw extruders are used on a versatile number of food extrusion; it was only found to have negative impact on the starch impairment. The twin screw extruder has two rotating parallel screw having same dimension present inside the barrel. Twin screw extruder is entangled than single screw extruders, and yet gives considerably better control and more versatility. With its ease and flexibility, extrusion has a great promise to continue to be a valuable processing technology for the food industry especially as its use in the local production of various food snacks is still evolving and yet to be adequately harnessed. It is therefore important to explore its application in the production of some of the local snacks that are still being produced under unhygienic conditions and crude methods.

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DESIGN AND CONSTRUCTION OF SMALL-SCALE POULTRY WASTE DRYER

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Abstract

The high moisture content in poultry waste makes it very difficult to handle, store, transport and use. Drying treatment of poultry waste can solve this difficulty as it can be well utilized as organic fertilizer. There are dryers that can dry products of higher moisture content such as rotary dryers, flash dryers and vacuum dryers but are rather in a larger scale and not always available and assessable for small and medium scale poultry farmers, especially farmers who have their farms where there is no electricity supply. This reason prompted the need to design and fabricate a small-scale poultry waste dryer. The dryer was designed, fabricated, and tested. Some of the components designed for are the drying chamber, drying media, heating chamber (charcoal energy efficient stove) and the chimney. The test performance carried out on the machine showed that it effectively dried the waste. The maximum temperature achieved was 110^0c, drying time of 9 hours and average drying rate of 0.0088kg/min. The small-scale poultry waste dryer proved to be an effective means of converting poultry manure into a value-added product while reducing the environmental and health problems that are associated with land disposal options

Keywords: poultry waste, design, Fabrication, Test

1.0 Introduction

The poultry population is estimated to be 140 million (Ocholi *et al.,* 2006). They are the most commonly kept livestock. The poultry commonly reared in Nigeria include chickens, ducks, guinea fowls, turkeys, pigeons and more recently, ostriches. Over 70% of those keeping livestock are reported to keep chickens. The scientific name of poultry is *Gallus domestics* and it belongs to the family *phasiendae*.

However, the great problem of intensive animal production, especially in countries with high density of population and also with high density of animal farms, is the animal waste management. Poultry waste has much water content which makes disposal and storage of raw poultry manure to become an environmental problem such as air, water and soil pollution. Poultry manure begins to decompose immediately after excretion giving off ammonia which, in high concentrations, can have adverse effects on the health and productivity of birds as well as the health of the farm workers (Ghaly, 2013).

Therefore, one of the treatments that can be used to convert poultry waste into usable products is drying. Drying of poultry waste is the removal of moisture from the poultry waste. Dried poultry wastes when treated have numerous importance as they can be integrated into other useful and saleable products such as organic fertilizer and feed supplements. It can be utilized as a soil conditioner to improve soil tilt and reduce the problems associated with soil compaction and also as a feed for ruminants because of its high nitrogen content. Drying can be done using natural means or by mechanical means. Mechanical means of drying is the most efficient as it proffer solution to the problems associated with other methods of drying waste (Akanni and Benson 2014). Application without treatment or non-appropriate disposal can become risky for environment and humans as such application might lead to the spread of diseases and may pollute soil and groundwater. Therefore, strong attention is paid to the technical solutions in the areas with intensive animal production.

Different systems or approach have been used in the past to remove the moisture content in products by means of drying, such as the conventional dryers in drying grains, tubers and processed food products, most of which are cannot handle the complexity involved in removing moisture of 70 percent to 80 percent moisture from a product.

There are also dryers that can dry products of higher moisture content from a product such as rotary dryers, flash dryers and vacuum dryers but are rather in a larger scale and not always available and assessable for small and medium scale poultry farmers, especially farmers who have their farms where there is no electricity supply.

Hence, this calls for the need to develop a specialized system of poultry waste drying that is simple, non-electric, energy efficient, affordable, and easy to maintain.

Poultry manure have up to 78.4 percent moisture content. This makes most of the organic nutrient in it to evaporate to the atmosphere before use. Also there is an uneven distribution of the manure in slurry form when applied to crops and soils; these can have adverse effect on the crop.

The most common method in managing poultry waste among Nigeria farmers most especially the ones in the rural area is to dump the poultry waste in a dumping site or to dispose into streams, this can also have adverse effect on human and animals as it breed pathogenic organism.

Conventional dryers using organic material such as charcoal as heating material in the combustion unit have associated fluctuating energy supply mostly when loading the material into the combustion unit, in turns, reducing the thermal efficiency of such dryers.

Existing poultry waste dryers cannot be used in area where there is no electricity supply because they are mostly on a larger scale and the airing and heating unit are electrically controlled. These pose a need for a system that considers the problems in achieving a solution.

The aim of the study is to develop a small scale poultry waste dryer, while the objectives of the study are to:

1. Design a drying system capable of drying poultry waste as well as other animal manures
2. Fabricate the poultry waste drying system
3. Test and assess the performance of the dryer

2.0 Materials and Methods

2.1 *Materials Used*

The materials used for the fabrication of the small scale poultry waste dryer include:

1. Galvanized steel pipes
2. Angle iron
3. Aluminium sheet
4. Stainless steel sheet
5. Mild steel sheet
6. Analogue temperature control
7. Bolts and nuts
8. Fibre glass
9. Rivet pins

2.2 *Description of the Small Scale Dryer*

The small scale poultry waste dryer is a batch dryer with two units: the drying unit (drying chamber) and the heat generating units (heating chambers). The heat generating unit is an insulated heat efficient stove. The heat from the stove is transferred and channeled into the drying chamber through circular galvanized pipes. The drying chamber is an insulated rectangular shaped box with pipes around it and two pipes inside it to ensure proper heat distribution in the drying section. The smoke from the heating chamber through the cylindrical pipes was prevented from entering the drying chamber and from having direct contact with the poultry waste through a square pipe channeling the heat and the smoke out of the drying unit to the atmosphere. A chimney was constructed at the roof of the dryer to aid the drying and evaporative process of poultry waste. The drying unit also consists of racks for the drying media to be placed. The drying bucket was designed with grooves to allow heat conduction into the feed stock. The dryer employed the three modes of heat transfer, conduction, radiation and convection. Heat was transmitted from the base of the dryer to the drying media through radiation and the heat from the drying media was conducted to poultry waste through conduction. The heat was circulated through the system as well as exit moisture from the material through the chimney by convection.

2.3 *Design Consideration and Assumptions*

The following factors were considered in designing of the small scale poultry waste dryer were
Availability of construction material, versatility of machine application, maintenance consideration, cost consideration and machine durability

Assumption: The assumed drying capacity for the small scale poultry manure dryer was 35kg/batch. The assumed drying capacity was based on 170g of poultry manure per hen per day, by (Liska and kic2011). This design would serve for daily production range of waste from 205-1000 birds.

2.4 *Design Computations*

2.4.1 *Drying Cones or Bucket*

A drying capacity of 35kg/batch was assumed for the calculation.

The drying bucket is as shown in the design. Volume of the slump cone shape is determined by equation1 and equation 2. A_1, A_2, h are15, 10, 15 respectively and the volume was calculated to be 1865.6cm^3

$$\text{Volume of slump cone} = \frac{h}{3}\left(A_1+A_2+\sqrt{A1XA2}\right) \qquad 1$$

$$A_1 \text{ and } A_2 = \frac{\Pi D2}{4} \qquad 2$$

Where A1 = bigger area of the slump cone (cm^2)

A2 = Smaller area of the slump cone (cm^2)

H = height of the cone (cm)

To calculate the total mass of product for the dryer, the relation in equation 3 was used. (Ghaly and Alhattab 2013), reported a bulk density of 0.96g/cm^3 for poultry layer manure. It is best to use bulk density of poultry layer manure, as it is more moisture to be removed than that of manure with bedding material.

$$\text{Bulk density} = \frac{Total\ mass\ of\ the\ product}{Total\ volume\ of\ product} \qquad 3$$

Mass of the product per bucket = 1865.6cm^3 x 0.96g/cm^3 = 1790.956g = 1.7kg

Fifteen number of slump cones is required for the dryer to hold 35kg of the manure for drying.

2.4.2. *Design of Drying Chamber (Dimension):*

The drying chamber was designed in such a way that the drying bucket would fit well and allow even flow of heat through convection. The shape of the drying chamber is rectangular.

To calculate the volume of the rectangular box, the Length (L), width(W) and height (H) of the dryer was chosen to be 69cm,60cm and 65cm respectively while external length, width and height was calculated to be 70cm, 61cm and 65cm. The inner volume of the rectangular drying chamber body is 269100cm^3. The volume of the dryer was calculated using equation 4

Volume of rectangular box (cm^3) = L x W x H 4

2.4.3 *Amount of Moisture to be Removed*

For manure waste with initial moisture content of 78.4% and to be dried to 10% moisture for long term storability, the moisture to be removed can be calculated from equation 5.

$$M_R = M\left[\frac{Q1-Q2}{1-Q2}\right] \quad 5$$

Where

M = Dryer capacity per batch (35kg)

Q_1 = initial moisture content of the manure to be dried 78.4%,

Q_2 = maximum desired final moisture content, which is 10%

The value gotten for moisture to be removed from 35kg of manure waste (M_R) was 26.4kg

2.4.4. *Heat Energy Required To Remove Water*

The heat required to remove water from a produce was calculated using the formula provided by (Tiruwork B.T. 2015). It considers drying as a two stage process where the first one is raising the temperature of the wet material to a desired level at which the moisture will be removed. This is given by:

$$Q_1 = W_w \times C_p \times \Delta T \quad 6$$

Where:
Cp = the specific heat capacity of the produce (in kJ/kg ^oC)
T = T_d - T_a, is temperature change (in ^oC).

(Ghaly and Macdonald 2012), reported a specific heat capacity for poultry manure to be 4.19kj/kg ^oC(this is assumed to be same as that of water). W_w is the assumed drying capacity (mass) for the dryer which was 35kg. T_d is 70 ^oC while T_a is taken to be the 27.5 ^oC.

Q_1 = 35 x 4.19x (70-27.5) = 6232.625kj

The second stage is evaporating the moisture from the produce. As water starts to evaporate after the produce is warmed up to the drying temperature, heat required to evaporate it is given by:

$$Q_2 = M_w \times L \quad 7$$

L = h_g- h_f is latent heat of vaporization. The values for enthalpy h_g and h_f at the drying temperature are obtained from psychometric chart. The enthalpy for final drying temperature 70^{0}c was read to be 367.68kj/kg while for ambient temperature 27.5^{0}c was 57.01kj/kg. Mw = M_R (mass of water to be removed).

Q_2 = 26.4 (367.68-57.01) = 8, 201.688kj

2.4.5. *Heat Losses in the Dryer*

1 *Dryer Heat Loss at the Vertical Walls*

$$\frac{dQ}{dT} = K \times A\frac{dT}{dL} \quad 8$$

$$\frac{Q}{T} = \frac{AdT}{\frac{L1}{K1}+\frac{L2}{K2}+--------+\frac{Ln}{Kn}}$$

Where;

ΔT= difference between oven inner temperature and outer temperature. = 42.5^{0}c

L_1= inner wall thickness 0.0005m

K_1= inner wall thermal conductivity = 50,w/mK

A_1= inner wall cross-sectional area == 0.455m^2

L_2= insulation thickness = 0.01905m

K_2= insulation thermal conductivity = 0.04w/mK

A_2= insulation cross-sectional area 0.455m^2

L_3 =outer wall thickness = 0.0005m

K_3=outer wall thermal conductivity = 50w/mK

A_3= outer wall cross-sectional area = 0.455m^2

$\frac{Q}{tv}$ = 150.781262 J/s

2 *Dryer Heat Loss through Horizontal Walls*

$\frac{Q}{tH}$ = 11.243799$\frac{J}{s}$

The total heat power loss through the walls of the oven is given by;

$$\frac{Q}{t} = \frac{Q}{tH} + \frac{Q}{tv} \quad 9$$

= 162.025061$\frac{J}{s}$ ≅ 0.162 KJ/s

Therefore, Q_t = 162.725 x 40 x 60 = 388.8KJ

2.4.6. *Quantity of Charcoal Required*

Calorific value of charcoal = 6,900Kcal/Kg = 6900 x10^{3}cal/Kg = 1,642.857143KJ/Kg

Mass of charcoal to be combusted = $\frac{Heat\ energy\ required\ to\ dry\ 35kg\ of\ manure}{calorific\ value\ of\ charcoal}$=8.7Kg

Table1: Parameters of design calculation

ARAMETERS	ESCRIPTION	ALUE

	ɜngth of the drying chamber	) cm
⁷	⁷idth of the drying chamber	) cm
	eight of the drying chamber	ʖcm
[R	mount of moisture to be removed	ʖ.4kg
[	ryer capacity per batch	ʖkg
i	itial moisture content of the manure to be dried	ʒ.4%
2	[aximum desired final moisture content	)%
	eat to be removed	ɂ32.625kj
p	pecific heat capacity	19kj/kg °C
d	rying temperature	)^{0}c
a	mbient temperature	⁷.5^{0}c
:	eat required to evaporate	201.688kj
[w	ssumed drying capacity	ʖkg
	[ass of charcoal to be combusted	7Kg
	alorific value of charcoal	900 x10^{3}cal
t	otal heat loss through the wall of the oven	ʒ8.8KJ
ɂ	sulation thickness	01905m
1	ner wall thermal conductivity	),w/mK
2	sulation thermal conductivity	04w/mK
3	uter wall thermal conductivity	)w/mK
1	ner wall thickness	0005m
	olume of drying bucket	ʒ65.6cm^3
1	igger area of the slump cone	ʖcm^2
2	naller area of the slump cone	)cm^2
	eight of the cone	ʖcm

2.5. *CAD Design for the Dryer*

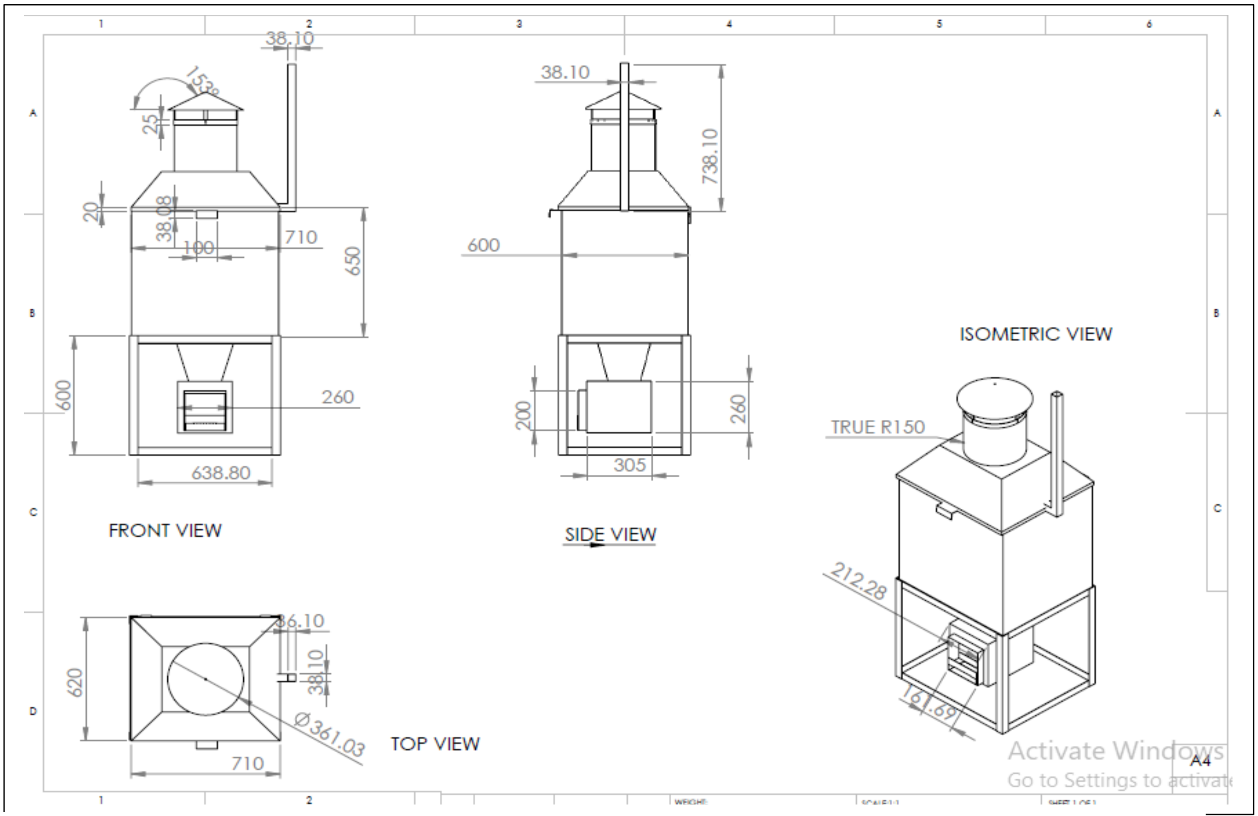
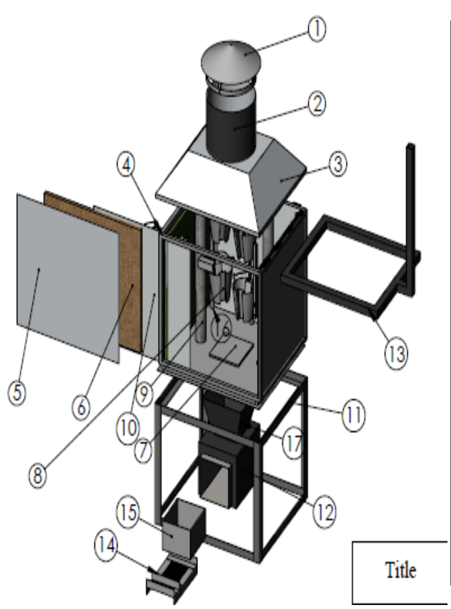


Figure 1: schematics of the small scale dryer



S/N	COMPONENTS
1	Chimney cover
2	Chimney
3	Door
4	Body frame
5	outer plate
6	Insulation
7	Heat exchanger
8	Drying bucket
9	Conducting pipe
10	Inner plate
11	Support frame
12	Efficient stove
13	Smoke collector
14	charcoal holder
15	Charcoal box
16	Smoke pipe
17	Heat distributor

Title

Figure2: Exploded view of the dryer

figure3: Pictorial view of the dryer

2.6 *Performance Test*

The poultry manure was collected from Poultry Production Unit, ministry of livestock and fisheries, Bosso, Minna, Niger State. It was collected very early in the morning to ensure that it is fresh. The performance indice used for the experiment is the equation 10.

1. ***Drying rate***: Drying rate was determined using the expression

$$D_r = \frac{Mi - Mf}{t} \qquad 10$$

Where

M_i and M_f = initial mass of manure before drying and final mass of chips after drying respectively

t = time taken

3.0 Results and Discussion

3.1 *Results*

Table2: Summary of the performance test of the small scale poultry waste dryer when loaded

'N	emperature C)	'eight :g)	rying [edium	nal 'eight(kg)	[oisture duction(kg)	verage ne(min)	rying te(kg/min)
	5	5	ectangular ate	)		47	0089
		5	ump cone	l	2	34	0087

3.2 *Discussion*

The dryer was designed and fabricated. The SolidWorks software was used in the drawing of the isometric view, exploded and orthographic projection of the dryer as shown in figure 1 and 2 respectively.

The machine was tested at no load in order to know the maximum possible temperature rise in the drying chamber. When the dryer was tested without loading for 30minutes, the temperature in the drying chamber rose to 72^0C which is expected to give higher drying rate than open sun drying and solar drying. The maximum attainable temperature for the small scale dryer was at 110^0C.

Table 2 shows the summary of the performance test on the poultry waste dryer when loaded with 15kg quantity of the waste when dried in a slump one bucket as well as a rectangular plate. Drying in rectangular plate is faster, compared to slump cone. This is true with the experiment performed by (Ghaly and Alhattab 2013), The thinner the manure layer, the lower the amount of
moisture it contained and consequently the shorter the time duration required to drive off the moisture.

3.3 Conclusion

The small-scale poultry waste dryer is effective and with efficiency of 85% and it can be adopted as a better option for drying poultry waste and other animal dungs as compared to drying under sun and using solar dryers.

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A REVIEW OF WOMEN PARTICIPATION IN PALM OIL PROCESSING IN DEKINA LOCAL GOVERNMENT AREA, KOGI STATE. NIGERIA

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Abstract

The study describes the Socio-economic characteristics of palm oil processors in Dekina Local Government Area of Kogi state and examine the methods of palm oil processing in the study area, to ascertain the level of women participation in palm oil processing in the study area, identify the constraint of palm oil processing in the study area, and determine the influence of socioeconomic characteristics of the respondent on the method of processing adopted. The study shows that several problems are militating against palm oil processing in the study area. Hence, it there is need for women to have ready access to productive resources like credits, land, processing facilities, and information on mechanized method of processing.

Keywords: Women, oil palm, processing, mechanized

1. Introduction

The participation of women in agriculture especially in developing countries has been appreciated silently, without much recognition and documentation of their contribution. Millions of women work as farmers, farm workers and natural resources manager (onyemobi, 2000). Women have contributed greatly to the nation agricultural output, the maintenance of the environment and family food security. In Nigeria, female farmers are often among the voiceless-particularly when it comes to influencing agricultural policies and projects, they have not been for active involvement in the development proves. Women are predominantly engaged in the processing of palm oil in different agro-ecological zones of Nigeria. Palm oil is a product from oil palm fruit (*Elaeis guineensis*) which originated from the Tropical Rain Forest region of West Africa (FAO, 2002) of which Nigeria is located. The oil palm tree *(Elaeis guineenesis)* is one of the important economic crops in the tropics (Soyebo *et al.* 2008*).* Palm oil is currently the second largest traded edible oil and accounts for about one quarter of the world's fats and oil supply *(*Ibekwe, 2008*).* it is the highest yielding and most important source of vegetable oil of all oil-bearing plants. Oil palm fruit is predominantly found in abundance in the South-Western, middle-belt and Eastern parts of Nigeria where Palm oil fruit bunches is processed into palm oil using traditional method which is simple but stressful, the semi-mechanized method which mashes the fruits and presses out the crude palm oil and the fully mechanized method. Adeniyi *et al.* (2014) reported that the process of producing palm oil requires a large set of equipment which ranges from crude, manual mechanism to advance automated machinery. Women have been largely ignored when research priorities are set and their needs are therefore not addressed. The altitude of ignoring such an essential resource limited the capacity of many women to engage in fruitful and productive activities. Women contribution to economic development and food security of any nation seems not to gain much recognition because; data on women's socio-economic and agricultural activities that lead to food production are scanty especially in Nigeria. But the fact that women contribute immensely in socio-economic development of the rural areas with less authority and opportunity than men implies that the socio-economic constraints militating against their efficient resource management must be fully understood. This would suggest possible solution to their efficient performance and particularly important in the area where palm oil processing is an increasing occupation of the rural inhabitants.To conclude women in Nigeria constitute more than 60% of the nation's population and the bulk of this percentage partake in agricultural activities which involved processing and marketing farm commodities that leads to food security (ARMTI news September 1999).

2. Materials and Methods

2.1 *Women in Agriculture*

It is a long established fact that in Africa, women perform more than 70% of agricultural activities including cash crop production and processing of food crops as well as animal husbandry (FAO, 2000). They carry out 90% of the work of processing food crops (Madeley, 2010). These agro-based food processing and preservation activities engaged in by rural women including palm oil extraction are usually and almost entirely on a small scale basis as shown in figure 2.1. Although they do these from the vantage point of increasing their income level, they also stimulate expansion of agricultural production because of the demand for raw materials to feed the industry. In fact, women are found in nearly every sector of the economy where they derive income for the survival of their household. They were reported to engage in more multiple income generating activities than men (Omiye, 2004). It was observed that women probably produce 60 – 80% of Africa's agricultural products as earlier observed; Palm oil processing in Nigeria is mainly carried out by women. It is even, traditionally, regarded as exclusively a female job (Olawoye, 2001) and they have never shield away from it. Generally, processing involves transformation ofthe raw produce into other forms in which it can be stored or eaten. Indeed, processing improves the acceptability of the produce. Research findings reveal that about 60% of all agricultural (onfarm) labour and 100% of labour involved in agricultural processing are supplied by the women folk (Olawoye, 2001). Imoukhuede *et al*.(2011) reported that, small-scale processors dominate the palm oil industry in West Africa countries, but they did not report women involvement in palm oil industry. More so*,* Adeniyi *et al.* (2014) reported the sources of labour used in palm oil processing in Nigeria, in which, family labour has 52% and none for traditional, semi-mechanized and fully mechanized methods respectively. In the study area, Dekina Local Government Area of Kogi State; a good number of women are into Processing of palm oil which is basically for consumption and for sale. Reports has it that women are responsible for at least 70% of food production in Africa and are also important in marketing cash crops and animal husbandry (Ibekwe*,* 2008*).* It has also been observed that women are directly involved in pre and post-harvest handling of agricultural produce from the point of initial production to urban centres where most consumption take place. Within the palm oil growing states, women in the southern and central regions of Nigeria have defined roles in agriculture and constitute major component of the work force (Omoti, 2003). In most areas women have the responsibility of managing grove palms owned by individual families. They organize labour for harvesting fresh fruit bunches, picking loose fruit and processing bunches for oil extraction. Women are also involved in the palm oil extraction and clarification. Other activities performed by women are kernel oil extraction, local soap production and marketing of the products. Processing of fresh fruits bunches (FFB) into palm oil remains one of the most difficult activities in traditional palm oil processing in Nigeria (Okolo, 2002).

Figure 2.1: Women participation in oil Processing

2.2 Method of Extraction of Palm Oil from Oil Palm Fruit

The Food and Agriculture Organization (FAO, 2002) of the United Nations compiled a bulletin describing methods of palm oil processing as; small-scale facilities, which process two or less tonnes of fresh fruit bunch per hour, employ batch processes that utilize manual labour and have low operating costs. Large-scale facilities typically use continuous systems and require skilled labourers and greater management. Large-scale plants process more than ten and often up to sixty tonnes of fresh fruit bunches per hour (Kwaski, 2002).

2.2.1 Manual/Traditional Method

The traditional methods are tedious, laborious, time consuming, inefficient and yield very low oil output and often of poor quality. Traditional processing can lead to a loss of between 25 percent and 75 percent of the processed oil due to the inefficient method adopted by the processors (Omoti, 2003). Pounding (digestion) and oil extraction are the most tedious and essential operations in traditional palm fruit processing; therefore, early efforts concentrated on these tasks. In small-scale processing, digestion, that is, the breaking up of the oil-bearing cells of the palm fruits' mesocarp, is the most labour intensive activity (Kwasi, 2002). According to Omereji (2005) processing palm fruit bunches into palm oil is one of the most difficult activities in indigenous food processing in Nigeria. The indigenous method of processing can lead to a loss between 25 percent and 75 percent of the processed oil due to its inefficiency (Omoti, 2003) as shown in figure 2.2

Figure 2.2: Boiling of palm oil.

2.2.2 Mechanized/Modern Palm Oil Processing

The process of producing crude palm oil requires a large set of equipment, which can range from crude, manual mechanisms to advanced automated machinery. Regardless of the types of machines used to produce crude palm oil, there are still a set of basic steps needed to produce palm oil. There has been considerable research work done to improve on the indigenous palm oil processing. Some of these efforts include the design and fabrication of simple and affordable cottage small mill to the improvement of the equipment and production of some models which gives higher extraction efficiency with less labour inputs as well as recovery of palm kernel as bye product.

The promotion and adoption of the mechanized operations is aimed at reducing drudgery, enhancing processing efficiency and avoiding the hazards associated with the manual techniques. The success or failure of processing depends largely on the efficiency of the processing technology used. An efficient processing technique according to Ukpabi (2004*)* increases the quality and quantity of palm oil available for consumption and trade. The objective of any palm oil processor as noted by Oladipo (2008) is to obtain the highest percentage of possible palm oil and palm oil processors from their individual stand points must be convinced and satisfied that their personal gains from palm oil processing should be more than their cost of processing for them to remain in the palm oil processing business. A number of research have been carried out to improve the traditional method of processing palm oil, some of which include the design and fabrication of simple and affordable cottage small mill to the improvement of the equipment and production of some models which gives higher extraction efficiency with less labour inputs as well as recovery of palm kernel as bye product. The promotion and adoption of the mechanized operations is aimed at reducing drudgery, enhancing processing efficiency and avoiding the hazards associated with the manual techniques. The success or failure of processing depends largely on the efficiency of the processing technology used. An efficient processing technique according to Ukpabi (2004*)* increases the quality and quantity of palm oil available for consumption and trade. The objective of any palm oil processor as noted by Oladipo (2008) is to obtain the highest percentage of possible palm oil and palm oil processors from their individual stand points must be convinced and satisfied that their personal gains from palm oil processing should be more than their cost of processing for them to remain in the palm oil processing business. A number of research have been carried out to improve the traditional method of processing palm oil, some of which include the design and fabrication of simple and affordable cottage small mills at the Nigerian Institute for oil Palm Research (NIFOR) in collaboration with the Food and Agricultural Organization (FAO) and the United Nation Development Programme (UNDP). This joint NIFOR/FAO/UNDP collaboration led to the production of the NIFOR Small Scale Processing Equipment (SSPE). Further development work on the SSPE in the 1990s led to the improvement of the equipment and production of various models which give higher extraction efficiency with less labour inputs as well as the recovery of palm kernel. In spite of this major breakthrough in palm oil processing technique, the level of income generated by the processors is still generally low. Palm oil is used domestically, locally and industrially. Domestically, used for cooking, soap making and lamp oil, metal plating. Its palm kernel oil is also used for soap making, as a source of glycerin, for manufacturing of margarine, cooking fat and making pomade. The residue after extraction of oil is called palm kernel cake, which is useful in livestock feeding. (Oke, 2002) outlined that the leaves of oil palm are used for making brooms and for roofing materials. The thicker leave stalks are used for thatch wall of the village huts. The bark of the palm frond are peeled and woven into basket. The main trunk (tree) can be split and used as supporting frames in building. For the purpose of this study, much emphasis would be laid on the principal product of oil palm which is palm oil fruit, it processing methods and involvement of women in the processing of this important economic product.

3. Results and Discussions

3.1 *Level of Women Participation in Palm Oil Processing*

Palm oil is very important as an income generator for women in Nigeria. In most cases it is women who are in charge of processing the oil palm fruits into red palm oil and of selling the product in the local and even national market (Omoti, 2009). Women make up a large share of the palm oil processor, although, this is not a definitive figure to show the involvement of women in the processing of palm oil in the Kogi State region. It is also inferred that gross income earnings in oil palm production is reasonable enough to encourage women participation in the business, according to a recent BBC report on palm oil production. The harvest from a handful of trees takes 48 hours to process "the amount of kernels will get us one full jerry can of oil, that's about 20 litres. The red palm oil is a common ingredient in the cooking of almost every type of dish prepared in Nigeria.

3.2 *Constraints of Palm Oil Processing*

There are various degrees or quality levels desire for palm oil produce. In order to attain the quality, the palm produce must be harvested and processed within 12 hours. However, most small holders that lacks the techniques and labour required to do this, usually processed their harvest within a week, under poor processing conditions, which result in high level of dirt, high FFA levels and high iron content(owed to high deposits from the use of old machines). Over 70% of nations processing centers are nonoperational and without capital and spare parts required for maintenance, these poor processing practice continue to reduce quality. About 80% of palm oil produced in

Nigeria is sold out to industries. However, only about 20% of the oil produce is of premium quality. Some other constraints that pose threat to palm oil processing in Nigeria include: adequate access to productive resources, access to land or land tenure system, provision of affordable credit facilities, access to agricultural inputs and technologies and need training and access to extension services among others.

3.*3* *Knowledge Gap and Limitation*

1. Extension should be geared towards encouraging the farmers to adopt the mechanized processing method which seems to be less laborious and cost effective, construction of feeder roads to enhance easy accessibility for carriage of produce and products from the farm should be a project of preference to the government to encourage farmers and reduce transportation and cost boost revenue
2. Government should provide women processors with easy access to input facilities such as credit, information, and subsidizing capital for processing machines and other incentives that can increase their participation in palm oil processing. Social amenities like electricity, water and hospitals should be provided in the areas where oil is processed to facilitate palm oil production and enhance welfares.
3. Both Private and public intervention in improving the socio-economic statuses of women folk should give priority attention to education (adult education), and access to productive resources.

4.0 Conclusions

The review showed that majority of the sampled processors were within their active ages and are engaged in palm oil processing, it further showed that the majority of processors were aware of the mechanized method of palm oil processing and engaged it use for processing oil palm fruits. The result also revealed that processors participate in the major activities involved in palm oil processing of which major problems identified affecting palm oil processing in the study area were harvesting problem, lack of credit facilities, lack of processing machines, inadequate storage facilities and transportation problem. The need for training of women processors of palm oil is also of importance because result revealed that that most of the respondents affirm they needs training in harvesting, extraction and processing of palm oil to obtain high quality oil yield and packing of palm oil. Binary logistic regression results on the influence of socio-economic characteristics on the mechanical method of processing adopted by processors revealed that household size, education, farm size and farming experience had a positive regression with the influence of socio-economic characteristic on the mechanical method of processing adopted by processors.

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DEVELOPMENT OF A MAIZE SHELLER

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Abstract

Maize botanically called Zea mays is a cereal crop that is grown widely throughout the world in a wide range of agro ecological environments. Maize is one of the most extensively studied crop plant in the history. Maize is an important stable food for more than 1.2 billion people in sub-Sahara Africa and Latin America. Manual methods of shelling maize which results in low efficiency, high wastage and huge labour requirement has been the usual way of maize shelling by many local farmers because they could not afford the high cost of imported shelling machines. In this project, basic design of maize shelling machine was carried out.. Readily available materials such as mild steel sheet 2 mm thickness, 50 mm by 50 mm angle iron of 4 mm thickness and steel shaft of 35 mm diameter. The test result of the developed sheller gave mean percentage whole grain, percentage breakage, throughput capacity and performance efficiency of 54.93 %, 1.70 %, 327.89 kg/h and 86.31 % respectively at shelling speed of 250 rpm while at 300 rpm it was 53.38 %, 2.35 %, 460.56 kg/h and 90.53 % respectively. The result shows that increase in shelling speed leads to decrease in percentage unshelled grain and percentage whole grain but leads to increase in shelling capacity and shelling efficiency.

Keywords: Maize, Maize sheller, Design, Fabrication.

2.0 Introduction

Maize botanically called *Zea mays* is a cereal crop that is grown widely throughout the world in a wide range of agro ecological environments. Maize is one of the most extensively studied crop plant in the history and despite this, conflicting views still exist as to its origin.

Matsuoka *et al* (2002) reported from a study that, all maize arose from a single domestication in southern Mexico about 9 000 years ago. The study also indicates that the oldest surviving maize types are those of the Mexican highlands. Later, maize spread from this region over the Americas along two major paths.

Maize is the most important cereal crop in sub-Sahara Africa and an important stable food for more than 1.2 billion people in sub-Sahara Africa and Latin America (IITA, 2011).

Large-scale shelling of maize for commercial purposes cannot be achieved by the traditional methods of shelling. Nigeria is the tenth largest producer of maize in the world, and the largest maize producer in Africa (IITA, 2011). The northern part of Nigeria which is the highest producer of maize in the country practices mostly the hand shelling method. Hand shelling is tedious and time consuming even with some hand operated simple tools. With these tools, a worker can only shell 8 to 15kg of maize an hour (Wanjala, 2014). Most mechanical shellers were designed for multi-grain threshing or shelling, which causes great damage to the maize seeds besides breaking the cob to pieces. Also, the cost of purchasing mechanical shellers were high for the rural farmer, and therefore necessitated the design of low cost system that will be affordable and also increase threshing efficiency but reduce damage done to the seed.

Specific presentation of the grain size, geometrical dimensions of the grains and grain mechanical properties were the key parameters that could enhance successful separation of the grains free of plant residues (Olaoye and Oni, 2001). Impact is the primary threshing action for detachment of grain from the ear head (Vas and Harrison, 1969). The shelling capacity at a particular operating speed decreased with increased in the maximum diameter of cobs (Tiwari *et al.,* 2010).

This research aimed at developing a locally fabricated and low cost maize sheller that is affordable and can easily be maintained by the local farmers. The objectives of the study are:

- To design and fabricate a maize shelling machine
- To evaluate the performance of the maize shelling machine

2.0 Materials and Methods

2.1. *Material Selection*

The appropriate and readily available materials such as mild steel sheet, mild steel flat bar and angle iron were used for the fabrication of the shelling machine. The maize sheller comprises of the following components: frame, hopper, screen, shelling drum, shaft, cob outlet, blower housing, bearing, belt, pulleys, spikes, grain outlet and prime mover.

2.2 *Machine Description*

Frame: The frame is the main skeleton of the machine which was made up of 50mm-by-50mm angle iron of 4mm thickness. It supports other components of the machine.

Hopper: The hopper is the point where the maize is introduced into the machine for shelling. It was fabricated in trapezoidal shape using mild steel sheet of 2mm and it was induced at an angle of 30^o which is sufficient for the maize to slide into the shelling drum by gravity.

Screen**:** The screen was made from 2mm thick mild steel sheet. It was 810mm long and 450mm wide. It was perforated at intervals and rolled to a concave shape which was bolted to the frame.

Shelling drum: The shelling drum covers the shelling compartment. The shelling drum makes a cylinder with the screen where shelling is achieved by beating, rubbing and rolling of ear maize against the screen clearance and the spikes tooth. The drum is made from 2mm thick mild steel sheet.

Rotary shaft**:** This is the most important part of the machine which transmits power from the prime mover to the shelling drum for shelling mechanism. It was made from high speed steel to resist bending and twisting action during usage. The shaft is 1000mm length and 35mm diameter which was reduced to 32mm diameter at both ends to accommodate bearing and pulleys.

Blower**:** Blower is part that performs the winnowing operation. It comprises of shaft and three blades arranged at equal angle to one another on the shaft. The shaft is of length 495mm and 25mm diameter..

Bearing**:** This is the machine element that support shafts and allow circulatory motion of the shaft. They support shelling shaft for shelling mechanism and blower shaft for winnowing. Steel ball bearings of 32mm and 25mm diameters were used for shelling and blower shafts respectively.

Pulleys and Belt: Pulleys are grooved circular disc which accommodate belts for power transmission. Three pulleys were used, one on the shelling shaft, one on the winnowing shaft and the last on the prime mover. Belt is an element that transmits power from prime mover to the shaft. Belts are frequently necessary to reduce the higher rotational speed of electric motors to lower values required by mechanical equipment (Spott, 1985). Standard V-belts 17mm for top width, 11mm thickness and 38^o groove angle were used.

Spikes: The spikes perform the shelling operation by beating and rubbing action against the screen. They were welded spirally on shelling cylinder. They are made from 5mm thick and 25mm wide flat bar and they are of the same height of 85mm.

***Prime over*:** This is a gasoline engine that supplied power for the operation of the sheller. It has 5HP capacity with head pulley of diameter 50mm. It has a control where its power can be regulated.

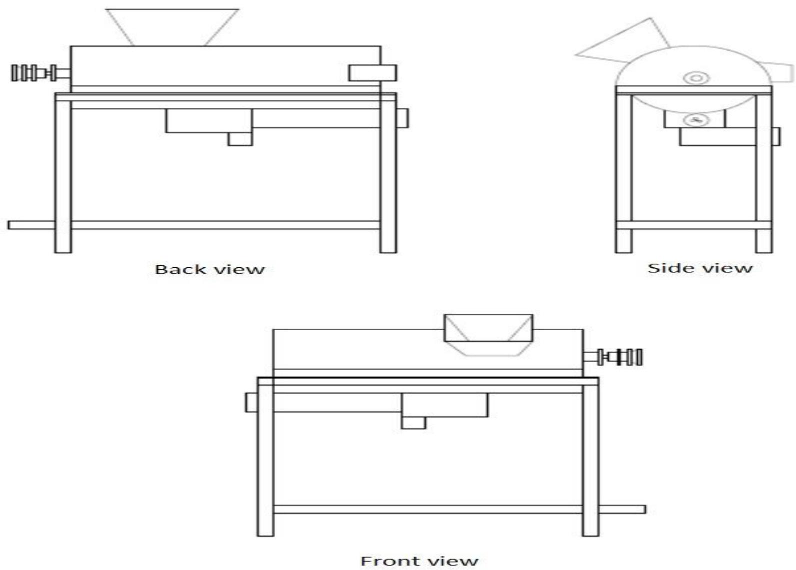

Figure 1: Schematic Diagram of the Developed Maize Sheller

2.3 *Design Analysis*

***Hopper*:** The hopper was designed to take about 10kg of grain at a time. The density of maize is 760kg/m^3, therefore, the volume of the hopper was obtained from equation expressed by (Gbabo *et al.*, 2013).

$$m = \rho \times V \quad (1)$$

Where: m is the mass of maize, ρ is the density of maize, V is the volume of hopper

***Power requirement*:** The power required to drive the maize shelling machine is given by Khurmi and Gupta (2005) as;

$$P = \frac{2\pi N\tau}{60} \quad (2)$$

Where: P is the power requirement of the machine (watts), N is the speed of shelling (rpm), τ is the torque generated (N)

***Shaft diameter*:**

$$T = \frac{\pi\tau D^3}{16} \quad \text{(Khurmi and Gupta, 2005)} \quad (3)$$

$$T = \sqrt{\tau^2 + M_b^2} \quad (4)$$

$$M_b = (T_1 + T_2 + T_C) \times H \quad (5)$$

Where: T is the equivalent twisting moment (Nm), □ = permissible shear stress, D is the shaft diameter (m), τ is the torque transmitted (Nm), M_b is the bending moment of shaft due to the pull on the belt (Nm), T_1 is the belt tension in the tight side (N), $T_2$is the belt tension in the slack side (N), T_c is the centrifugal tension in belt (N), H is the distance of the pulley from the nearest bearing (m)

2.4 *Test Methodology*

Prior to the testing of the developed maize sheller, the prime mover and belt tension were checked and tested. The machine was placed on a tarpaulin to ensure minimum loss to the environment. The machine was then loaded with weighed sample at the shelling speeds of 250 rpm and 300 rpm. Mass of input grain (w_i), mass of whole grain (w_g), mass of unshelled cobs (w_u), mass of shelled grain (w_s), mass of dust (w_d), mass of broken grain (w_b), time of operation (h) ans speed of shelling (rpm) were recorded in kilograms.

After obtaining the above parameters, the following quantities expressed by Naveenkumar (2011) were computed:

$$Percentage\ broken\ grain\ = \frac{mass\ of\ broken\ grain}{mass\ of\ input\ grain} \text{ x } 100 \quad (6)$$

$$Percentage\ whole\ grain\ = \frac{mass\ of\ whole\ grain\ (kg)}{mass\ of\ input\ grain\ (kg)} \text{ x } 100 \quad (7)$$

$$Throughput\ capacity = \frac{Maass\ of\ shelled\ grain\ (kg)}{Time\ taken\ (h)} \text{ x } 100 \quad (8)$$

$$Shelling\ efficiency\ = \frac{Mass\ of\ shelled\ grain}{Mass\ of\ input\ grain} \text{ x } 100 \quad (9)$$

3.0 Results and Discussion

At the end of experimental evaluation carried out on the developed maize sheller, the results are discussed in this chapter. The percentage whole grain, percentage broken, throughput capacity and performance efficiency at different speeds of 250 rpm and 300 rpm were evaluated and discussed. The performance efficiency increases with speed but broken grain was more at 300 rpm as shown in the Tables 1 and 2.

Table 1: Performance Evaluation of the Developed Maize Sheller at the Speed of 250 rpm

S/N	Input (Kg)	Whole grain (Kg)	Broken grain (Kg)	Dust (Kg)	Shelled cobs (Kg)	Unshelled cobs (Kg)	Time taken (min)	Whole grain (%)	Broken grain (%)	Throughput capacity (Kg/h)	Performance efficiency (%)

1	30	16.69	0.55	0.71	7.55	3.95	4.9	55.63	1.83	318.98	86.83
2	30	16.40	0.53	0.98	7.56	4.48	4.7	54.67	1.77	325.79	85.10
3	30	16.35	0.42	0.54	8.51	4.12	4.8	54.50	1.40	323.50	86.27
4	30	16.12	0.60	0.89	7.80	4.52	4.7	53.73	2.00	325.28	84.93
5	30	16.84	0.45	0.62	8.53	3.48	4.6	56.13	1.50	345.91	88.40
Mean	30	16.48	0.51	0.75	8.05	4.11	4.74	54.93	1.70	327.89	86.31

Table 2: Performance Evaluation of the Developed Maize Sheller at the Speed of 300 rpm

S/N	**Input (Kg)**	**Whole grain (Kg)**	**Broken grain (Kg)**	**Dust (Kg)**	**Shelled cobs (Kg)**	**Unshelled cobs (Kg)**	**Time taken (min)**	**Whole grain (%)**	**Broken grain (%)**	**Throughput capacity (Kg/h)**	**Performance efficiency (%)**
1	30	16.11	0.68	0.54	10.14	2.53	3.6	53.70	2.27	457.83	91.57
2	30	15.85	0.71	0.72	9.34	3.38	3.5	52.83	2.37	456.34	88.73
3	30	15.92	0.69	0.61	9.56	3.22	3.7	53.07	2.30	434.27	89.27
4	30	16.15	0.62	0.59	9.96	2.68	3.5	53.83	2.07	468.34	91.07
5	30	16.04	0.82	0.65	10.03	2.46	3.4	53.47	2.73	486.00	91.80

Mean	30	16.01	0.70	0.62	9.81	2.85	3.54	53.38	2.35	460.56	90.53

Percentage of whole grains: The whole grain recovery was affected by varying shelling speed. The whole grain reduced from 16.48 kg at the shelling speed of 250 rpm to 16.01 kg at the shelling speed of 300 rpm. The percentage whole grain of 54.93 % and 53.38 % obtained using equation (8) were evaluated at the speeds 250 rpm and 300 rpm respectively.

Percentage broken grain: The broken grain increased with increase in shelling speed. The percentage broken grain obtained using equation (7) increased from 1.70 % at 250 rpm to 2.35 % at 300 rpm shelling speeds and this was because shelling spikes strike more rapidly with impact force.

Throughput capacity: The throughput capacity measured by equation (9) was obviously different at the two shelling speeds. Higher shelling capacity of 460.56 kg/h was found at the shelling speed of 300 rpm and this was because, the time of shelling was less at this speed.

***Performance efficiency*:** The shelling efficiency of the developed machine increased significantly from 86.31% to 90.53% at the shelling speeds of 250 rpm and 300 rpm respectively. This increase in shelling speed also led to obvious reduction in unshelled cobs from 4.11kg to 2.85kg. The shelling efficiency was obtained by equation (10).

4.0 Conclusion and Recommendations

4.1 *Conclusion*

A maize shelling machine was designed, fabricated and tested at varying shelling speed. The effects of speed on the performance of the machine can be deduced as:

- Increase in speed resulted decrease in percentage whole grain
- Percentage damaged grain increased with increase in shelling speed
- Unshelled cobs decreased significantly with increase in shelling speed
- Increase in shelling speed led to increase in shelling capacity due to reduction in shelling time
- Shelling efficiency significantly increased with increase in shelling speed

4.2 *Recommendations*

- Since the shelling capacity of the developed maize sheller increased with increasing shelling speeds, the performance of sheller at higher speeds should be evaluated.
- Germination tests should be performed on kernels shelled by the developed sheller to determine its suitability for maize seed production.

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SOIL AND WATER ENGINEERING

FORMULATION OF FORTIFIED BIOMASS WITH NPK FOR SOIL NUTRIENTS

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Abstract

This experiment attempts to formulate an organic fertilizer that is fortified with inorganic nutrient source (NPK). Two different types of plant material were used for the experiment. They are: sugarcane leaves (monocot) and Balsam leaf litter (dicot). Both samples were milled to three different grain sizes (coarse, medium and fine). NPK (granular) was used as a nutrient fortifier and mixed with the ground biomaterial in the ratio 1:2. Liquid starch of cassava origin was used to bind the aggregates together. The resultant mixture was extruded through a die hole of 6mm and the pellets produced were dried and subjected to proximate analysis. Carbohydrate content for both sugarcane and Balsam leaves was found to be 72.6 ±.010 and 70.0 ±.078respectively. Protein content was found higher in Balsam leaves than sugarcane which are; 11.4 ±.021 and 8.1 ±.015 respectively. Analysis of variance (ANOVA) performed on nutrients composition shows that Phosphorus, Potassium Magnesium, and calcium all tested for were significant atP≤0.05 except Nitrogen which indicated no significant effect. The Nitrogen content of the pellets was generally very low ranging from 0.200-0.280Cmol/kg. No significant effect of biomass grain size on nutrient content of the resultant pellets.

Keywords: *Bio materials, organic, inorganic, nutrients, formulation*

Introduction

Fertilizers may be broadly classified as organic and inorganic. Organic fertilizers are made of animal or plant biomass that has completely decomposed until the original material has become soil-like in texture, technically referred to as humus (Fernandez 2018). Organic fertilizers could be used either as soil conditioners or growth enhancers. Sometimes, it can be formulated in such a way as to achieve both ends. On the other hand, inorganic fertilizer, also known as mineral or commercial fertilizer, is mined from mineral deposits or manufactured from synthetic compounds (Okese, 2017). Examples are complete fertilizers (NPK), incomplete Fertilizers such as Urea, Triple super phosphate and Potash.
Inorganic as well as organic fertilizers indeed have some form of advantages one over the other. The limitations of one could be almost completely countered by the strengths of the other. Researchers over the years have decided to produce a combined mix of organic and inorganic fertilizers in varying formula depending on crop and soil types. The essence of this is to be able to reduce the negative effect that each fertilizer type may have on the crop and soil.
Major limitations associated with the use of Inorganic Fertilizers are: Higher procurement cost, over accumulation or build-up of unused chemical nutrients which distorts soil chemistry, applying too much fertilizer per crop stand, prolonged rainfall with low intensity may result in leaching. Furthermore, washing of inorganic nutrients by rain may cause pollution of water bodies downstream and render them unhealthy for consumption by humans or livestock. Finally, most soil organisms do not survive in areas of consistent application of inorganic fertilizers. (Kumar and Sreenivasulu 2004). The limitations of organic fertilizers on the other hand are: Slow nutrient release for direct intake by plants. It is also not available in sufficient quantity for large farms. Organic manure can be quite messy and may possess bad odour**.** (Rajpaul *et al.*, 2004). Zhao J. and Zhou L. (2011) combined organic and inorganic fertilizer experiment on maize crops in order to know the effect of long-term combined application of organic and inorganic fertilizers on black soil fertility and crop yield. The research showed increase in the organic matter, alkaline nitrogen, available phosphorus and available potassium. It was observed that increase application of organic fertilizer could reduce the soil bulk density and improve the field moisture capacity

An investigation that uses combined application of organic and inorganic fertilizers in rice production was performed by Fernandez (2018). It was observed that combined application is better than organic fertilizer alone. Also, continuous incorporation of rice straw increased soil potassium content while chicken manure increased phosphorus in the paddy soils.

This research tried to utilize plant materials which are abundant in supply. The Balsam tree especially sheds almost all its leaves at winter. This constitutes such a nuisance to the environment. Instead of burning the leaves to release toxic gases to the atmosphere, it was utilized as organic manure. The biomaterials were mixed with inorganic fertilizer to formulate plant nutrients that could balance the negative effect of the use of either manure separately.

The objective of this study is to formulate a fortified soil biomass from plant waste that can provide necessary plant nutrients in combination with inorganic fertilizer. This will not only reduce the nuisance effect which the plant materials have on the environment, it also reduces the tendency of releasing toxic gases into the atmosphere through burning.

2.0 Materials and methods

The formulation and production of a combined organic and inorganic fertilizer for soil fortification and plant nutrient supplement was carried out in the department of Agricultural and Biosystems Engineering university of Ilorin in 2019. The experiment was performed on two different varieties of plant materials. They are Sugarcane leaves and dried leaf litter from Copaiba Balsam tree. The former being a monocot while the latter, a dicot plant. Both materials could be found in sufficient quantities as residual wastes after harvest or after the dried leaves are shed off from the parent tree.

2.1 Materials collection

The dried leaf litter was collected from Balsam tree located in university of Ilorin while the sugarcane leaves were obtained from the sugar research farm of the university. Other materials used for the biomass formulation were liquid starch which was used as a binder and NPK fertilizer. The equipment used for production were: Hammer mill (for size reduction), motorized sieve shaker, set of Tyler sieves with different mesh sizes, weighing balance, beakers and measuring cylinders, pelletizing machine and tumbling apparatus.

Figure 2a: Dried Balsam leaf litter Figure. 2b: Dried Sugarcane leaves

2.2 Biomass preparation

The biomaterials under study were individually sundried and subjected to size reduction using hammer mill. A set of Tyler sieves were used on a motorized sieve shaker to separate the ground material into coarse, medium and fine product. Sieve analysis was performed on the ground product and the resultant fineness Modulus of sugarcane and Balsam leaf was 3.14 and 2.90 respectively .

2.3 Fertilizer formulation

The three different particle sizes of biomaterial were mixed with liquid starch which acts as a binding agent. Whereas there are other binding agents that may be used, organic binders like cassava starch are particularly useful not only to bind the particles together but to also contribute to the organic constituents of the soil. It is important to determine the appropriate mix ratio of liquid starch to biomaterials so as to achieve the desired strength of the final pellets. The pellets are required to have sufficient strength to withstand all handling processes and so they don't disintegrate into powder before and after packaging. Likewise, the resultant pellets must not be too tough so much they are difficult to break down and release their nutrient content to the soil for plant take up. To this end, a 1000g of ground biomaterial (sugarcane leaves) was mixed with 100ml of liquid starch. On the other hand, Balsam leaf litter was mixed with 450g of biomaterial to 150ml of starch. For both samples, the ratio of NPK (15:15:15) to plant biomass is 1:2

2.4 Pelletizing of fertilizer

The mixture of biomaterial, fertilizer and starch was subjected to pelletizing procedures which involved a sequential process of mixing, extrusion, pelletizing, cooling, drying, and packaging. The mixture came out as a densified material or coarse granules known as pellets. A locally fabricated 2Hppeletizing machine was used to extrude the mixed product into pellets. The pelletizing of biomass helps increase density of the material, ease of handling, reduces storage and transport cost, lowers dust level (Gil *et al.* 2010)

Figure 2: 5mm ring diameter Pellet

2.4 Pellets durability test and proximate analysis

Durability test was carried out with the use of tumbling apparatus. The process involved is as describes by Temmerman *et al* (2006)

$$\text{PelletDurabilityTest} = \frac{\text{WeightofParticlesbeforetumbling}}{\text{weightofparticlesaftertumbling}} \times 100$$

Proximate analysis was conducted on the pellets to determine the nutrients and mineral contents

3.0 Results and discussion

For the two different Biomass in consideration, and three different particle sizes of each ground product, results were obtained for the proximate analysis (Carbohydrate, Protein, Crude Fibre, Ash, Moisture content and Fat). Also, some selected Minerals (Nitrogen, Phosphorus, Potassium, Calcium, and Magnesium) which are very essential for plant growth and development were also determined. Results were obtained also for durability test carried out on the pellets.

3.1 Proximate analysis

Table 3.1 and 3.2 shows proximate values obtained for sugarcane and Balsam leaves respectively. The values are means of three replicates of coarse, medium and fine particles sizes with the corresponding standard deviations.

3.2 Summary of statistical analysis of proximate analysis for sugarcane leaves

Summary of the data obtained from the analysis of selected minerals for the three samples (coarse, medium and fine) is presented in the Table 3.1. Selected minerals (nitrogen, phosphorus, potassium, calcium and magnesium), their mean values, standard deviation are shown in the table. The content of selected minerals varies with the samples. The medium sample has highest content of Nitrogen (0.220), Potassium (1.747) and Magnesium (0.650). Fine particle has the highest value of Phosphorus (4.617) and Calcium (0.797). The results presented is in line with the research report of Muchukuri *et al.,* (2004) that the plant leaves are very rich in other nutrients (especially phosphorus) apart from nitrogen, because the nitrogen in plants especially those of the grass family can be lost to the atmosphere at a very appreciable amount living the plant nitrogen deficient.

3.3 Results of analysis of variance for sugarcane leaves (ANOVA)

The results of analysis of variance (ANOVA) of the proximate analysis and mineral composition show that the formulation has significant effect on the three major treatments. All the parameters (Carbohydrate, Protein, Crude Fibre, Ash, Moisture content and Fat) tested for were significant at$P \leq 0.05$. For mineral composition, it was observed that the formulations had significant effect on all the minerals (Phosphorus, Calcium, Potassium and Magnesium) tested for at $P \leq 0.05$, except for nitrogen which was not significant. Muchukuri *et al.,* (2004) reported that the plant leaves have little composition of nitrogen about 14-18%, this is because nitrogen is easily released into the atmosphere which correspond with the result of this research, that the plant (sugarcane leaves) used has little or no significant value of nitrogen.

Mineral composition of dried leaves

Table 3.1 and 3.2, shows mineral composition of sugarcane and Balsam leaves respectively. The values are means of three replicates of coarse, medium and fine particles sizes with their corresponding standard deviations.

Table 3.1: Mineral composition for Sugarcane leaves

Mineral composition	Coarse (2.38mm)	Medium (1mm)	Fine(0.420mm)
Nitrogen	0.205, ±0.005	0.220, ±0.010	0.210, ±0.010
Phosphorus	3.960, ±0.020	4.507, ±0.012	4.617, ±0.012
Potassium	1.437, ±0.021	1.747, ±0.031	1.457, ±0.025
Calcium	0.740, ±0.010	0.733, ±0.006	797, ±0.012
Magnesium	0.620, ±0.021	0.650, ±0.010	0.607, ±0.006

3.4 Summary of proximate values of balsam leaf litter

The mineral composition of Balsam leaf litter as shown in Table 3.2 indicates that the different particle sizes (coarse, fine and medium) high values of phosphorus and potassium with average mean value of 5.0 and 2.0 respectively. Other mineral composition present (nitrogen, calcium and magnesium) are less than 1.0 with nitrogen having the lowest level of 0.25. This shows the prevalence of phosphorus as the most occurring mineral in this fertilizer followed by potassium.

Table 3.2: Mineral composition of Balsam leaves

Mineral composition	Coarse (2.38mm)	Medium (1mm)	Fine (0.420mm)
Nitrogen	0.273, ±0.006	0.227, ±0.006	0.237, ±0.006
Phosphorus	5.130, ±0.044	4.967, ±0.012	5.080, ±0.053
Potassium	2.100, ±0.000	2.237, ±0.055	2.050, ±0.050
Calcium	0.827, ±0.021	0.803, ±0.006	0.780, ±0.010
Magnesium	0.803, ±0.006	0.660, ±0.020	0.660, ±0.030

3.5 Pellet durability test result

The results generated from the tumbling process are as presented in Tables 3.3 and 3.4 for Sugarcane and Balsam leaves respectively.

From the result obtained, the medium particle size had the highest durability index (74.28). This is most likely due to the fact that it had the lowest moisture content (10.890) compared to fine (11.205) and coarse (11.470). This shows that the medium size pellet would withstand more stress than coarse and fine pellet and also take more time to decompose into the soil.

Table 3.3: Durability test for sugarcane fertilizer pellets

Particle sizes	Sample weight before tumbling (g)	Mean Weight after tumbling (g)	PDI (%)
Fine	2000	1313.50	65.68
Medium	2000	1485.50	74.28
Coarse	2000	1101.5	55.08

As shown in the Table 3.4, Pellet durability index was highest in fine particle size with 91.14%, medium particle size pellet had 81.28% while coarse assumed the least pellet durability of 71.79% which indicates that the fine and medium particle sized pellets remain intact at shock or friction when handled during storage and transport as compared to coarse pellets. Generally, the high pellet durability index indicates that the pellets can withstand repeated transfers in handling systems. This result is in correlation with Theerarattananoon *et al*., (2011), reported that, pellets durability is high when the computed value exceeds 80%, medium if the value is between 70-80%, and low for values below 70%. The significant differences in pellet durability of fine, medium and coarse particle size pellet might be as a result of the formulation, difference in moisture content, particle size and bulk density.

Table 3.4: Durability test for Balsam Leaf fertilizer pellets

Particle sizes	Sample weight before tumbling (g)	Mean Weight after tumbling (g)	PDI (%)
Fine	2000	1822.75	91.14

Medium	2000	1625.5	81.28
Coarse	2000	1435.86	71.79

4. Conclusion

The two essential nutrients present in both sugarcane and Balsam leaves are phosphorus and potassium, which also differ from each particle size. Nitrogen content of both plant leaves is quite low. Sugarcane leaves which are of the grass family shows lower level of mineral nutrients when compared to Balsam leaf litter. The fact that one of the biomaterials is a monocot while the other is a dicot could justify the difference. Anten *et al* (1995) explains that Dicot plants have more leaf Nitrogen storage than monocot plants. The durability test shows that the finer the particle sizes, the more durable the pellets are likely to be. Although, for sugarcane leaves, the medium size pellets indicated higher durability level then the fine size. Also, the moisture content of pellets relates inversely with the durability of the same.

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TEMPORAL RAINFALL AND TEMPERATURE PATTERN IN A CHANGING CLIMATE FOR THE LOWER NIGER RIVER BASIN

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Abstract

The regional climate has been changing with attendant physical, social, economic and environmental consequences culminating in extreme like flood, drought, and other climate related hazards. In view of this, temporal rainfall and temperature patterns over the Lower Niger River Basin (LNRB) was examined. To do this, temporal trend pattern was explored by using anomaly concept. Thirty-five years (1979-2013) of rainfall and temperature time series data from six synoptic stations within the Basin. From the results obtained, it is evident that the period 1999-2013 for temperature within the period under review exhibited tremendous variability in warm and cold weather regime; specifically, it has been greatly characterized by warmer than normal temperature conditions. This implies increase in evaporation and consequently more rainfall. The standardized rainfall anomalies showed 60%, 70% and 40% in the last 35 years. Year to year variation that contributed only contributed 34.68, 13.24 and 16% for maximum and minimum temperature, and rainfall, respectively. Based on the results, it suffices to note that there is increasing trend in the temperature regime over the Lower Niger River Basin. Thus, this portends disturbing signals; thus, an understanding of the implication is central to Agricultural food security planning management and water resources management.

Keywords: *Trend, Standardized anomalies, Coefficient of Variation, skewness.*

1. Introduction

Rainfall and Temperature variations in spatial and time patterns had been described as the most evident effect of climate change (IPCC, 2014). The quasi and fundamental ocean circulation brings about extreme rainfall and temperature changes that result in flooding, drought and heat waves in Nigeria (NIMET Climate Review, 2018). Recent studies revealed that climate variability in the 20th century was characterized by apparent rainfall and temperature variability at different time and space scale (Folland *et al*., 2001). Rainfall is one of the substantial weather indicators of climate change (Sarwar *et al*., 2014). Rising temperature in combination with rainfall anomalies due to climate change influences soil moisture. This may have negative effect on major crops grown by inducing drought (Sarwar *et al*., 2014). Erratic rainfall with rising temperature can cause excessive damage in Agricultural and Water Resources sectors. The Second Assessment Report (SAR) of the IPCC (2007) have it that there has been 0.3 to 0.6ºC temperature increase in the instrumental temperature record. Annual trend in daily minimum and maximum temperature in the latter half of the twentieth century increase in many locations throughout the world Global warming has been predicted to range between 1.4-5.8ºC by the end of twenty-first century IPCC, (2007). Similarly, changes in global mean temperature have been found to be significantly associated with the median intensity of extreme precipitation changes (Zubayed, 2013).

These changes have attendant consequences in terms of flood, drought, heat waves and other climate related extremes resulting in diverse socio-economic impacts. Over 2 million have been displaced globally due to climate extremes as of September, 2018 in Nigeria (NIMET Climate Review, 2018). Flash flooding and other climate related episodes continued to be recorded across the nation due to climate change. Rising temperature as a result of climate change could result to heat related mortality, diseases, malnutrition in children due to inadequate diet. In view of the dynamics of climate change phenomenon, an understanding of spatial rainfall and temperature characteristics is central to Agriculture and Water Resources Planning and Management. Characterization of temporal rainfall and temperature with attendant mitigation measures will help to reduce heat related mortality, enhancing living conditions where natural resources continue to meet human needs without undermining the stability of the natural systems. Therefore, the objective of this study was to analyze temporal rainfall and temperature variability for a period of 35 years (1979-2013).

For the study, rainfall and temperature data were obtained from the LNRB Headquarters in Ilorin. The period of the data covers 35 years; both rainfall and temperature (minimum and maximum) data were obtained from six gauging station, Oke-Oyi, Ekirin Ade, Obandede, Olamaboro, Ganaga and Lafiagi cutting across the entire LNRB. The data collection on these meteorological variables was limited to six gauging stations because of paucity of information for the other stations. The LNRB is located in the middle belt region of Nigeria between latitude 9^0N and 12^0N and between longitude 3^0E and 9^0E. The LNRB shares boundaries with Niger state in the North, Oyo on the West, Edo in the South, Benue on the North-East and Enugu on the East. The annual rainfall ranges between 800mm-1500mm with an average temperature of 26.7^0C. Raining season begins by April and ends in October. Temperature within the basin ranges from 11^0 to 27^0C minimum and 20^0 to 43^0C maximum. The river flow within the basin is unimodal.

2.0 Material and methods

Daily rainfall and temperature (maximum and minimum) time series data were obtained from monitoring station namely; Oke-Oyi, Ekirin Ade, Obandede, Olamaboro, Ganaga and Lafiagi within the River Basin was collected from LNRB headquarters Ilorin. The daily secondary data was aggregated to monthly and annual times series from the six stations. Pre-data analysis was carried out to ensure homogeneity of data, consistency and avoid break up point. Descriptive Statistics and the Standard Anomaly Index was employed. The procedure are as follows:

Collate the rainfall depth and a temporal period
Compute the first and second moments
Compute the Standardized Anomaly using the formula below

3.0 Results and discussion

3.1 Descriptive statistics of temperature (maximum, minimum) and rainfall from 1979-2013

From Table 1.0, the mean annual maximum temperature within the Basin ranged from 11650 at Ganaga station to a highest of 13223 at Lafiagi from 1979-2013. The coefficient variation showed partial deviation within the Basin. This may account for the variability that contributed to the anomalies in the pattern of temperature. The Higher the mean annual temperature, the higher the coefficient of variation 3.75%. The skewness showed partial deviation from negative to positive. Similarly, From the table 2.0 the mean annual minimum temperature (1979-2013) shows Oke-Oyi having the least of 7754.7^0C to a highest value of 8017.7^0C. Ekirin Ade shows the highest deviation of 413. The coefficient of variation shows partial variability within the Basin. The skewness also showed partial deviation of the distribution from negative to positive. From table 3.0, Rainfall result of the descriptive statistics reveals that annual mean over the LNRB from 1979 to 2013 rose from 1113.7mm to a high of 1775.1mm at Ekirin Ade. From table 3.0 partial variability of annual rainfall shows deviation from 262.6 at OkeOyi to 337.6 at Ekirin Ade. Coefficient of variation for annual rainfall within the Basin ranges from 19.02 to 25.19% a with Ekirin Ade having the least and Lafiagi having the highest. The skewness revealed partial deviation in the negative from the symmetry of distribution.

Table 1.0 Descriptive Statistics for Maximum Temperature

Name	Mean	Standard Deviation	CV	Min.	Max	Skewness

Ekirin Ade	11840	335	2.86	11365	12488	0.36
Ganaga	11650	432	3.42	11932	13406	-0.01
Lafiagi	13323	481	3.48	12992	14701	0.22
Obandede	12017	382	3.16	11450	12766	0.35
OkeOyi	13020	426	3.72	12151	13904	0.23
Olamaboro	12640	413	3.26	12037	13508	0.43

Table 2.0 Descriptive Statistics for Minimum Temperature

Name	Mean	Standard Deviation	CV	Min	Max	Skewness
Ekirin Ade	12640	413	3.26	1203.7	13508	0.43
Ganaga	8079.0	168.7	2.09	7688.1	8386.2	-0.13
Lafiagi	8067.9	158.3	1.96	7712.5	8337.5	-0.16
Obandede	7826.1	169.1	2.11	7449.0	8134.8	-0.12
OkeOyi	7754.7	166.6	2.15	7354.4	8016.6	-0.53
Olamaboro	8017.3	188.6	2.35	7602	8322.5	-0.21

Table 3.0 Descriptive Statistics of rainfall

Name	Mean	Standard Deviation	CV	Min	Max	Skewness
Ekirin Ade	1775.1	337.6	19.02	752.6	2431.2	-0.71
Ganaga	1199.1	289.5	24.14	470.3	1859.1	-0.04
Lafiagi	1161.9	292.7	25.19	308.6	1657.3	-0.83
Obandede	1480.3	312.3	21.10	626.2	2078.8	-0.37
OkeOyi	1113.7	262.6	23.58	361.6	1535.7	-1.01
Olamaboro	1331.5	281.4	21.14	489.7	1945.6	-0.46

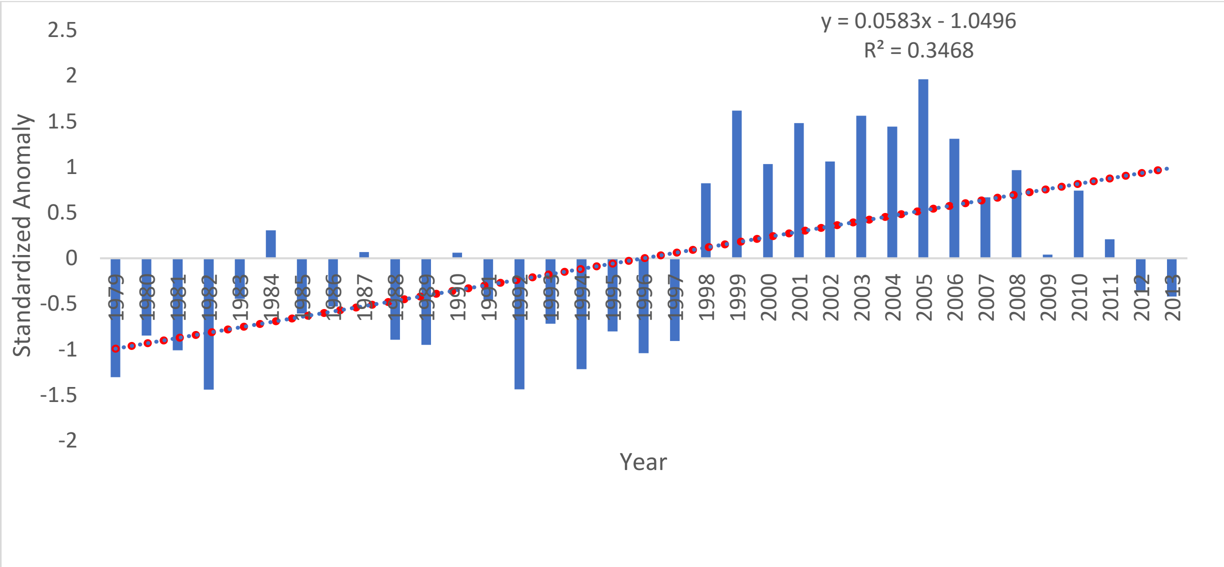

Fig. 1. Maximum temperature standardized anomaly and trend of Ekirin Ade during 1979-2013.

Table 4.0 Summary of the warmer than normal maximum temperature standardized anomaly from 1979-2013 ranked from latest years of warming trend for 3 gauging stations

Ekirin Ade		**Olamaboro**		**Lafiagi**	
Warmer yrs.	Standardized anomaly	Warmer yrs.	Standardized anomaly	Warmer yrs.	Standardized anomaly
2005	1.96	2005	2.18	2006	1.20
2004	1.44	2004	1.25	2005	1.62
2003	1.56	2003	1.35	2004	1.45
2002	1.31	2002	1.33	2003	1.29
2001	1.43	2001	1.05	2002	1.45
2000	1.66	2000	1.12	2001	1.54
1999	1.61	1999	1.69	2000	1.85

Table 5.0 Summary of the colder than normal maximum temperature standardized Anomaly from 1979-2013 ranked from latest years of warming trend for 3 gauging stations

Ekirin Ade		**Olamaboro**		**Lafiagi**	
Colder yrs.	Standardized anomaly	Colder yrs.	Standardized anomaly	Colder yrs.	Standardized anomaly

1994	-1.21	1995	-1.43	1997	-1.21
1992	-1.43	1992	-1.23	1994	-0.98
1988	-0.89	1989	-1.17	1992	-1.47
1982	-1.43	1988	-1.17	1989	-0.93
1981	-1.01	1980	-1,03	1982	-1.48
1979	-1.30	1979	-1.75	1979	-1.44

3.2 Maximum temperature standardized anomaly

According to WMO, the last decade has been the warmest globally since the pre-industrial baseline. The last ten years has been the warmest from 1979-2013 as seen from the table below. This may account for the increase in wetter period experienced. The year-to-year variation is contributed only 34.68% to the standardized anomalies. From figure 1.0 above and table 5.0 shows that from 1979 to 1997 negative trend in maximum temperature persist except for 1990, 1987 and 1984 which are warmer than normal, this accounted for drier period in those years (dry spell). However, the year-to-year variation contributes only 34.68% to the standardized anomalies. This connotes that even though there is temporal change variability, the dynamics is not so swift. The colder than normal for maximum temperature equally depicted higher temperature rise in the night than normal which could result heat mortality humans, animals and livestock.

3.3 Minimum temperature standardized anomaly

The standardized minimum temperature anomalies from (table 6.0) 1979-2013 shows that minimum temperature has been consistently warmer than normal in the LNRB. However, the general trend is similar,1980,1981, 1983,1984, 1992, 1993, 2000, 2011, 2012&2013 are colder than normal signaling less rainfall. From 2003-2006 &2010 remains warmer than normal for Ekirin Ade environment. The year-to-year variation is 13.24% to the computed standardized minimum temperature. Table 6 and 7 shows the minimum warmer and colder than normal temperature standardized anomaly

The Minimum temperature trend revealed that there was more warming over a period under analysis. This implies wetter years for positive trend and little spell for negative anomalies. Maximum temperature has been increasing by 0.04^{o}c. the warming rate for minimum temperature is 0.05^{o}c. The transition from drier years to wetter years and colder to warmer shows evidence of climate change.

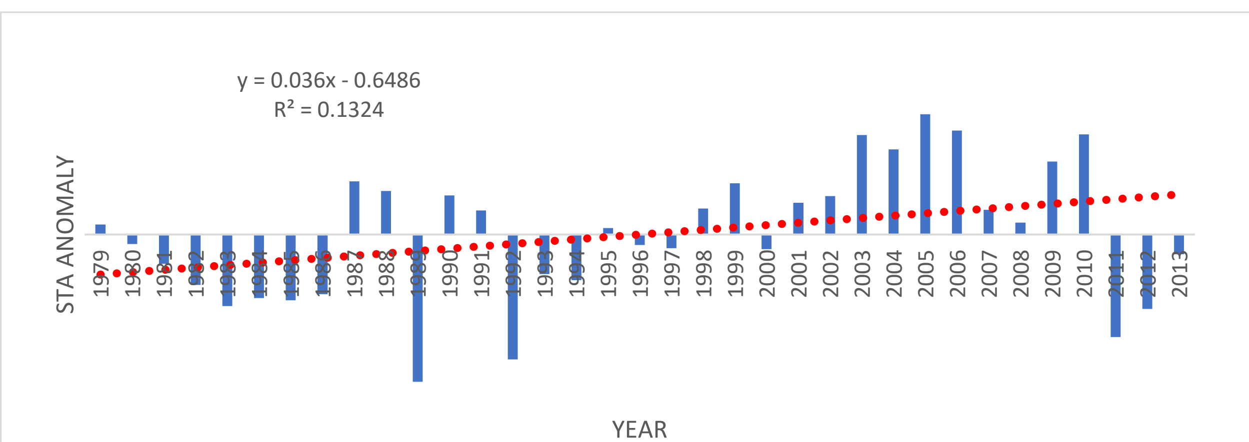

Fig. 2.0: Minimum temperature anomaly and trend over Ekirin Ade from 1979-2013

Table 6.0 Summary of the warmer than normal Minimum Temperature Standard Anomalyfrom 1979-2013 ranked from latest years of warming trend for 3 gauging stations

Ekirin Ade		**Olamaboro**		**Lafiagi**	
Warmer yrs.	Standardized anomaly	Warmer yrs.	Standardized anomaly	Warmer yrs.	Standardized anomaly
2010	1.53	2013	0.69	2010	1.23
2009	1.11	2010	1.64	2006	1.63
2008	0.18	2009	1.24	2005	1.58
2007	0.38	2007	0.10	2004	0.73
2006	1.59	2005	1.64	2003	1.53
2005	1.83	2004	1.47	1987	1.15

Table 7.0 Summary of the colder than normal Minimum Temperature Standard Anomalyfrom 1979-2013 ranked from latest years of warming trend for 3 gauging stations

Ekirin Ade		**Olamaboro**		**Lafiagi**	
Colder yrs.	Standardized anomaly	Colder yrs.	Standardized anomaly	Colder yrs.	Standardized anomaly
2013	-0.30	2012	-0.22	2011	-1.13
2012	-1.13	2011	-0.81	2008	-0.58
2011	-1.57	2001	-0.33	2001	-0.32
2000	-0.22	2000	-1.74	2000	-0.79
1997	-0.21	1997	-0.61	1998	-0.30

3.4 Rainfall Anomalies

The rainfall anomaly data used was from 1979 to 2013 (35years) from one Ekirin Ade station within the basin depict similar behavior across the other meteorological stations within the basin. Rainfall anomaly showed correlations in behavior. The points at which the anomaly is positive indicates wetter than normal rainfall which is by the upward bars while negative anomalies (downward bars) show rainfall below normal. (Little dry spell). From the figure below, it is evident that there were positive anomalies from 1979 to 1997 in rainfall variability within the Basin. From the figure 3.0 there has been negative-positive-negative pattern in rainfall anomalies. This transition could be as a result of climate change. From Figure 4 below, dry years (dry spell) accounted for 30% of the years under review

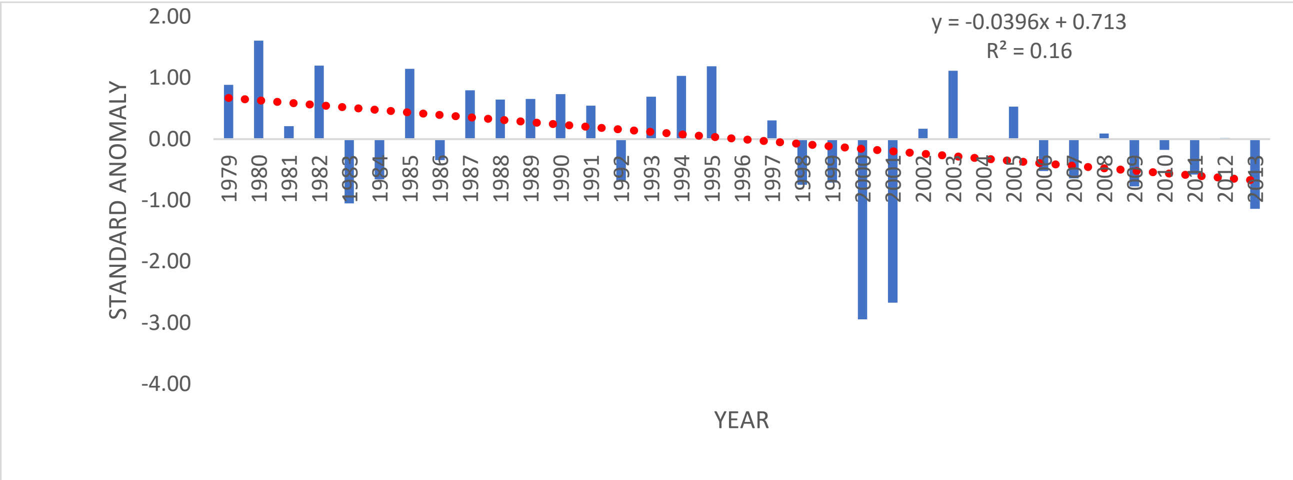

Fig. 3.0: Minimum rainfall anomaly and trend over Ekirin Ade from 1979-2013

5.0 Conclusions

Based on the findings as discussed in section 4.0 and their physical implication, it could be concluded as follows; The standardized anomalies for rainfall (figure 3.0) clearly shows positive anomaly of 60%, 70% and 40% for the first decade, second and the last fifteen years respectively. This result shows wetter than normal and similar to **NIMET CLIMATE ANNUAL REVIEW REPORT** of 2018 till date.

The standardized anomalies for maximum and minimum temperature shows an increase in temperature in all the synoptic stations within the Basin. The state transition of temperature regime (maximum and minimum anomalies) shows 20% rise in the first decade, 65% in the second decade. The first two decades (1979-1998) of temperature anomalies depict negative trend which was responsible for colder period (little dry spell). Rising temperature may result in heat related mortality for humans and livestock. Local trend in temperature regime is similar to global temperature since the beginning of world temperature measurement.

It is evident that variability of rainfall and temperature in time and space exist in the LNRB resulting in warmer temperature and wetter years. This portends more rain than normal which could cause flash flooding within the Basin. Farmers understanding of the analysis of temporal rainfall and temperature pattern in a changing climate in the LNRB is imperative in order to initiate climate adaptation (climate smart farming) and risk management. This study will support evidence-based decision making in climate change mitigation and planning. As the consequences of climate change are not evenly distributed within communities, individual and social factor will lead to differential vulnerability and capacity to adapt to the impact of change. The findings of this study can simplify the larger analysis that depends on this type of data as inputs especially in LNRB.Against this backdrop of the conclusion drawn up, it suffices to note that national climatic variable characterization should be looked into using (parametric and non-parametric methods) in order to mitigate any future scenario which could frustrate Nigeria food security.

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DEVELOPMENT OF MICRO SPRINKLER IRRIGATION SYSTEM USING PLASTIC BOTTLE AS SPRINKLER HEAD

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Abstract

Irrigation has undergone several forms of modernizations. Sprinkler system is one of those improvements in water application techniques in agriculture but due to high initial installation costs and other relevant factors, there is need to develop a micro sprinkler irrigation system using plastic water bottle as sprinkler head to bridge the gap. Plastic water bottle was used for this design because it is locally available and also a bio degradable material that causes a lot of pollution around the world. In this study, a sprinkler system was designed, developed and installed using fixed sprinkler system to irrigate a small-sized plot for preliminary performance evaluation. The plastic bottle nozzle height was varied from5cm to 15cm from the bottle head and a variation punch point of 6 to 7 round the bottle with different nozzle diameter from 5mm to 2.5mm. The results showed that the plastic nozzle height of 15cm,7 punch point and a nozzle diameter of 2.5mm gave the best coefficient of uniformity, distribution uniformity, radius of spray and wetted parameter.

Keywords: *plastic sprinkler, irrigation system.*

1.0 Introduction

Irrigation is simply the application of water artificially to the land for the purpose of crop production (Egharevba, 2009). One of the methods of water application is the sprinkler system of irrigation. It involves the application of water in the form of a spray formed from the flow of water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping, although it may be obtained by gravity if the water source is high enough above the area irrigated (United States Development Agency/Natural Resources Conservation Service, USDA/NRCS, 2016). Sprinkler systems have revolutionized the development of irrigated agriculture. Efficient water application with sprinkler irrigation involves the design and operation of pumps, pipes, and sprinkler devices to match soil, crop, and resource conditions. Thus, sprinkler systems can be designed and operated for efficient irrigation for a wide array of conditions. Sprinkler irrigation also facilitated the expansion of irrigated agriculture onto lands classified as unsuitable for surface irrigation. USDA/NRCS (2016) indicated that sprinkling devices were used as early as 1873. By 1898 seventeen patents had been issued for sprinkler devices. Since that early beginning many developments have occurred. The patent for impact sprinklers as we know them today was issued in 1934. Aluminum pipe with rubber gaskets were first produced in the late 1940s while an early version of the side roll machine was first produced in the 1950s. Self-propelled center pivot and lateral move systems were invented in the late 1940s. Producers quickly recognized that controlling an irrigation system was essential for proper performance. One of the first controllers for sprinkler irrigation was installed in 1924.These early developments laid the foundation for the growth of sprinkler irrigation. In the late 1940s and early 1950s development began in earnest and continued with large increases in the 1960s and 1970s when automated systems were commercialized. The amount of land irrigated with sprinkler systems continue to increase. Most of the development today is devoted to automated and semi-automated sprinkler systems. In Nigeria, the history of irrigation can be traced back to the period of colonial rule. However, it became more pronounced after the drought of the early 70s (postcolonial era), which led to severe hardship due to food shortage (Ugalahi *et al.,* 2016). As the need for irrigated crop cultivation grew between 1972 and 1974, three pilot public irrigation schemes were developed by the Federal Government of Nigeria namely: Bakori Scheme, Kano River Irrigation Scheme and the Chad Basin Scheme (NINCID, 2015). In most part of the country irrigation has not gone beyond the usual surface type, which is mostly associated with poor designs leading to water wastages, excessive power usage, loss of fertile soils and drudgery. The objective of this study was to achieve the best sprinkler head height and nozzle diameter.

2.0 Materials and methods

2.1 The study area

The experiment was conducted on a 20m x 20m piece of land behind the Departmental laboratory of the Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Niger State. The geo-location of Minna is on the north and east hemisphere, stationed on Latitude $9^o36^I\ 54.86^{II}$ N and Longitude $6^o\ 32^I\ 51.94^{II}$ E. Politically, it is classified among the north-central states of Nigeria, with an estimated human population of approximately 304,113 as at 2006 (CENSUS, 2006).

2.2 Experimental materials

The items used to carry out this experiment include sprinkler head and nozzle (plastic bottle), storage tank, measuring tape, gum, catch cans (45 in numbers), pressure gauge, Stop watch, the sprinkler set up consist of PVC pipe of mainline, lateral lines, risers, fittings which include t-joint, end-plug and 1.5hp water pump machine.

2.3 Design of sprinkler system

The following factors were considered in designing the sprinkler system:

i. The area to be irrigated was measured accurately.

ii. The sprinkler system was drawn on paper (Figure 1).

iii. The sprinkler head was also sketch out showing the punch points that were varied (figure 2).

iv. Construction/installations was done based on the design calculations. Sprinkler irrigation Design and Installation Guide/Manual as presented in (Rainbird, 2012) was followed for the installation.

2.3.1 Factors considered during design

The following were the factors considered in the fabrication of micro sprinkler system:

Reservoir (R), Riser (Ri), water Pump (P), distance between risers (Xi) and distance between laterals (r) as illustrated in figure 2.1 below.

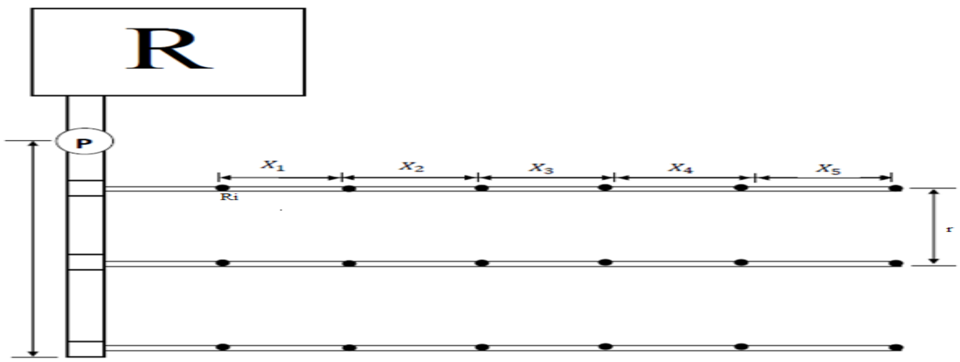

Fig 2.1 Design Used for the Fabrication of Micro Sprinkler System

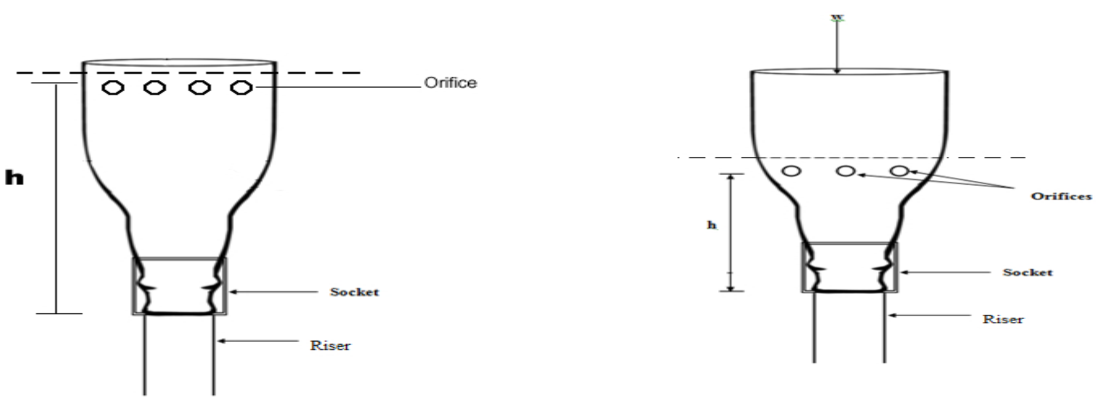

Fig 2.2: Sketch of the Sprinkler Head (Plastic Bottle)

Where:h = Height of punch; w = punch at top

2.3.2 Design of sprinkler head irrigation system:

A sprinkler head system was designed to suit the condition of normal conventional sprinkler head of high performance (Table 2.1).

Table 2.1 Different Sizes of Nozzle Diameter

	Nozzle Size		
Sprinkler Made	**Large (mm)**	**Small (mm)**	**Riser (inch)**
Nelson	4.8	3.1	2
Somlo	4.8	3.2	2
Naan	4.4	2.5	2

Parrot	4.8	3.8	2

Source: Nagasoh *et al.,* (2018)

Figure 2.3 below shows the convergence of the sprinkler discharge through the nozzle.

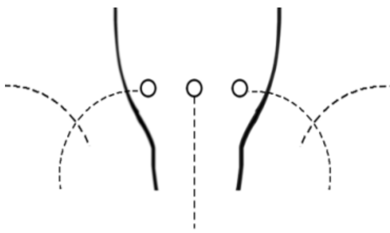

Fig. 2.3: Lapping of the Sprinkler Discharge

2.4 Determination of radius of spray

This is one of the most important parameters considered to determine the efficiency of a sprinkler irrigation design. The distance from the base of a riser to the point of last spray is termed radius of spray. Measured with a measuring tape, the parameters were noted and recorded.

2.4.1 Wetted parameters

This is the sum of length and breadth of the field segment touched by water during spray. The parameters were also obtained with the aid of a measuring tape and thereafter, noted and recorded.

2.4.2Coefficient of uniformity (CU)

Calculated as a percentage and also known as the Christianson uniformity coefficient, CU is defined as follows (Kinfe *et al*., 2018):

$$CU = \left(1 - \frac{\sum(x-\bar{X})}{n \times \bar{X}}\right) \times 100 \qquad (2.1)$$

Where;

$\bar{X}$ =depth of water in catch can; x =mean depth caught in mm; and

n =number of sample (catch can).

2.4.3 Water Distribution Uniformity (U_d)

Distribution uniformity (U_d) is the percentage of average application amount received in the least-watered quarter of the field (Kinfe *et al*., 2018). It is calculated mathematically as:

$$U_d = 100\left(\frac{Lq}{Xm}\right) \qquad (2.2)$$

Where; U_d = distribution of Uniformity; L_q = Average low-quarter depth of water infiltrated;

X_m = Average depth of water infiltrated (or caught)

The distribution uniformity, defined as the percentage of average application amount in the lowest quarter of the field, indicates of the magnitude of the distribution problem (Kinfe *et al.,*2018).

2.5 Installation and performance evaluation of the sprinkler irrigation system

The testing of the sprinkler irrigation system started by coupling the sprinkler head (plastic bottle) to the socket and to the riser, done carefully to avoid leakage. After connecting joints to the main line, the pump was tightly connected to the reservoir and its discharge outlet connected to the 32mm main pipe, 19mm lateral line and 12mm riser line. The pump was first primed and then water was pumped into the main pipe via the laterals, risers and then the sprinkler nozzles. Eventually, the sprinklers started spraying water as expected and the preliminary tests were carried out. Figure 2.4 shows the installation, settings and fitting of the sprinkler head system.

Figure 2.4: Installation, Settings and Fittings for the Sprinkler Head

3 Results and Discussion

3.1 Descriptive performance statistics of the sprinkler head

Data obtained during experiments were analyzed statistically using Design Expert 9.0 statistical package to determine the surface respond analysis of variance (ANOVA). The result of performance evaluation on the installed sprinkler system is presented in Table 3.1.

Independent Samples Test

	Levene's Test for Equality of Variances	t-test for Equality of Means

		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Distribution uniformity	Equal variances assumed	124.556	0.001	-1.791	10	0.103	-18.06667	10.08473	-40.53685	4.40351
	Equal variances not assumed			-1.791	7.532	0.113	-18.06667	10.08473	-41.57618	5.44284
Coefficient uniformity	Equal variances assumed	62.214	0.001	-1.920	10	0.084	-23.08333	12.02347	-49.87329	3.70662
	Equal variances not assumed			-1.920	7.045	0.096	-23.08333	12.02347	-51.47727	5.31060
Wetted parameter	Equal variances assumed	92.949	0.001	-2.009	10	0.072	-29.85000	14.85456	-62.94801	3.24801
	Equal variances not assumed			-2.009	5.453	0.096	-29.85000	14.85456	-67.10032	7.40032
Radius of spray	Equal variances assumed	80.366	0.001	-2.071	10	0.065	-1.45833	.70401	-3.02697	.11031
	Equal variances not assumed			-2.071	5.743	0.086	-1.45833	.70401	-3.19982	.28315

Table3.1: Interaction of sprinkler head height and nozzle diameter

	Levene's Test for Equality of Variances	**t-test for Equality of Means**

		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidenc Interval of th Difference	
									Lower	Upper
Distribution uniformity	Equal variances assumed	124.556	0.001	4.630	10	0.001	30.26667	6.53721	15.70086	44.83248
	Equal variances not assumed			4.630	6.077	0.003	30.26667	6.53721	14.31988	46.21345
Coefficient of uniformity	Equal variances assumed	62.214	0.001	4.151	10	0.002	35.38333	8.52348	16.39183	54.37484
	Equal variances not assumed			4.151	5.974	0.006	35.38333	8.52348	14.50475	56.26192
Wetted Parameter	Equal variances assumed	92.949	0.001	3.072	10	0.012	38.78333	12.62321	10.65707	66.90959
	Equal variances not assumed			3.072	5.096	0.027	38.78333	12.62321	6.51684	71.04982
Radius of spray	Equal variances assumed	84.529	0.001	3.230	10	0.009	1.90167	.58879	.58976	3.21358
	Equal variances not assumed			3.230	5.306	0.021	1.90167	.58879	.41401	3.38932

Nozzle Head Height (cm)	Orifice Diameter (mm)	Distribution Uniformity (%)	Coefficient of Uniformity (%)	Wetted Parameter (m)	Radius of Spray (m)
5	2.5	59	58.4	38.6	1.63
15	2.5	86.7	94.4	93.6	4.18
5	5	38.4	35.9	25	0.8
15	5	46.8	46.1	29.6	1.18

The minimum acceptable performance level for distribution uniformity and coefficient of uniformity are DU > 65% and CU > 78% respectively (Kara *et al.*, 2008). Table 2.2 revealed the interaction of sprinkler head height of 15 cm from bottle head and nozzle diameter of 2.5mm, giving the best distribution uniformity index of 87.2%, coefficient of uniformity index of 98.1%, radius of spray index of 4.62m and wetted parameter index of 104m. This is in line with the findings of (Osman *et al*.,2014; Chen *et al*., 2020) which noted that it is not recommended to equip the sprinkler with a large nozzle under low working pressure and specified the acceptable range of nozzle size under low working pressure to be (2.4mm – 2.8mm).

3.2 Statistical analysis result to f independent sample test for equality of variance

Tables3.2 and 3.3 showed the variances of the responses from the preliminary tests, using the independent sample test of Levene's test for equality of variance and T-test for equality of mean.

Table 3.2: Levene's test for equality of variances and t-test for equality of means for sprinkler head height

Table 3.2showedthe Levene's test has significant variance on distribution uniformity of 0.001, and same for the rest, but the 2-tail mean test showed no significance on the mean. The equal variances assumed and equal variances not assumed of the parameters are as shown in the table. Therefore, the Levene's test shows that there was no significant effect on the nozzle head height that was varied during the preliminary experiment. This finding is similar to that of Friso, *et al.*(2012) who noted that different nozzle head heights do not always show serious significant differences on coefficient of uniformity.

Table 3.3: Levene's test for equality of variances and t-test for equality of means for punch diameter for orifice size.

Table 3.3 shows that the Levene's test has significant variance on distribution uniformity of 0.001, and same for the rest. The2-tailed mean test also shows significant variance on the mean. The equal variances assumed and equal variances not assumed of the parameters are as shown in the table. The statistical distribution goes to show that nozzle diameter has significant effect on the parameters. This also agrees with the findings of Chen *et al.,* (2020) which said that it's not recommended to equip the sprinkler with nozzles of large diameter under a low pressure. This justifies our choice of 95% confidence interval which yielded the optimal result at 2.5mm nozzle diameter.

4.0 Conclusions

A sprinkler irrigation was developed and its performance evaluated. The sprinkler head design that has the best performance after the preliminary test was 15cm punch height and 2.5mm orifice diameter of distribution uniformity index 87.2%, coefficient of uniformity index 95.7%, wetted parameter of index 104m and radius of spray index of 4.62m.

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URBANIZATION EFFECT OF INFILTRATION RATE PROPERTIES ON SOILS WITHIN MINNA METROPOLITAN AREA, SOUTH GUINEA SAVANNAH ZONE OF NIGERIA

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Abstract

Urban forest soil infiltration affected by various factors is closely related with surface runoff. This paper studied the effect of water infiltration characteristics of urban soils with different degrees of compaction and its effects on environmental problems in urban areas. the soils differ considerably between the six locations; that is, the undeveloped land, Farm land, Garden, Grazing land, paved compound and paved road side. The soil at the undeveloped site is a deep, well-drained, soil which consist of 56% sand, 25% clay and 31% silt. The soil at the farm land is dominated with loamy soil with relatively high degree of homogeneity both vertically across depths and horizontally from one sample locus to the next. These results also demonstrate that the effect of soil texture on infiltration rate was probably masked by the land use practices and soil management, which agrees with the fact that water infiltration into the soil is highly sensitive to land use and soil management. The models used in estimation infiltration rates were Kostiakov Equation Model; Horton Infiltration Model; Holtan Infiltration Model and Philip Infiltration Model.

Keywords: *Urbanization; Infiltration; Model; Soil; infiltration rates, soil compaction*

1.0 Introduction

In the past few decades, South Guinea savannah zone of Nigeria had experienced a rapid and unprecedented process of urbanization, with urban areas expanding almost exponentially outwards in many cities in parallel with infrastructural constructions, the natural movement of water into the soil is obstructed (Venter *et al*., 2019). In developing cities, different structural constructions often represent the urbanization gradients (Huang *et al*., 2010; Attard *et al*., 2016; Zhai *et al*., 2017). During the process of urbanization, forests and soils were significantly influenced by human activities and large areas of forests have been occupied. Meanwhile, many afforestation movements such as ‘forest city’ or ‘eco-city’ have been initiated in developed cities due to citizens’ desire for a better quality of life (Bae and Ryu, 2015; Lv *et al*., 2016). Urban forest soil is affected not only by plant-soil interaction and afforestation but also by human activities such as trampling (Hobbie *et al*., 2007; Zhang *et al*., 2018; Lasanta *et al*., 2019). Generally, with rapid urbanization, natural vegetated soils are replaced with impervious surfaces. This land conversion could exert profound influences on hydrological processes such as inhibiting rainwater infiltration and increasing surface runoff and peak discharge rates (Hood *et al*., 2007). However, the motivation for this study is informed by frequent flood event during the rainy season, and Poor surface runoff water quality. The aim of the study is the urbanization effect on infiltration rate properties of soils within Minna metropolitan area, south guinea savannah zone of Nigeria. Based on the aim of the study, the objectives designed to achieve this aim is to explore the water infiltration characteristics of urban soils with different degrees of compaction and its effects on environmental problems in urban areas.

2.0 Materials and Methods

2.1 *Soil sampling*

Soil samples was collected from five (5) different locations, at each site, five soil samples was collected from each of three depths: 0-15 cm (0-6 in), 15-30 cm (6-12 in) and 30-45 cm (12-18 in) which was used in the determination of initial moisture content, soil bulk density, and a first run of saturated hydraulic conductivity measurements. The initial moisture content was determined using soil moisture content instrument.

2.2 Development of Infiltration Rate

The infiltration rate was determined using a double ring infiltrometer. It consists of thin metal cylinder with inner diameter of 300mm and 600mm outer diameter, and this cylinder was driven into ground and 10-12cm of the cylinder was above the ground level. And water was poured from the top and the volume of water added to the ring was noted to find the Incremental Infiltration velocity. The infiltrated water depth was also noted for 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, and 180 minutes until we got the constant infiltration depth. A graduated jar was also employed to add water and scale was used to measure the depth of water infiltrated.

2.3 Determination of Infiltration Equations Parameter

2.3.1 Kostiakov Equation Model for the Estimation of Infiltration Characteristics

For the Kostiakov equation, the base values for the two empirical constants K_k and α will be determined by using equation (2.1)

$$f_p = K_k \, t^{-\alpha} \qquad (2.1)$$

where, f_p = infiltration capacity [Lt^{-1}], t= time after infiltration starts [t], and K_k [L] and α [unitless] are constants that depend on the soil and initial conditions. The parameters, K_k and α must be evaluated from measured infiltration data, since they have no physical interpretation.

Log f_p would therefore be plotted against log t and finding the slope and y-intercept of the resulting straight line. The intercept of the equation (infiltration rate at time t = 1) is log K_k and the slope is -α. Infiltration is directly proportional to K_k, but is inversely related to α.

2.3.2 Horton Infiltration Model for the Estimation of Infiltration Characteristics

The Horton equation (1940) is one of the most popular empirical models simulating infiltration of water into soils (Philips, 1957). The infiltration equation is a three-parameter equation and equation (2.2) were employed:

$$f = f_c + (f_o - f_c)e^{-kt} \qquad (2.2)$$

Where, f = infiltration rate at time t, mm hr^{-1}; f_o = initial infiltration rate, mm hr^{-1}; f_c = final infiltration rate, mm hr^{-1}; k = rate constant in dimension of time, t (t^{-1}).

The field measured infiltration rates versus elapsed time were plotted so that the infiltration rate at any time f_o and f_c can be estimated from the curve that would be represented as the intercept on the y-axis and the value of the steady-state (final) infiltration rates respectively. In other words, the initial infiltration (f_o) is equal to f at time zero (Verma, 1982). Since infiltration rate for all the measurement was taken from a starting time of 1 minute, a logarithmic trend line was used in the regression of infiltration rate against time to determine the intercept (f_o) at time zero. The procedure was repeated for all 10measurement points.

Equation (2.3) can be linearized as:

$$f - f_c = (f_o - f_c)\, e^{-kt} \qquad (2.3)$$

Taking the natural logarithm of both sides,

$\ln(f - f_c) = \ln(f_o - f_c) - kt$ (2.3b)

$\ln(f - f_c)/\ln(f_o - f_c) = - kt$ (2.3c)

$$\ln(\frac{f - fc}{fo - fc}) = - kt$$

Let the expression in parenthesis in Eq. (2.3d) be represented by y, therefore;

$\ln y = - kt$ (2.3e)

This can easily be taken back to its non-linear form given by:

$y = e^{-kt}$ (2.3f)

To solve for the equation, *f* was taken as the measured infiltration rate at any given time t.

Computing the values of the initial (f_o) and final steady-state infiltration (f_c) in the left hand-side of (Eq. 3.10d) and solving resulted in the natural logarithm of y (Eq. 2.3e) which was plotted against elapsed time to give a straight line on the semi-logarithm scale. Because (Eq. 2.3d) gives a semi-logarithmic expression, another way is plotting directly into exponential regression of *y* against time as a non-linear least sum of squares technique. In this study however, the estimates of *k* were obtained as the slope from the best fit regression line. The estimates obtained in linear plot of the natural logarithm of *y* and time was the same as that obtained directly in the exponential plot of y against time (Eqs. 2.3e and 2.3f). It shows that the exponential function represents the data fit for the Horton infiltration equation (Berndtsson, 1987, Turner,2006). Knowing *k*, the new infiltration rate will be calculated in (Eq. 2.3a). Infiltration rate was calculated for each point and later compare to actual field measurements using linear regressions from Microsoft office Excel 2010.

2.3.3 Holtan Infiltration Model for the Estimation of Infiltration Characteristics

The infiltration capacity was determined using Holton equation as shown in equation 2.4 below:

$f_p = GIaSA^{1.4} + f_c$ (2.4a)

where, f_p = infiltration capacity at given time; $[Lt^{-1}]$, *SA* = available storage in the surface layer, "A" horizon at given time; [L], *GI* = growth index of crop in percent of maturity *a* = an index of surface connected porosity ((in.hr.$^{-1}$ per (in.)$^{1.4}$ of storage). This is a function of surface conditions and density of plant roots. f_c = the constant or steady state infiltration rate and in Holtan equation is estimated from the soil hydrologic group; $[Lt^{-1}]$.*SA* is computed from:

$SA = (\theta_s — \theta_i)$ d (2.4b)

where,θ_s = saturated water content of the soil; $[L^3L^{-3}]$, θ_i= actual volumetric water content of the soil; $[L^3L^{-3}]$ and *d* = depth of the surface layer; [*L*]

2.3.4 Philip Infiltration Model for the Estimation of Infiltration Characteristics

For cumulative infiltration, the general form of the Philip infiltration model is expressed in powers of the square-root of time, t, as in equation (2.5);

$F = St^{1/2} + C_{a1}t + C_{a2}t^{3/2} + . . .$ (2.5a)

The time derivative of F is the infiltration rate, f; [Lt^{-1}] was calculated using the equation (2.5b)

$$f = St^{-1/2} + C_{a1} + 3/2C_{a2}t^{1/2} + \ldots \quad (2.5b)$$

where, F = cumulative infiltration; [L] S = sorptivity; [$Lt^{-1/2}$], a function of initial and final soil water content, $\theta_i$and θ_n Ca1, C_{a2} = constants that depend on both soil properties and on $\theta_i$and θ_n. Philip (1957b). In the Philip equation, the parameter C_a will be estimated to be *Ks*, 2*Ks*/3, *Ks*/2, and K*s*/3.

3.0 Results and Discussion

3.1 Comparison of Sites

3.1.1 Soil textural classification

Results of soil analyses of the five land use practices are shown in Table 3.1 below. The soil properties presented in the table are particle-size fractions (sand, silt, clay and loam), bulk density, saturated hydraulic conductivity and available water content. Considering the effect of the land use practices on soil properties (Table 3.1), the soils differ considerably between the six locations; that is, the undeveloped land, Farm land, Garden, Grazing land, paved compound and paved road side. The values for bulk density measured from this site are 1.47g/cm^3, 1.62g/cm^3,1.32g/cm^3, 1.5g/cm^3 and 1.31g/cm^3 as shown in (Figure 3.1) corresponded to the values for sandy loam (1.7 g/cm^3) and sandy clay loam (1.6 g/cm^3) in a diagram by Ellen (2006). The surface layers have significantly higher Ks of 3.10 cm/hr, 0.575 cm/hr and 0.725cm/hr for undeveloped land, Farm land and Garden study areas, respectively. The initial infiltration rates of Farm land for five different samples obtained from rainfall simulation are (75.75 cm h^{-1}, 73.76 cm h^{-1}, 76.76 cm h^{-1}, 74.76 cm h^{-1}, and 75.75 cm h^{-1}) and then decreased in a logarithmic fashion to approach an asymptote representing a final constant infiltration rate of approximately (26.05 cm h^{-1}, 27.25 cm h^{-1}, 27.26 cm h^{-1}, 25.36 cm h^{-1} and 24.05 cm h^{-1}), respectively. The infiltration curve in Figure 3.2, to 3.4 indicated that there is a slight difference between the initial infiltration values as well as the difference between the final values.

3.1.2 Moisture content

Seasonal and climatic conditions along with soil attributes were seen to have significant impact on initial water content at all the sites. The infiltration was carried out during the month of January, 2020. when the soils were extraordinarily dry and very hard. The undeveloped and Farm land surfaces because of exposure to the sun and wind, with scant vegetation for protection, was the driest layer prior to wetting. This is in conformity with the study carried out by Ellen (2006) for Poplar Hill site. Each subsequent depth was moister than the previous layer with the deepest layer having a water content of only 0.12 and 0.13 (cm^3/cm^3), respectively.

3.1.3 Hydraulic Conductivity

Hydraulic conductivity values of Undeveloped land, Farm land and Garden in (Figure 3.2) showed a clear trend of decreasing hydraulic conductivity (Ks) with increasing depth. The surface layers have significantly higher Ks of 3.10 cm/hr, 0.575 cm/hr and 0.725cm/hr for Undeveloped land, Farm land and Garden study areas, respectively. This may be due to the presence of plant roots, worm holes and plant debris which cause increased aeration and looser packing of soil, along with some preferential flow as water finds channels through the soil instead of moving uniformly through the column. This is in conformity with the findings of Ellen (2006) for Upper Marlboro and Poplar Hill sites study.

3.1.4 Bulk density measurement

Bulk density was measured after saturated hydraulic conductivity and soil water retention measurements, resulting in slightly lower bulk densities than would have been obtained by measuring bulk density of separate samples, because a small amount of soil was unavoidably lost during these procedures. Undeveloped plot bulk density values varied very little with depth (1.31-1.62 g/cm^3), aside from a slightly less dense surface layer, due to plant roots, and other organic matter, and a denser plow pan layer at approximately 16-20 cm. The similarity of bulk density values across depth at this site is not surprising, since the soil is relatively homogeneous with the majority of the layers being sandy loam. The values for bulk density measured from this site are 1.47g/cm^3, 1.62g/cm^3,1.32g/cm^3, 1.5g/cm^3 and 1.31g/cm^3 as shown in (fig 4.1) corresponded to the values for sandy loam (1.7 g/cm^3) and sandy clay loam (1.6 g/cm^3) in a diagram by Ellen (2006). Recalling that the bulk density measurements were low due to soil loss during other laboratory procedures performed on the soil samples, sandy loam is more plausible at this site. The bulk density values of the Farm land also varied very little with depth (1.36-1.52 g/cm^3) and it is predominated by loamy soil (mixed sandy and clayey loam samples) and the soil shows less homogeneity, with the surface layer having considerably lower average bulk density of (1.41 g/cm^3) due to more plant roots and worm holes in that layer. This is inconformity with Ellen Turner (2006) findings for Upper Marlboro and Poplar Hill sites. Density increases with depth until a plow pan is reached (1.52 g/cm^3) at approximately 25-30 cm depth and then decreases due to high clay content in the deeper layers.

Table 3.1: Soil Properties Analysis

Study Location	% Clay	% Sand	% Silt	soil texture	bulk density (g/cm^3)	moisture content	hydraulic conductivity (cm/hr)
Undeveloped							
I	18	56	38	Sandy loam	1.47	0.11	3.07E-01
II	9	83	74	Loamy sand	1.62	0.08	3.10E+00
III	41	44	3	Clay	1.32	0.11	5.81E-03
IV	14	53	39	Sandy loam	1.5	0.12	4.66E-01
V	42	42	0	Clay	1.31	0.11	4.08E-03
Farm Land							
I	24	39	15	Loam	1.39	0.13	7.56E-02
II	15	68	53	Sandy loam	1.52	0.09	5.75E-01
III	30	43	13	Clay loam	1.36	0.12	2.24E-02
IV	22	43	21	Loam	1.41	0.13	7.20E-02
V	29	43	14	Clay loam	1.37	0.12	2.15E-02
Garden							
I	33	37	4	Clay loam	1.34	0.013	1.86E-02
II	26	38	12	Loamy	1.38	0.13	3.83E-02
III	11	34	23	Silty loam	1.50	0.16	7.25E-01

IV	37	33	4	Clay loam	1.31	0.13	5.79E-03
V	30	49	19	Sandyclayloam	1.38	0.11	2.09E-02
Grazing Land							
I	39	52	13	sandy clay	1.34	0.1	1.18E-02
II	8	38	30	Silty loam	1.55	0.16	1.62E+00
III	22	55	33	Sandyclayloam	1.43	0.11	1.08E-01
IV	18	30	12	Silty loam	1.42	0.16	1.10E-01
V	17	57	40	Sandy loam	1.48	0.11	2.63E-01
Paved Compound							
I	23	62	39	sandy clay	1.44	0.09	1.33E-01
II	34	45	11	Sandyclayloam	1.35	0.11	1.33E-02
III	20	63	43	sandy loam	1.46	0.1	1.86E-01
IV	38	46	8	sandy clay	1.33	0.11	6.77E-03
V	48	48	0	sandy clay	1.30	0.1	2.82E-03
Paved Road Side							
I	49	47	2	sandy clay	1.30	0.1	4.69E-03
II	50	46	4	sandy clay	1.29	0.1	2.97E-03
III	38	56	18	sandy clay	1.35	0.09	1.01E-02
IV	39	53	14	sandy clay	1.34	0.09	7.01E-03
V	38	60	22	sandy clay	1.36	0.08	9.09E-03

(b)

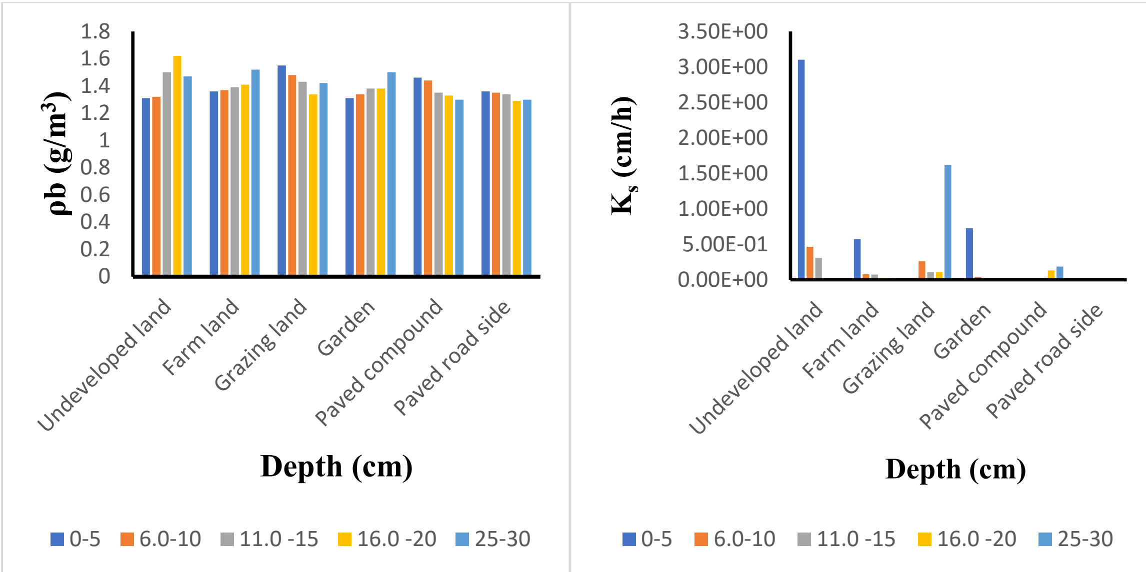

Figure 3.1a: Average Bulk Densities of the Five Study Locations as a function of depth and figure 3,1b: A function of depth for the various study locations

(b)

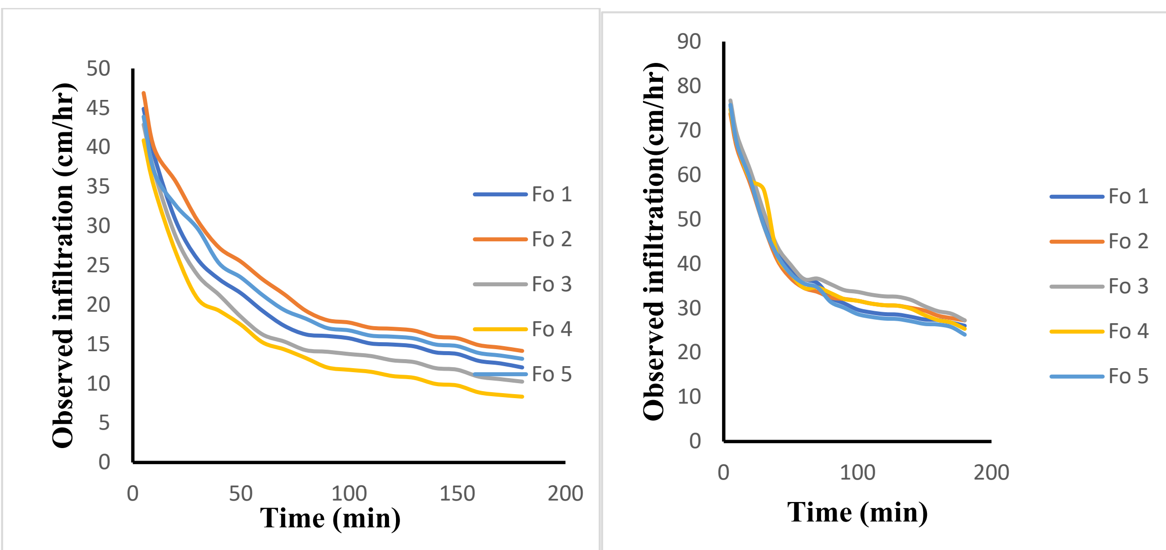

Figure 3.2: Infiltration Rate Curve (a) undeveloped land (b) Farm land

(b)

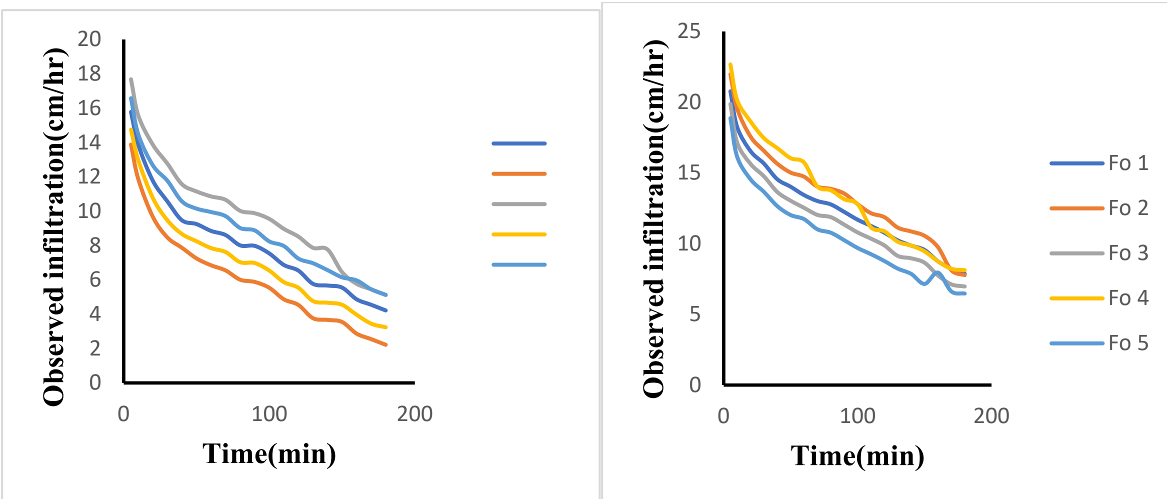

Figure 3.3: Infiltration Rate Curve (a) grazing land area (b) gardened area

(b)

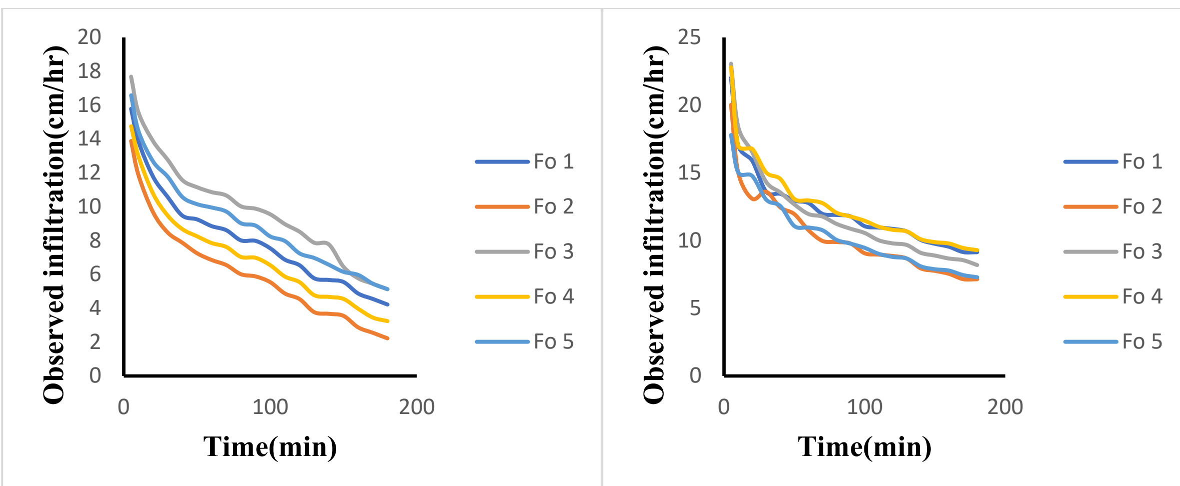

Figure 3.4: Infiltration Rate Curve (a) grazing land area(b) Paved Road side

4. Conclusion

Based on the results obtained, it can be deduced that Philip equation gives the best estimate of infiltration rates compared to Kostiakov and Horton equations. The suitability of Philip equation is as a result of dry soil conditions, and sandy soils with high saturated hydraulic conductivity values at majority of the sites (Undeveloped land, Farm land and Grazing land).

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ENVIRONMENTAL AND SOCIO-ECONOMOCAL IMPACT ASSOCIATED WITH IRRIGATED AGRICULTURE IN NORTHERN NIGERIA

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Abstract

Irrigation is the artificial supply of water to farmlands in the absence of rainfall or insufficient rainfall. This has become a norm especially in arid and semi-arid region of Nigeria to meet with the country challenges of projected food insecurity if appropriate measures are not put in place for a productive Agriculture. The objective of this study was to evaluate the environmental and socio-economic impacts associated with irrigated agriculture during the dry spells in Northern Nigeria. From the study a total of about 450,000 hectares of rice plantation and 50,000 hectares of crops including millet, sorghum, maize and sugarcane were. A total of 86 people were reported dead, A 3% decrease in rice production leading to increase in prices of rice while a total 37,754 people were displaced in six states (Kano, Borno, Zamfara, Katsina, Anambra and Nasarawa). The consequences, forms of manifestations of the impacts and Recommendations to appropriate responses to this very insidious phenomenon that challenge the sustainable development of irrigation in our country were recommended.

Keywords: *Irrigation, Food Security, Impact, Environment, Agriculture*

Introduction

Water is a precious natural resource, a basic human need and a prime national asset. The extent of water availability and water quality influences the extent and quality of human, animal and plant life. Human civilization is increasing rapidly leading to advances of scientific and technological innovations, thus changing the condition of life on earth and leading to transformation of the environment (Michael, 2009). Irrigation has contributed significantly to poverty alleviation, food security and improving the quality of life for rural populations, however sustainability of irrigated agriculture is being questioned both economically and environmentally, as the dependence on irrigation increases over the years, it came with some negative impacts on the environment and on humans.

The irrigation water provides moisture to plant growth by transporting essential nutrients, it also supplies water for leaching salts in soils and to cool the soil and the atmosphere to create a more favorable environment for plant growth (Ali, 2011). Irrigation has widely been adopted especially in arid and semi-arid regions of Nigeria to meet with current and future economic development of the country, which can only be achieved through an integral water resources management to attain a balance between food security, socio-economic development as well as environmental impacts (FAO,2011; Abubakar,2021).

Notwithstanding, adoption of irrigation systems have proven to be associated with problems of natural degradation, ineffectiveness and non-rational use of water supply, water logging, pollution, depletion deforestation etc. Proper management of irrigation systems requires reorientation from managing irrigation as an isolated response to food production, to one that treats it as part of a wider vision of economic development by focusing on irrigation water efficiency as well as improving water production under rain fed conditions**.**

The objective of this report is to evaluate the socio-economic and environmental impacts of surface irrigation during dry spells in Northern Nigeria.

2. Materials and Method

2.1 Study Areas

The study area is across some selected States in North East (Adamawa, Bauchi, Borno, Gombe, Yobe), North-West (Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto, Zamfara) and North Central (FCT, Kogi, Kwara, Nasarawa, Niger, Plateau, Taraba) of Nigeria.

2.2 Data Source

The data used for this study was obtained from the Annual Performance Survey report in year 2020 through interviews with farmers, using an open data kit (ODK) application connected to NAERLS server.

2.2 Data Analysis

Data analysis was done using IBM SPSS Statistics Version 26 as well as Microsoft Excel.

3. Results and Discussion

There were various problems resulting to environmental and socio-cultural impact associated with a surface irrigated agriculture in Northern Nigeria in 2020.Some of the impacts are described below;

3.1 Socio-Economic Impacts

The greatest socio-economic problem associated with irrigation is in high initial investment with the hope of comfortable profit at the end of harvest. This is not usually the case as farmers are faced with the depletion of natural resources, recent rise as well as additional risks and further unpredictability of harvests for farmers due to climate change as seen in Flooding of Agricultural Farmlands in 2020. (Mohammed, 2002; Evan,1972; Smith and Smithers, 1994; Wall and Smit,2005)

Table 3.1shows the socio-economic impacts resulting to decrease in rice production in 2020.

Table 3.1: Land Area and Production Output for Rice States

State	Land Area ('000) Ha			Production ('000) MT			Yield (Ton/Ha)	
	2019	2020	% Change	2019	2020	% Change	2019	2020
Adamawa	58.37	58.75	0.65	139.96	140.02	0.04	2.40	2.38
Bauchi	44.68	46.31	3.65	94.27	95.37	1.17	2.11	2.06
Benue	26.97	27.67	2.60	50.65	51.22	1.12	1.88	1.85
Borno	18.51	19.04	2.89	70.35	70.40	0.07	3.80	3.70
Gombe	50.14	51.78	3.28	89.84	91.04	1.33	1.79	1.76
Jigawa	29.57	30.46	3.02	78.46	79.89	1.83	2.65	2.62
Kaduna	31.99	32.90	2.85	103.49	105.05	1.52	3.24	3.19
Kano	50.80	51.80	1.97	117.89	124.44	5.56	2.32	2.40
Katsina	38.77	38.82	0.13	106.95	111.55	4.31	2.76	2.87
Kebbi	45.08	46.21	2.50	126.62	127.69	0.84	2.81	2.76
Plateau	39.80	41.39	3.99	51.47	53.87	4.66	1.29	1.30
Sokoto	31.44	32.32	2.80	123.10	142.13	15.46	3.92	4.40
Taraba	19.52	25.57	30.99	76.76	81.00	5.52	3.93	3.17
Yobe	49.30	50.30	2.03	94.06	94.12	0.07	1.91	1.87
Zamfara	27.97	28.99	3.66	126.49	130.91	3.49	4.52	

Rice is a major staple food in Nigeria which is cultivated across the six agro-ecological zones of the country. The estimated crop area for rice in 2020 was 4,195,070 Ha, which represented an increase of about 1.66% over the 4,126,670 Ha cultivated in 2019. The surge in the price of rice triggered increase in the land area cultivated by farmers in 2020. However, due to the surface irrigation technique adopted in it cultivation, there was flooding in some States like Jigawa, Kebbi, Kano, Sokoto and Kaduna, which lead to a decrease by 3%, that is, from 8,435,610 tons in 2019 to about 8,171,750 tons in 2020.

3.2 Environmental Impact

The study from the 2020 survey confirmed the occurrences of flood except in Benue State well as impact of surface irrigation in some States. Table 3.2(a) and 3.2(b) show respectively, the states affected in northern area of Nigeria and nature of impact of the flood according to the agro-geological zones in Nigeria. Houses, crops, bridges and human life were also lost. Flood situations were reported in almost all the States in Northern Nigeria with the exception of Benue State (APSR,2020).

Table 3.2(a): States that were affected by flood according to agro-ecological zones

Agro-ecological Zone	Affected States
North East	Adamawa, Bauchi, Borno, Gombe, Yobe
North West	Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto, Zamfara
North Central	FCT, Kogi, Kwara, Nasarawa, Niger, Plateau, Taraba

Table 3.2 (b): Nature of impact of the flood according to agro-geological zones

Zone	States	Crop/Infrastructure Affected
North East	Adamawa, Bauchi, Borno, Gombe, Yobe	Livestock and Crops and
North West	Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto, Zamfara	Livestock and Crops (rice, maize)
North Central	FCT, Kogi, Kwara, Nasarawa, Niger, Plateau, Taraba	Livestock, Crops, infrastructures and lives

Basically, rice is grown in swamp areas close to water bodies and are irrigated via the surface irrigation method during the dry spells, but due to excessive rainfall in 2020 which resulting in flooding of farm lands, over 450,000 hectares of rice plantation were submerged while another 50,000 hectares of crops including millet, sorghum, maize and sugarcane were affected in states like Kebbi and Jigawa State. In Kebbi about 25% of rice planted in 2020 was lost. Also, the chemicals/Fertilizers and Animal manure applied at the initial stage of cultivation were washed off and contaminants potable sources of water which if not properly treated before consumption could lead to some disease like goiter, birth defects, heart disease and stomach, liver and esophagus cancers (Conway and Pretty, 1991; Bhandari, 2014).Irrigation systems if not properly managed, can become breeding sites for vectors that transmit malaria and schistosomiasis diarrhea, cholera to a community(Ampadu *et. al*., 2015). It can also result to contamination of ground and potable water, fisheries as well as the aquatic ecosystems (Ofoezie, 2002). Also, the problem of salinity and water logging was not also left out in affected region.

4. Conclusion

From the study, social and environmental impacts of irrigation have reached a point where agricultural production is compromised. A decrease in 3% in the most popular staple food in Nigeria was recorded resulting to increase in its price, over 50,000 Hectare of agricultural land was lost,86 number of people was also recorded dead, as well as loss in various agricultural produce. Therefore, mitigating these impacts would require a holistic and multidisciplinary/multi-sectoral approach to achieve food security, through enhanced water use efficiency as well as expansion of irrigated land qualitatively and quantitatively.

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PRECISION FARMING, SOIL CONSERVATION AND IRRIGATION AS VERITABLE IMPETUS FOR BOOSTING AGRICULTURAL PRODUCTIVITY

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Abstract

Agricultural production takes place in an environment characterized by risk and uncertainty. This is particularly so in arid and semi-arid zones where water supply to crops from rainfall is variable and erratic. Even in areas under irrigation, water scarcity is not uncommon and yields are often affected, therefore procedures and tools are needed to apply precise and correct amount of inputs like water, fertilizer, pesticides and others at the correct time to the crop to reduce uncertainty and to manage risk in order for increasing its productivity and maximizing its yields. Precision agriculture along with Wireless Sensor Network (WSN) is the main drivers of automation in the agriculture domain. It uses specific sensors and software to ensure that the crop receive exactly what they need to optimize productivity. It involves retrieving real data about the conditions of soil, crops and weather from the sensors deployed in the fields. An aim of precision agriculture is to create a decision support system (DSS) for whole farm management with the aim of boosting agricultural productivity while preserving resources. This study highlighted the factors affecting agricultural productivity. The various ways in which soil conservation enhances agricultural productivity as well as the methods and techniques of soil conservation were discussed, while the concept of irrigation and roles in boosting agricultural productivity was enumerated. This paper seeks to illuminate the concept of precision farming, merits, importance and challenges. Investment in developing new farming techniques and in researching new approaches to farming need to be on a daily basis

Keywords: *Agricultural productivity, irrigation, precision farming, sensors, soil conservation*

Introduction

Agriculture constitutes about one-fifth of Africa's GDP. It is about half of the total value of exports in this continent. Yet more than two-thirds of the population live in rural areas while over 85% of the population in these regions depend on agriculture for their livelihood. Agricultural productivity is important to the economy of a nation. It is a key driver for the well-being of farmers, the agro-based industry and the general economy. It is linked to food security, food prices, and poverty alleviation in the developing countries (Darku and Malla, 2010). In addition, food supplies have to be geared towards meeting the challenges of increasing global population, changes in income, and the resultant changes in diet (Bruinsma 2009). Hence, research on agricultural productivity is of paramount importance. There are indices indicating increases in agricultural productivity which includes reduced poverty, real income changes, employment generation, non-farm livelihood assets, access to education and health. Agricultural production takes place in an environment characterized by risk and uncertainty. This is particularly so in arid and semi-arid zones where water supply to crops from rainfall is variable and erratic. Even in areas under irrigation, water scarcity is not uncommon and yields are often affected, therefore procedures and tools are needed to apply precise and correct amount of inputs like water, fertilizer, pesticides and others at the correct time to the crop to reduce uncertainty, and to manage risk in order to increase productivity and maximize crop yields. Low agricultural productivity may be a consequence of low fertilizer use, the loss of soil fertility, low technology, and rain-fed farming systems (Darku and Malla, 2010). A number of different factors can cause agricultural productivity to increase or decrease. It is important to note that productivity is not an absolute measure, but rather a reflection of the ratio between inputs and outputs. Factors affecting agricultural productivity are as follows:

Weather - unusual weather patterns, such as drought, a prolonged rainy season, early or late frosts and other factors can ruin crops and bring productivity down

The Capacity of a Given Farm - soil can't be forced to produce beyond capacity, although there are methods that can be used to improve production capacity, such as proper fertilizing to add nutrients to the soil so that it can support more crops

Pests occurred or not by certain weather conditions - in addition to spoiling crops, pests can add significantly to the costs of producing a crop. Controlling them may require measures such as fencing, chemical or biological treatments, companion planting or crop rotation, all of which change the ratio of inputs to outputs

Available Equipment - in regions where access to mechanized farm equipment is low, agricultural productivity can also be low as people handle their crops primarily by hand. This involves a big investment of time, energy and money and also limits the total capacity of the land

The Supply and Demand in the Market - farmers will adjust their activities to meet the needs of consumers and this can have an impact on agricultural productivity. In some cases, governments even pay subsidies to farmers to compensate them for not growing crops, which can skew productivity measures.

In order to boost agricultural productivity, the following agricultural productivity innovation key factors must be adopted such as soil conservation, irrigation and precision farming

2.Soil Conservation

2.1 Soil Conservation: meaning and benefits

Soil conservation is a "combination" of practices used to protect the soil from degradation. It involves treating the soil as a living ecosystem, and recognizing that all the organisms that make the soil their home, play important roles in producing a fertile healthy environment. Soil conservation enhances agricultural productivity, but also ensure soil structure and contents are preserved when diverse methods or techniques are employed for soil conservation, such as were highlighted by Olson et al. (1999), Schwab et al. (2002), Blanco and LaI (2008), and Sureh (2010; 2012).

Soil Conservation enhances agricultural productivity as follows:

To maintain an adequate amount of organic matter and biological life in the soil. These two components promote soil productivity which enhances crop yield

To ensure a secure food supply at reasonable prices. Soil conservation is proven to increase the quality and quantity of crop yields over the long term because it keeps topsoil in its place and preserves the long-term productivity of the soil.
To save farmers money. It prevents erosion that contributed to lost income due to lower crop yields, and the loss of nutrients from the soil.
To improve water quality. All forms of life need clean water to survive. Agricultural and urban soil erosion is major sources of sedimentation and contamination of water supplies.
To improve wildlife habitat: It provides buffer strips and windbreaks, or replacing soil organic matter, greatly enhance the quality of the environment for wildlife of all kinds.
For aesthetic reasons: To provide more attractive and picturesque scenery.
To help create an environment free of pollution where we can live safely.
For the future of our children, so that they may have enough soil to support life. It has been said that the land has not so much been given to us by our forefathers, but has been borrowed from our children.

2.2 *Methods and Techniques of Soil Conservation*

Many different techniques have been invented throughout the years with the aim of preserving the nutrient level of the soil, preventing erosion and enhancing agricultural productivity.

Keyline Design: It refers to topographic feature linked to water flow and a version of contour plowing. It allows the water runoff to run directly into an existing water channel, and prevent soil erosion caused by the water
Terrace Farming: Terracing is a method of carving multiple, flat leveled areas into hills. Steps are formed by the terraces which are surrounded by a mud wall to prevent run off and hold the soil nutrients in the beds. More commonly found in lesser developed nations due to the difficulty of using mechanized farming equipment in the terraces**.**
Contour Plowing: It involves plowing grooves into the desired farmland, then planting the crop furrows in the grooves and following the contours. It a very effective way for farmland on slopes to prevent runs off improves crop yields
Perimeter Runoff Control: This is the practice of planting trees, shrubs and ground cover around the perimeter of your farmland which impedes surface flows and keeps nutrients in the farmed soil.
Windbreaks: Planting of rows of tall trees in dense patterns around the farmland and prevents wind erosion.
Cover Crops/ Crop Rotation: Cover crops such as legumes and radishes are rotated with cash crops in order to blanket the soil all year- round and produces green manure the replenishes nitrogen and other critical nutrients. Using cover crops can also suppress weeds.
Soil Conservation Farming: A mixture of farming methods intending the mimic the biology of virgin land. These practices can be used to prevent erosion and even restore damaged soil and encourage plant growth. Eliminating the use of nitrogen fertilizer and fungicides can increase yields and protect crops from drought and flooding.
Agrostological Measures: Planting grass in heavily eroded areas is called an agrostological measure. Ley farming practices cultivating grass in rotation with regular crops to increase the nutrient level in the soils. When the grass is harvested it can be used as fodder for cattle.
No till farming: This is the method of growing crops year-round without changing the topography of the soil by tilling or contouring. This technique increases the amount of water that penetrates the soil and can increase organic matter of the soil which leads to larger yields.
Green Manures: Green manures are a few different crops that can be grown, not for produce or food usage, but grown in order to fertilize the farm land on which it grows. This method can improve the soil structure and suppresses the growth of weeds.
Salinity Management: When water evaporates from the soil, it leaves behind its salt. This can lead to damage of the soil and nutrient loss. Using humic acids can prevent this or growing crops like saltbush can rejuvenate the soils and replace lost nutrients. High levels of salt in the soil can often be caused by changes made to the water table by damming and other causes.

Stream Bank Protection: During floods, stream banks can often cave by constructing walls along the banks or plant useful tree species will prevent this in the future and prevent soil loss down the stream.

Earthworms: Earthworm casts contain a vast amount more nutrients than any natural soil in the world, and for that reason should be invited into the soils of farmland to help prevent erosion and will lead to larger crop yields.

Mineralization: Crushed rock or chemical supplements are added to the farmland, this helps combat mineral depletion. Normally used after flooding, it brings substantial amounts of sediment which can damage the nutrient level of the soil.

Korean Natural Farming: This method takes advantage of natural and indigenous microorganisms to produce fertile soils that yield high output and gets rid of the need to use herbicides or pesticides. An improvement in soil health and output is what keeps this method used in the respective areas.

Reduction of Impervious Surfaces: Driveways patios and paved pathways allow precipitation to flow freely off them. As the water flows it picks up momentum and in turn erodes any soil in which it flows over after leaving the impervious surfaces, reducing the amount of these around your farmland will prevent erosion.

Dry Farming: In areas with a very low amount of rainfall, crops which require very little water should be grown; this will lead to the preservation of the natural levels of moisture and nutrients in the soil.

Rain Gardens: A rain garden is a shallow depression in the land which holds and collects running water from impervious surfaces and prevents erosion while saving the nutrients that inevitably get washed away. This also gives you a good bed to grow wetland plants.

Re-establish Forest Cover: A dense amount of trees in a forest leads to a vast network of deep roots that offer a long term solution to soil erosion, another benefit is the windbreak that these trees can provide.

Maintaining pH levels of soil: Contamination of soils due to acid rains and other pollutants can lead to loss of soil fertility. Use a pH indicator monthly to check the levels of acids in the soil and treat the soils with eco-friendly chemicals to prevent a loss of crops and low yields.

Indigenous Crops: The growth of indigenous crops is a good way to conserve soil, as the plants have a natural need for the nutrients in the soil in your area; they help to prevent soil erosion.

Prevent Overgrazing: Try not to let overgrazing happen by moving herds around often. If overgrazing occurs, plant hardier and more nutritious species of forage in order to rebuild the soil. You can also harvest these crops and feed them to the grazers during the winter season.

The Sharing of Knowledge: More developed countries can and should share their farming knowledge gained throughout the years with the lesser developed nations of the world. This will lead to a better quality of soil worldwide and can help to prevent famine and solves the food crisis in some areas of the world.

3. Irrigation

Agriculture production and water use are inextricably linked. Water has always been the main factor limiting crop production especially in arid and semi-arid zones where rainfall is insufficient to meet crop demand. A lot of factors increasing competition for finite water resources globally and the demand of agricultural produce steadily rising, it is imperatively necessity to improve the efficiency and productivity of water use for crop production, to ensure future food security and maintaining environmental sustainability. Drip irrigation is the latest technology of irrigation, is also known as trickle irrigation, it is an improved form of the sub-surface irrigation (Sureh, 2010). In this system water is supplied directly to the soil near the root of the plants through special outlet device called an emitter or dripper. Drip irrigation enhances agricultural productivity as follows:

It provides an excellent control on water application.
Minimized water loss by evaporator, seepage, deep percolation.
The level of soil moisture deficit in the root zone can be maintained to a very low level.
Application of fertilizers and plant nutrients directly to the root zone.
Saving of irrigation water.

It reduces soil erosion.
Increase yield.
In the absence of superfluous flow of irrigation water weed growth is minimum. It results in saving of farm labour charges.

4. Precision Agriculture (PA)

The world is witnessing rapid growing human population which has been attributed to increase food demand for people survival on the earth. One of the challenges of any nation is meeting the food requirements with limited resources of the earth. Several technologies are being used in the agriculture area to boost agricultural productivity to cope with this challenge. Precision farming is one of emerging technologies and also known as digital farming. It can also be referred to as satellite farming or site-specific crop management (SSCM) that employs farm management concept based on observation, measurements and then responding to inter and intra field variability within crops (McBratney *et al.,* 2005). It can be defined as an application of precise and correct amount of inputs such as water, fertilizer, pesticide and others at the correct time to the crop for increasing its productivity and maximizing its yields (Reyns *et al*., 2002). It is comprised of near and remote sensing techniques using Internet of Things (IoT) sensors, which help to monitor crop states at multiple growth levels (Wang et al., 2006). PA along with Mobile Wireless Sensor Network (WSN) is the main drivers of automation in the agriculture domain. It uses specific sensors and software to ensure that the crop receive exactly what they need to optimize productivity. It involves retrieving real data about the conditions of soil, crops and weather from the sensors deployed in the fields. An aim of precision agriculture is to create a decision support system (DSS) for whole farm management with the aim of boosting agricultural productivity while preserving resources. The merits and importance of precision agriculture were highlighted by Wang et al. (2006), Schieffer and Dillon (2015) and Abbasi et al. (2014).

Merits of precision farming:

It reduces the amount of nutrients and other crop inputs used while boosting yields (Pepitone, 2016)
It increases productivity on their investment since is saving water, pesticide and fertilizer costs
It maintains environmental sustainability which promotes agricultural sustainability whereby enhancing agricultural productivity
It boosting competitiveness through more efficient practices by improved management of fertilizer usage and other inputs
It prevents soil degradation in following ways:
It presents salt build up and leaching of nutrients which corrupt the quality of soil by creating undesirable changes in the essential soil chemical ingredients
It prevents misuses or excess use of fertilizer and pesticide: The excessive and misuse of pesticides and chemical fertilizers contributing to the killing of soil's beneficial bacteria and other micro-organisms that help in soil building and formation
It prevents salinization

Importance of precision farming to farmers

It builds up a record of their farm
It improves decision making
It fosters greater traceability
It improves lease arrangement and relationship with landlords
It enhances the inherent quality of farm products
It provides precisely what parameters are needed for healthy crop, where these parameters are needed and in what amount required at a particular instance of time

The main driver of PA is a Mobile WSN, which is a network of multiple wireless nodes connected to monitor the physical parameters of environment such as soil properties, cropping practices, climatic conditions, moisture level, weeds and disease (Abbasi et al., 2014). WSN is comprised of a radio transceiver, a micro-controller, sensor (s), an antenna, along with other circuitry that enables it to communicate with some gateway to transmit information collected by the sensor(s). Wireless sensor nodes are equipped with sensing unit, a processing unit, communication unit and power unit (Abbasi et al., 2014). Each and every node is capable to perform data gathering, sensing, processing and communicating with other nodes. The sensing unit senses the environment, the processing unit computes the confined permutations of the sensed data, and the communication unit performs exchange of processed information among 3 neighboring sensor nodes.

4.1 *Mobile WSNs*

These networks consist of a collection of sensor nodes that can be moved on their own and can be interacted with the physical environment. The mobile nodes have the ability to compute sense and communicate. The mobile wireless sensor networks are much more versatile than the static sensor networks. The advantages of MWSN over the static wireless sensor networks include better and improved coverage, better energy efficiency, superior channel capacity, and so on.

The others driver of PA includes robots, drones and satellite imagery, the internet of things (IoT) and Smartphone applications (Pepitone, 2016, Al-Sarawi et al., 2017, Goap *et al.,* 2018).

4.2 *Robots*

Agricultural robots, also known as AgBots, already exit. We have advanced developed harvesting robots that identify ripe fruits, adjust to their shape and size, and carefully pluck them from branches.

4.3 *Drones and satellite imagery*

Drones take high quality images, while satellite capture the bigger picture. Light aircraft pilots with combination of aerial photography with data from satellite records to predict future yields based on the current level of field biomass.

4.4 Internet of Things (IoT)

The Internet of Things is the network of physical objects outfitted with electronics that enable data collection and aggregation. It operates through the uses of sensors and farm-management software (Pepitone, 2016)

4.5 Smartphone applications

Smartphone come with many useful applications storage devices include camera, microphone, Global Positioning System (GPS) accelerometer. They are simple, portable, affordable, and have a high computing power (Suporn et al., 2015). It is useful in various agriculture applications such as field mapping, tracking animal, obtaining weather and crop information, and more.

4.6 ***Machine Learning***: It is commonly used in conjunction with droves, robots, and internet of things devices. It allows for the input of data from of these sources which allows for more efficient and precise farming with less human manpower (Goap et al., 2018). The some of the most common sensors used in the agriculture domain that capture environmental parameters related to crops are presented in Table 1.

Table 1: Wireless nodes used in the agriculture domain

S/N	Sensor Name	Parameters Captured
1	ECH2O Soil moisture sensor	Soil Temperature, Soil Moisture, Conductivity

2	Hydra probe 11 soil sensor	Soil Temperature, Salinity level, Soil Moisture, Conductivity
3	MP406 Soil moisture sensor	
4	EC sensor (EC250)	Soil Temperature, Soil Moisture
5	Pogo portable soil sensor	Soil Temperature, Salinity level, Soil Moisture, Conductivity
6	107-L temperature sensor	Soil Temperature, Soil Moisture
7	237 leaf wetness sensor	Plant Temperature
8	SenseH2™ hydrogen sensor	Plant Moisture, Plant wetness, Plant Temperature
9	Field scout CM1000TM	Hydrogen, Plant Wetness, CO_2, Plant Temperature
10	YSI 6025 chlorophyll sensor	Photosynthesis
11	LW100, leaf wetness sensor	Photosynthesis
12	TT4 multi-sensor thermocouple	Plant Moisture, Plant Wetness, Plant Temperature
13	TPS-2 portable photosynthesis	Plant Moisture, Plant Temperature
14	PTM-48Aphotosynthesis monitor	Photosynthesis, Plant Moisture, CO_2
15	Cl-340 hand-held photosynthesis	Photosynthesis, Plant Moisture, Plant Wetness, CO_2, Plant Temp.
16	CM-100 Compact Weather sensor	Photosynthesis, Plant moisture, Plant wetness, CO_2, Plant Temp.H_2, L
17	Met Station One (MSO)	Air Temperature, Air Humidity, Wind Speed, Air Pressure

Source: (Abbasi *et al.,* 2014; Shafi *et al.,* 2019)

Similarly, there are various communication protocols due to increase in IoT devices and WSN technologies. The most commonly used protocols for wireless communication in IoT devices and WSN technologies-based applications in agriculture are presented in Table 2. Each protocol has its own specifications depending on the bandwidth, number of free channels, data rate, battery timing, price, power, topology, area cover and physical range. 6LoWPAN and ZigBee are considered to be more suitable for PA application because both are based on mesh networking, which makes them suitable to cover large area (Shafi *et al.,* 2019).

Table 2: Wireless communication protocols used in Precision Agriculture (PA)

Communication Protocol	Data Rate	Topology	Standard	Physical Range	Power
6LoWPAN	0.3 – 50 Kb/s	Star, Mesh	IEEE 802.15.4	2 – 15 Km	Low
ZigBee	250 Kb/s	Star, Mesh		10 – 100 m	Low

Bluetooth	1 – 2 Mb/s	Star, Bus	IEEE 802.15.4	30 m	Low
RFID	50 tags/s	P2P	IEEE 802.15.1	10 – 20 cm	Ultra low
LoRaWaAN	27 – 50 Kb/s	P2P, Star	RFID	5 – 10 Km	Very low
WI-FI	1 – 54 Mb/s	Star	IEEE 802.11ah	50 m	Medium
			IEEE 802.11		

Source: Shafi *et al*. (2019)

Some of common applications of wireless sensor networks used in agriculture are smart irrigation, smart fertilization, smart disease detection system and smart pest control systems (Heble et al., 2018)

Smart Irrigation system: It is an artificial irrigation application that controls the quality of water. It provides precisely amount of water required at a particular instance of time, which has a great impact on crops' hearth, cost and productivity. One of the major expect of smart irrigation system is avoid the wastage of water.

Smart Fertilization System: It is artificial application that gives optimal quantity of fertilizers needed for the growth of the plants. It provides fertilizers in a very precise amount in order to improve productivity

Smart Disease Detection system: It is artificial application that detects disease and gives early warning to the farmers.

Smart Pest Control system: It is artificial application that provides pesticide in a very precise amount in order to prevent misuses or excess

Challenges of Precision Agriculture:

PA has been proved to enhance crop yield with reduced costs and human effort, although the adoption by farmers is still very limited due to the following challenges (Abbasi et al., 2014; Shafi et al., 2019).

Hardware Cost: It involves high cost of installation especially drone-based systems for crops' health monitoring.

Weather Variations: It is one of major challenges and it affects the accuracy of data collection. This is caused by interruption due to interference induced in between wireless nodes and atmospheric disturbance.

Data Management: It generates immense amount of data, which require high resources to perform data analysis. Besides, an intruder can corrupt the readings, false readings will adversely reduce the effectiveness of the system.

Literacy Rate: It influences the adoption ratio especially in underdeveloped areas where the literacy rate is not high. Besides, it is not very common due to the limitations of resources and education.

Interoperability: It is biggest challenges PA faces, due to different digital standards. It is slowing down their growth and inhibits the gain of production efficiency through smart agriculture applications.

5. Conclusion

This low agricultural productivity has been attributed to the low use of fertilizer, the loss of soil fertility, and traditional, low technology, rain-fed farming systems. Soil conservation, irrigation and precision agriculture enhance agricultural productivity. PA is a modern technology using latest technology that is WSN, IoT and Machine learning to enhance agricultural productivity by optimizing the resources such as water, fertilizers, pesticide and others. The adoption and deployment of PA is very low due to challenges such as resources and education especially in developing and underdeveloped areas. Investment in developing new farming techniques and in researching new approaches to farming need to be on a daily basis. The Government at all levels should establish irrigation scheme to assist farmers at low-rate charges. Government at all levels should train the farmers on new technologies of farming. Establishment of Soil and Water Conservation Society (SWCS) at communities' levels.

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EFFECTS OF POULTRY WASTES ON PHYSICOCHEMICAL AND BIOLOGICAL PROPERTIES OF SOIL

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Abstract

The effect of poultry manure application on physicochemical and biological properties of sandy clay loamy soil was conducted in a controlled chamber of Federal College of Agriculture, Ibadan using three different poultry wastes (Broiler, Layer, and Cockerel) collected fresh from the poultry farm while the soil samples used were collected from the Teaching and Research Farm. The soil samples were air-dried, pulverized and sieved. 7.0 kg of soil each was filled into four buckets labelled A, B, C and D, while 2.0 kg each of different poultry wastes from Broilers, Layers, and Cockerels was mixed with the soil samples already in the four buckets. Buckets A, B, C, and D designated as broiler waste soil, layer waste soil, cockerel waste soil, and control soil (no application of waste) respectively were replicated four times for each sample. After the application of wastes, 75cl of distilled water was applied to each bucket and stimulated to ensure that the waste goes into the soil. The samples were thereafter taken to laboratory in order to analyze for various soil properties. Pre-soil analysis of the samples used was initially carried to establish the basic properties of soil and the textural class of soil sample used for the experiment. The results of One-way ANOVA showed that there are significant differences in the bulk density, particle density and porosity among the three soil samples with poultry wastes and the control sample with no waste ($F = 336.759, 12.605, 592.713$ respectively, $df = 15$, $P < 0.05$). However, there are no significant differences in moisture content, DO, BOD_5, COD and pH among the three samples with poultry manure and the control sample with no waste ($F = 0.006, 0.157, 0.002, 2.116, 0.282$ respectively; $df = 15$, $P < 0.05$). Hence, it can be deduced that the application of different poultry wastes has different effects on the soil properties with cockerel waste having the highest effect almost on the all-soil parameters except for bulk density where broiler has the highest and pH where layer also has the highest effect.

Keywords: Poultry manure, soil properties, bulk density, organic matter, environment.

1. Introduction

The poultry industry is one of the major employers of labour in South Western Nigeria with dominance production in Ogun, Osun, and Oyo State (Odunsi and Farinu, 1997). Historically, some of the advantages of poultry over other livestock shows in the growth of poultry industry which began as a result of its high level of energy and protein yield, rapid turnover rate and short incubation period (Mokwunye, 2000). This growth is also attributed to population increase and rising demand for poultry meat and egg product probably because poultry meat is low in cholesterol content (Bolan *et al.,* 2010).

In the developing nations such as Nigeria, the rate of expansion of small and medium scale poultry farms is so rapid associated with the effect of huge waste generation. The extent of this generated poultry waste has resulted to inappropriate disposal which include improper application timing thus creating pollution problem to soil water and air environment. According to Adeoye *et al*. (2004), the various modern management methods for poultry waste such as re-feeding to animals; green disposal, gasification and biogas production have not really gained importance in Nigeria possibly due to awareness level, lack of strict regulation from government in respect to animal waste disposal and care-free attitude of the farm owners.

Soil, the loose material that covers the land surface of the earth, is a loose combination of inorganic and organic materials. The organic materials are composed of debris from plants, decomposition of many tiny life forms which inhabit the soil and also manure that is applied to the soil. Soil physical properties are those features which can be seen with the eye or felt. They are the result of soil parent materials being acted upon by climatic factors (such as rainfall and temperature), and affected by topography (slope and direction,) and life forms (kind and amount such as forest, grass, soil animals) over a period of time. A change in any of the influences typically results in a difference in the type of soil formed (Tayel and El-Hady, 2005).

Soil physical and chemical properties have great influence on agricultural related activities such as tillage, erosion, drainage, and irrigation which could in turn affect crop production either positively or negatively. These properties of the soil are very important for the sustainable use of soil for agricultural production since the amount and rate of water, oxygen, and nutrient absorption by plants depend on the roots' ability to absorb the soil solution as well as the soil ability to supply it back to the roots. María, *et. al.* (2018) revealed that, some soil properties such as low hydraulic conductivity, can limit the free supply of water, oxygen and even nutrients to the roots of plants thereby affecting negatively their yield. This is because soil in itself is not essential to a growing plant but only serves as a reservoir for nutrients, air and water needed by the plant.

In order to improve the structure of soil for greater productivity, the soil primary mineral particles are usually added with organic materials to form small clusters or aggregates (Walia and Dick, 2008). This added organic matter in the soil acts as a cement that can help the formation of these aggregates and, therefore, the soil structure. Without the aggregate structure, medium and fine-textured soils such as loams and clays would be nearly impermeable to fluids and gases. Also, the soil organic carbon has greater effect on aggregation especially in coarse-textured soils. This shows that organic matter is the key components of soil structural stability (Watts, *et. al*., 2006).

Animal excreta from modern intensive farms contain some harmful components, such as heavy metal, pathogenic microorganisms, and veterinary drugs (Zhang *et al.,* 2005). Detrimental impacts on soil quality may occur after long-term application of animal excreta. Soil physical properties, such as soil pore structure and aggregate stability, were the basal indicators to define soil quality. The pores in the soil play very important role in formation of soil structure, maintenance of soil moisture and nutrients, and protection of microbial diversity, while aggregate stability has a positive impact on the germination of seed, plant roots and development of shoots.

Poultry waste can help to cement soil aggregates and thus to increase their strength. It has been proven over time that Ammonia and hydrogen sulphide contents could increase odour potential, contains major amount of uric acid which can decomposed readily and improve soil tilt (Meck and Westman, 2002). Manure has several effects when added to the soil including manure contains nitrogen (as ammonium), phosphorus, potassium and micro-nutrients that can be used directly by plants. These compounds also trigger-off biological activities which make nutrients in the manure and organic matter available to plant. The objective of this research is to characterize poultry wastes from Broiler, Layer and Cockerel, while using the wastes to amend the soil and thus investigating the resultant effect of the wastes on the soil properties.

2. Methodology

2.1 *Soil/Waste Collection and Sampling*

The experiment was conducted in the Controlled Chamber of Federal College of Agriculture, Ibadan using three different poultry wastes (Broiler, Layer, and Cockerel) collected fresh from the poultry farm while the soil samples used were collected from the Teaching and Research Farm. The soil samples were air-dried, pulverized and sieved with a 2 mm mesh-sized sieve. 7.0 kg of soil each was filled into four buckets used for the experiment which are labelled A, B, C, and D. 3.0 kg each of the three poultry wastes from Broiler, Layer, and Cockerel was collected from deep litter system. About 1.0 kg each of waste samples was taken to laboratory in order to analyze for waste characterization, while 2.0 kg each of the samples was mixed with the soil samples already in the four buckets.

Buckets A, B, C, and D designated for Broiler Soil, Layer Soil, Cockerel Soil, and Control Soil respectively were replicated four times for each sample. Control Soil was the soil with no application of poultry waste. After the application of wastes, 75cl of distilled water was applied to each bucket to ensure that the waste goes into the soil. The samples were thereafter taken to laboratory in order to analyze for various properties of soil.

2.2 *Soil Sample Analysis*

Pre-analysis of the soil used was initially carried to establish the basic properties of soil and the textural class of soil sample used for the experiment. The samples represented in each bucket were thereafter analyzed using standard test methods as shown below in order to determine the soil properties.

Bulk Density

The soil sample for bulk density was oven-dried at 105^{o}C and weighed, also the volume of soil sample was determined. The bulk density of the soil was calculated using following expression (Blake and Hartge, 1986).

$$Bulk\ Density\ (g/cm^3) = \frac{Mass\ of\ oven\ dried\ soil\ sample}{Volume\ of\ soil\ sample}$$

Moisture Content

The moisture content of the soil was determined using standard method as given below. 2.0 g each of the soil samples was put in moisture can and oven dried at 105°C for 24 hours until constant weight was attained after a period of cooling in a desiccator.

$$Mositure\ Content = \frac{Weight\ of\ wet\ sample - Weight\ of\ dry\ sample}{Weight\ of\ wet\ sample} \times 100\%$$

Dissolved Oxygen (DO)

The Winkler test, which is manual titration method, was used to determine the concentration of dissolved oxygen in the soil samples. Winkler (1888) first proposed the method and it was modified by Strickland and Parsons (1968). The analysis was performed in the laboratory to avoid delays that may result in a change in the oxygen content of the soil. It is usually expressed in mg/L.

Biochemical Oxygen Demand (BOD_5)

The biochemical oxygen demand (BOD_5) is a five-day test carried out to measure the quantity of oxygen required by bacteria to biologically oxidize organic material under aerobic conditions (Sawyer and McCarty, 1978). It is usually expressed in mg/L. The soil sample in this experiment was incubated for five days at 20^{o}C in the dark using a Winkler bottle to carry out the test.

Chemical Oxygen Demand (COD)

The chemical oxygen demand (COD) is a test carried out to determine the amount of oxygen that can be consumed by reactions in a measured solution and it is commonly expressed as mass of oxygen consumed per volume of solution (mg/L). COD is a measure of the amount of oxygen required for complete oxidation to CO_2 and H_2O of organic matter present in a sample. The COD test in this experiment was carried out using 0.5 N solution of potassium dichromate in 50% sulphuric acid under standard temperature condition using ASTM standards.

pH

The pH of the sample was determined using a glass electrode digital pH meter i.e. by potentiometric method (Brady and Weil, 1990).

Particle Density

Particle density has been defined as the density of the solid particles that make up a soil sample which is expressed in grams per cubic centimetre. The particle density of the samples was determined by volumetric flask method, which is given by the following equation (Bashour and Sayegh, 2007).

$$Particle\ Density\ (g/cm^3) = \frac{Mass\ of\ oven\ dried\ sample}{Volume\ of\ soil\ solids\ only}$$

Porosity

Porosity is the volume of soil voids that can be filled by water and/or air. It is inversely related to bulk density. The porosity of the samples is calculated by the equation below (Tarighi *et al.,* 2011; Naderiboldhaji *et al.,* 2008)

$$Porosity = (1 - \frac{Bulk\ Density}{Particle\ Density}) \times 100\%$$

2.2 *Data Analysis*

The experimental data were statistically analysed by One-way Analysis of Variance and the post-hoc analysis was done to further compare and check the levels of significance and variations among the parameters of the soil. The experimental layout adopted was Randomized Completely Block Design (RCBD) replicated four times as shown in Table 1.

Table 1: Experimental Layout

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
	R_1	R_1	R_1	R_1	R_1	R_1	R_1	R_1
T_1	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2
	R_3	R_3	R_3	R_3	R_3	R_3	R_3	R_3
	R_4	R_4	R_4	R_4	R_4	R_4	R_4	R_4
	R_1	R_1	R_1	R_1	R_1	R_1	R_1	R_1
T_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2
	R_3	R_3	R_3	R_3	R_3	R_3	R_3	R_3
	R_4	R_4	R_4	R_4	R_4	R_4	R_4	R_4
	R_1	R_1	R_1	R_1	R_1	R_1	R_1	R_1
T_3	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2
	R_3	R_3	R_3	R_3	R_3	R_3	R_3	R_3

	R_4	R_4	R_4	R_4	R_4	R_4	R_4	R_4
	R_1	R_1	R_1	R_1	R_1	R_1	R_1	R_1
T_4	R_2	R_2	R_2	R_2	R_2	R_2	R_2	R_2
	R_3	R_3	R_3	R_3	R_3	R_3	R_3	R_3
	R_4	R_4	R_4	R_4	R_4	R_4	R_4	R_4

Where:

P_1, P_2, P_3, P_4, P_5, P_6, P_7, and P_8 represent the various soil properties analyzed (Bulk Density, Moisture Content, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, pH, Particle Density, and Porosity respectively).
T_1 is the soil sample with broiler waste (Broiler Soil), while T_2 is the soil sample with layer waste (Layer Soil); T_3 is the soil sample with cockerel waste (Cockerel Soil), and T_4 is the soil sample with no waste application (Control Soil).
R_1, R_2, R_3, and R_4 are the replicates of each sample.

3.Results and Discussion

The particle size distributions of the soil samples are shown in Table 2. From the textural analyses, it was discovered that the soil is sandy clay loamy with sand ranging between 83-86% while silt ranges between 10-12% and clay ranges between 2-5% among all the soil samples with the control soil inclusive. It was observed that the soils have very high sand content leading to high water infiltration, and low water holding and nutrient storage capacities. The distribution of particle size places the soils in sandy – clayey – loamy textural classification.

Table 2: Particle Size Distribution of Soil Samples

Sample	**Sand**	**Clay**	**Silt**
Broiler Waste Soil	86.73	2.42	10.85
	86.05	3.07	10.38
	84.89	4.15	10.95
	83.90	5.32	10.79
Layer Waste Soil	85.20	4.03	10.78
	84.93	4.23	10.83
	83.88	3.64	12.48
	83.49	4.03	12.49

Cockerel Waste Soil	86.47	3.68	9.86
	85.87	3.62	10.52
	84.60	3.50	11.90
	83.78	3.90	12.32
Control Soil	84.17	5.52	10.31
	86.28	3.22	10.56
	85.93	3.27	10.81
	85.64	3.65	10.71

From the results of the characterization of poultry wastes (Table 3), it was observed that the application of different poultry manures has different effects on the engineering properties of the soil samples. It was observed that cockerel waste has the highest BOD_5 and COD values during characterization which has great effect on these two properties of the soil after the four treatments.

Adesodun *et al.* (2005) observed that application of poultry manure to soil increased soil organic matter, N and P and aggregate stability. The improvement in soil physical properties is capable of improving the soil organic matter content. According to Aluko and Oyedele (2005), the improvement in soil moisture which is associated with poultry manure is capable of increasing mulching effect of organic matter and improves the moisture holding capacity and receiving water as a result of improved soil structure and macro porosity.

Table 3: Characterization of Poultry Waste Samples

Parameter	**Broiler**	**Layer**	**Cockerel**
Moisture (%)	43.70	67.90	55.70
Total Solid (%)	81.75	90.90	86.84
Volatile Solid (%)	81.75	86.31	85.35
Fixed Solid (%)	3.30	3.31	3.30
Total Dissolved Solids (%)	1.48	1.29	1.20
COD (mg/l)	21.22	21.63	22.67
BOD_5 (mg/l)	16.82	16.66	17.88
Dissolved Oxygen (mg/l)	5.86	6.22	6.71

Nitrogen (%)	1.05	1.17	1.09
Phosphorus (%)	0.58	0.63	0.62
Potassium (%)	0.70	0.78	0.81
Organic Matter (%)	56.30	67.90	55.70
Organic Carbon (%)	46.38	44.62	45.97
NH_4-N (%)	0.016	0.016	0.011

From the results of physicochemical and biological properties (Table 4), it was observed the control sample has highest bulk density while cockerel sample has the least, which shows that the control sample (without waste application) has great effect on the bulk density of the soil followed by cockerel sample. It explained that the wastes generally have effect on the bulk density of the soil. For moisture content, control soil has the highest value with least value recorded for cockerel waste soil. The rate of oxygen dissolved was high for the second replications of all the waste and control soils.

However, BOD_5 and COD values fall almost in same ranges across all the waste soils and the control soil, meanwhile, the layer waste soil has the highest BOD_5 while broiler waste soil has the least BOD_5; the highest COD was recorded at cockerel waste soil and lowest COD at control soil. The pH of all the samples shows that the soil is slightly alkaline, as the values falls within same range. The particle density also ranges within same while the highest porosity was recorded for cockerel waste soil and least was recorded for control soil as porosity of broiler and layer waste soils fall within same range. The application of different poultry manures in the soil could be responsible for the high porosity.

It can be observed that the application of poultry manure has a positive impact on organic parameters of the soil as its continuous usage will increase the soil salinity and thus render it useless after some years of cultivation. Cockerel waste is hereby recommended more as it increases the organic properties most. From Table 4, the highest porosity was recorded from soil treated with cockerel waste (68.97-74.13). According to Alabadan, *et al.* (2009); this is good as it will improve the infiltration properties of the soil and the ease with which crop roots will penetrate the soil. The result also supports the earlier findings by Bauer and Black (1992) that application of organic manure enhances the promotion of biological activity which in turn increases the organic matter content of soil.

The results also revealed that application of organic manure increased nitrogen, phosphorus and potassium content of the soil. The availability of some elements and their supply to the plant during the period of growth is enhanced by organic manure. In addition, poultry manure increased the presence of P, K and Mg in the soil as a result of the continuous lowering of the pH by manure applications.

Table 4: Physicochemical and Biological Properties of Soil Samples

Sample	Bulk Density	Moisture Content	Dissolved Oxygen	BOD	COD	pH	Particle Density	Porosity
Broiler Waste Soil	0.89	28.50	6.45	16.72	26.18	7.78	2.65	66.65
	0.86	31.90	6.66	17.61	26.32	8.45	2.65	67.55
	0.77	23.30	4.41	15.77	21.77	7.69	2.57	69.81
	0.77	36.50	5.23	14.52	20.83	7.50	2.56	69.97
Layer Waste Soil	0.89	38.60	6.61	15.94	24.92	7.90	2.68	66.80
	0.87	26.10	6.64	16.49	25.13	8.51	2.66	67.28
	0.77	25.30	5.42	17.80	23.80	7.72	2.55	69.75
	0.77	29.20	5.30	14.62	22.91	7.95	2.55	69.95
Cockerel Waste Soil	0.88	29.70	6.44	16.84	25.69	7.48	2.84	68.97
	0.86	21.90	6.50	17.25	26.49	8.31	2.89	70.17
	0.72	32.10	5.46	14.87	24.87	7.87	2.76	73.81
	0.71	37.60	5.28	15.61	23.14	8.02	2.75	74.13
Control Soil	1.99	27.80	5.75	15.81	22.45	7.88	2.75	27.41
	1.98	27.20	6.25	16.30	22.69	8.50	2.72	27.25
	1.97	24.80	5.62	17.65	21.65	7.51	2.71	27.24
	1.97	39.60	5.28	14.92	21.52	7.08	2.71	27.27

One-way ANOVA in Table 5 shows that there are significant variations in the bulk densities among the three soil samples with poultry wastes and the control sample with no waste ($F = 336.759$, $df = 15$, $P < 0.05$). It was observed that the bulk densities were relatively low, indicating low degree of compaction which could have been responsible by the nature of the soil in that area and may not really favour plant growth and other agricultural practices due to the presence of manures. It can then be inferred from the analysis that poultry wastes have significant effect on the bulk density of soil samples. Akinyele *et al.* (2019) observed that the level of soil compaction is however measured by bulk density. Generally, high bulk density means less pore space for movement of water, root growth and germination of seedlings.

The results of analysis (Table 5) also reveals that there are significant differences in the particle densities among the three soil samples with poultry wastes and the control sample with no waste (F = 12.605, df = 15, P < 0.05). This suggests that the different poultry manures really impacted on the soil particle density. The soil particle density is measured by the mass of soil samples in a given volume and centres only on the soil particles and not the total volume occupied by the particles and pore spaces in the soil. It can be seen that the poultry wastes have significant effects on the soil particle density.

According to Table 5, the one-way ANOVA as well shows that there are significant variations in the porosities among the three soil samples with poultry wastes and the control sample with no waste (F = 592.713, df = 15, P < 0.05). A reduction in porosity is likely to prevent water infiltration which eventually results in increased run-off (Akinyele *et al.,* 2019). The sandy soil is responsible for the high porosity (Akinyele *et al.,* 2019). The study revealed that as the total porosity increased there is also reduction in soil bulk density, which also gave rise to in increased water infiltration and water holding capacity leading to decrease in soil temperature. It was observed that there was significant difference at P < 0.05 in the porosity values obtained and the implication is that the poultry wastes have impacted on the soil porosity.

However, same ANOVA results in Table 5 shows that there are no significant differences in moisture content, dissolved oxygen (DO), biochemical oxygen demand BOD), chemical oxygen demand (COD) and pH, among the three samples with poultry manure and the control sample with no waste (F = 0.006, 0.157, 0.002, 2.116, 0.282 respectively; df = 15, P < 0.05). Though the major organic properties are BOD_5, COD and DO and organic matter but it can be inferred that application of poultry manures has a cumulative effect on the biological properties of soil (Alabadan *et al.,* 2009). Other parameters follow the same trend as depicted even in the control sample. This means there is a direct relationship between the biological properties of the soil and the amount of poultry waste applied. It can also be seen that the acidic soils often show calcium, phosphorus and magnesium deficiencies while alkaline soils exhibit deficiencies in phosphorus and various micronutrients (Akinyele *et al.,* 2019).

Table 5: Analysis of Variance (ANOVA) of Effects of Poultry Wastes on the Soil Properties

Parameters		Mean	df	F	Sig.
	Between Groups		3	336.759	.000*
Bulk Density	Within Groups		12		
	Total	1.1044*	15		
	Between Groups		3	.006	.999
Moisture Content	Within Groups		12		
	Total	30.0063	15		
	Between Groups		3	.157	.923
Dissolved Oxygen	Within Groups		12		
	Total	5.8312	15		

	Between Groups		3	.002	1.000
BOD	Within Groups		12		
	Total	16.1700	15		
	Between Groups		3	2.116	.152
COD	Within Groups		12		
	Total	23.7725	15		
	Between Groups		3	.282	.837
pH	Within Groups		12		
	Total	7.8844	15		
	Between Groups		3	12.605	.001*
Particle Density	Within Groups		12		
	Total	2.6875*	15		
	Between Groups		3	592.713	.000*
Porosity	Within Groups		12		
	Total	59.0006*	15		

Note: Statistics is significant at $P < 0.05$*, Means with * in a column are significantly different

Table 6 shows the results of the post hoc test for multiple comparisons between the properties that are significantly different. It can be deduced for bulk density and porosity that three waste samples (Broiler, Layer and Cockerel) are significantly different from control sample, for particle density, it can be seen that broiler and layer waste samples are both significantly different from cockerel waste sample as the control sample against the other three samples does not show any differences.

Table 6: Multiple Comparisons between Significantly Different Properties at P < 0.05

Dependent Variable	**(I) Sample**	**(J) Sample**	**Mean Difference (I-J)**	**Sig.**
Bulk Density	Broiler Waste	Layer Waste	-.00250	1.000
		Cockerel Waste	.03000	.907
		Control	-1.15500^{*}	.000*
	Layer Waste	Broiler Waste	.00250	1.000

		Cockerel Waste	.03250	.886
		Control	-1.15250*	.000*
		Broiler Waste	-.03000	.907
	Cockerel Waste	Layer Waste	-.03250	.886
		Control	-1.18500*	.000*
		Broiler Waste	1.15500*	.000*
	Control	Layer Waste	1.15250*	.000*
		Cockerel Waste	1.18500*	.000*
		Layer Waste	-.00250	1.000
	Broiler Waste	Cockerel Waste	-.20250*	.001*
		Control	-.11500	.051
		Broiler Waste	.00250	1.000
	Layer Waste	Cockerel Waste	-.20000*	.001*
		Control	-.11250	.057
Particle Density		Broiler Waste	.20250*	.001*
	Cockerel Waste	Layer Waste	.20000*	.001*
		Control	.08750	.165
		Broiler Waste	.11500	.051
	Control	Layer Waste	.11250	.057
		Cockerel Waste	-.08750	.165
		Layer Waste	.05000	1.000
	Broiler Waste	Cockerel Waste	-3.27500	.085
		Control	41.20250*	.000*
		Broiler Waste	-.05000	1.000
Porosity	Layer Waste	Cockerel Waste	-3.32500	.079
		Control	41.15250*	.000*
	Cockerel Waste	Broiler Waste	3.27500	.085
		Layer Waste	3.32500	.079

	Control	44.47750*	.000*	
	Broiler Waste	-41.20250*	.000*	
Control	Layer Waste	-41.15250*	.000*	
	Cockerel Waste	-44.47750*	.000*	

Note: Statistics is significant at P < 0.05*

4. Conclusion

From this study, it was concluded that the application of different poultry wastes has different effects on physicochemical and biological properties of soil with cockerel waste having the highest effect virtually on the all-soil parameters except for bulk density which broiler has the highest and pH that layer waste also has the highest effect. The poultry manure reduced the bulk density of the soil and enhanced its moisture content. It was revealed that the use of poultry manure will improve soil organic matter, nutrient availability and high yield. It is therefore recommended that more studies can still be carried out on the poultry waste to know if the age of the birds has any impact on the type of waste produced at different stages of their growth.

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ANALYSIS OF IRRIGATION WATER QUALITY OF KAMPE IRRIGATION SCHEME

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Abstract

This aim the project is to determine the water quality of Kampe irrigation scheme. The Kampe (omi) irrigation scheme is located in Yagba west local government area of Kogi state. During the water analysis, parameters such as pH, electrical conductivity, chloride, total dissolved solid, phosphate, sulphate, nitrate, boron, potassium, SAR were studied. Samples were collected from 7 points namely; Omi main canal, Omi reservoir, distributory canal, seepage water from distributory canal, borehole at Elejiba's compound, Oyi river and borehole at the Lower Niger River Basin Office. Results were analyzed from the samples and compared with baseline data of the scheme and FAO irrigation water standard. The result show pH range from 6.9 – 7.2 which is within the acceptable FAO standard for irrigation. This implies that the seepage water form distributory canal and borehole at the Lower Niger River Basin Office are acidic while other samples are alkaline. Electrical conductivity levels are very low at all the sampling points. Also, chloride, total dissolved solid, nitrate and SAR levels were significantly lower than both FAO standard and the baseline data obtained. Phosphate levels of the scheme are significantly higher than that of FAO standard as there were no baseline data available. The values range from 20.64 – 21.58 mg/l. This could be very hazardous to crops. However, sulphate levels were generally higher than the baseline data but within the FAO standard. The highest level of sulphate was 2.8 me/l recorded at the seepage water from distributory canal. This could be attributed to leaching due to the application of inorganic fertilizers. Boron levels at all the points are within the FAO standard. The potassium levels were slightly higher than the FAO standard at distributory canal, borehole at Elejiba's compound and borehole at the Lower Niger River Basin Office with values of 3.60, 3.60 and 4.00 mg/l respectively. It is recommended that water analysis should be carried out on the scheme from time to time so as determine the quality of the water and to avoid further deterioration.

Keywords: Analysis, water quality, inorganic, defoliation, leaching, organic.

1. Introduction

Irrigation is the controlled use of multiple water sources in a timely manner for increased or sustained crop production. Irrigation comprises of the water that is applied by an irrigation system during the growing season and also includes water applied during field preparation, pre-irrigation, weed control, harvesting, and for leaching salts from the root zone (Dieter, 2015). As the world's population grows, the risk increases that more people will be deprived of adequate food supplies in impoverished areas, particularly those subject to water scarcity (FAO, 2009). Agricultural production of food needs to increase by an estimated 60% by 2050 to ensure global food security (FAO, 2009) and irrigation will increasingly be called upon to help meet this demand. In the race to enhance agricultural productivity, irrigation will become even more dependent on substandard sources of water. Therefore, it is of utmost importance to access our current state of knowledge and explore the effects of irrigation water quality on crops. This understanding will help ensure adequate crop production to meet increased demand as well as to maintain proper food and soil quality. Water quality influences its suitability for a particular use, i.e. how well the quality fulfills the requirement of the user. Water quality deals with the physical, chemical and biological characteristics of water in relation to all other hydrological properties. For example, river water having good quality with sediment load can be applied for irrigation successfully but may be objectionable for municipal use without treatment. Similarly, snowmelt water is acceptable for municipal purpose and may not be applicable for industrial due to its corrosion potential. The characteristics of water quality have become important in water resources planning and development for drinking, industrial and irrigation purposes (Shakoor, 2015). Water quality is the basic to judge the fitness of water for its proposed application for existing conditions.

Certain constituents emerge as indicators of quality-related problems with sufficient reported experiences and measured responses (FAO, 2013). The major concerns in terms of water quality and quantity are due to its inadequate distribution on the surface of earth and the rapid declining of fresh useable water (Irfan et al., 2014). The possible contamination in water included organic matter, nutrients, suspended solids, heavy metals, pesticides and industrial chemicals. Water quality is critical for the survival of humans, animals, industry and agriculture. Furthermore, the proper management is requisite to meet water quality standards and for ecosystem health.

The agriculture success is highly dependable on the quality of water applied in an agriculture area. Due to the application of poor or hazardous quality water the agriculture land/soil is affected and damages the crop yield in several ways. The accumulation of salts in root zone, limited the availability of water and plant can take up lesser water which resulted in high plant stress and decreased crop yields. (Shakoor, 2015).

2. Materials and Methods

2.1 Experimental Site

Kampe Dam Irrigation Project (KODIP) is located in Yagba West Local Government Area of Kogi State, Nigeria. It lies between longitudes 60 37' and 60 42 E of Greenwich and latitudes 80 34' and 80 38'N of the Equator. The project was first conceived in 1979 while the construction works started in 1983. Kampe irrigation dam was constructed on Oyi river at Omi. It is being constructed by Niko Construction Company. The completion of the Dam at Omi River will definitely hasten irrigation projects in the country.

It involved the construction of 42 meter-dam with a water reservoir capacity of about 250 million cubic meters. The irrigation network consists of 39 km length of main canal and about 300 km length of feeder canals and complimentary drainage lines. The dam will be capable of irrigating about 4100 hectares when all the phases are completed. Given the abundant water resources in the country and its potential for increasing agricultural production in Nigeria, the Federal Government established the River Basin Development Authority (RBDA). The scheme became necessary because of the persistent too short rainy season in many states of the federation. It is against this background that Kampe irrigation project was constructed (Ibitoye, 2012).

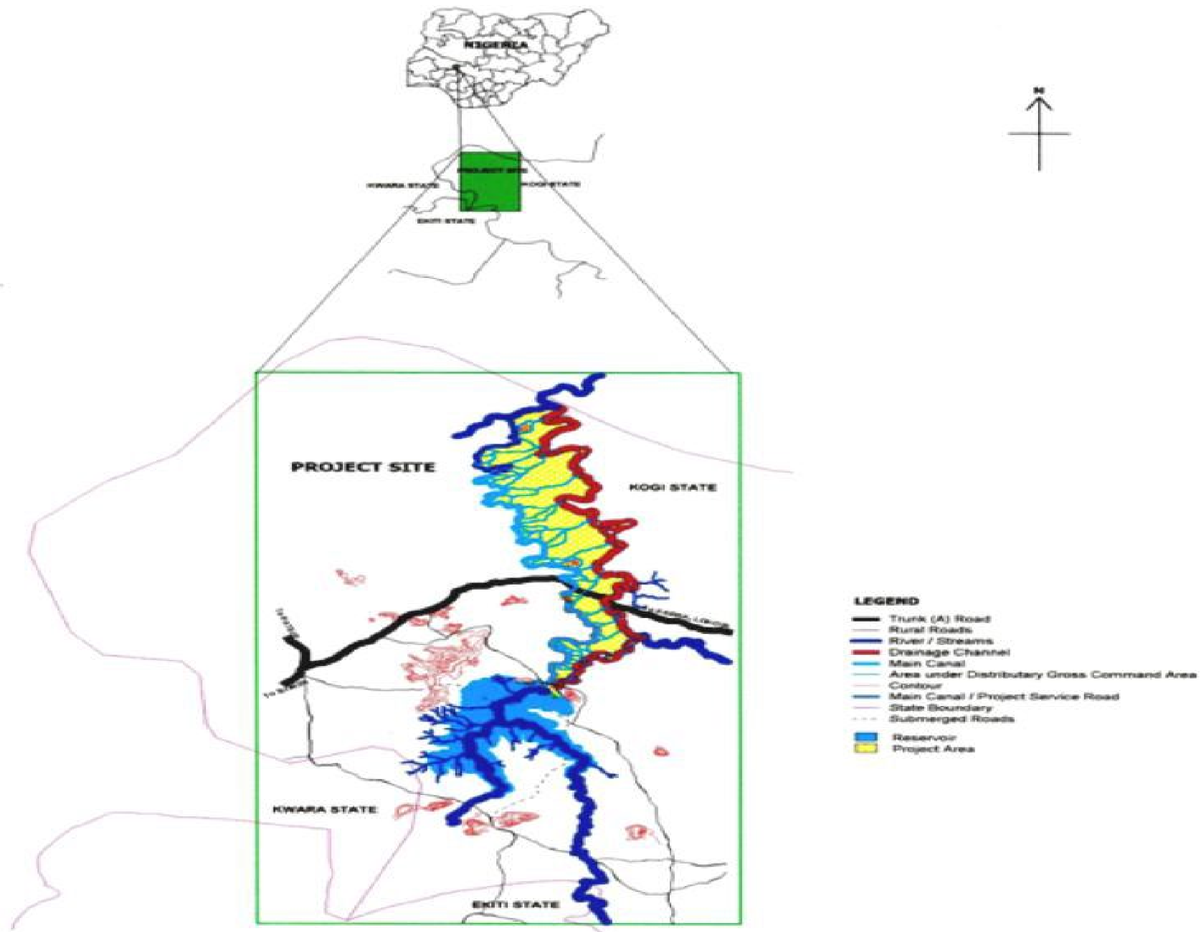

Fig 3.1: The map showing the various locations of Kampe irrigation scheme.

2.2 *Materials*

The material that was used to take water samples at sampling points are:

Plastic: to serve as medium to store the samples. Measuring cylinder: to measure the quantity of water to be used for analysis.

2.3 *Sampling Point*

Water samples were collected from the following sources; Omi reservoir, main canal, Distributory canal, Oyi river, Seepage from Distributory canal, Borehole at Elejiba's palace and the borehole at Lower Niger Development Authority.

2.4 *Collection of Water Samples*

At each of the sampling point, 2 samples were taken using sterilized bottles for the purpose of water analysis identification. The sample bottle was submerged and allowed to fill without allowing air to mix with the sample.

The bottle was completely filled and held submerged until cap is firmly in place. The samples were transported to the laboratory to be tested for the following parameters namely properties; pH, Electrical conductivity, Chloride, Total dissolved solids, Phosphate, Sulphate, Nitrate, Boron, Potassium and SAR.

2.5 *Methods of Analysis*

The samples were analyzed in the laboratory using the following method; pH was determined by the potentiometer. EC was determined by EC meter. The chloride present in the water samples was measured in milligram/liter using argentometric method. TDS was determined by TDS meter. The phosphate was measured by ascorbic acid spectrophotometric method. Sulphate was measured in milligram/liter using Nepheolometry method. Nitrate was determined in milligram/ liter by UV spectrophotometer. Boron was determined by axomethane H colour development and absorbance was determined colometrically. Potassium was determined by flame photometry method. Calcium, magnesium and sodium were determined using titrimetric method in the laboratory and then the sodium absorption ratio (SAR) was calculated.

3. Result and Discussion

The pH is the concentration of hydrogen ions (H+) and hydroxyl ions (OH-) in the water. It is used to determine the acidic, basic or neutral behaviors of water. The pH values range from 1 to 14, which means, if pH of water is less than 7 then it is called acidic water whereas, pH equal to 7 as neutral and more than 7 is called the basic nature water. The pH of water and soil could not harm the plant growth directly (Tahir et al., 2003). pH highly affects the efficiency of coagulation and flocculation process (Kahlown et al., 2006). Table 2 shows the pH value ranges from 6.5 to 7.3 for water sources with the mean value of 7 and CV of 4.14% which indicates that there is no variation in pH between the points (Table 2). Seepage water from distributory canal and borehole at Lower Niger River Basin Office were acidic while other points were alkaline.

The electrical conductivity (EC) of water is defined as the capacity of water to transmit the electric current. It depends on the dissolved ions in the water and their charge and movement. It is a good solvent therefore, water dissolved mineral salts in the form of ions, which hold the electric current due to ionic conduction. When the EC of water is high, it shows that there is high concentration of ions in the water. The EC indicates the number of total solids in water and is dependent on the temperature of water. The electrical conductivity of water also affects the plant growth. The electrical conductivities for the water sample sources range from 0.01 to 0.03 $dscm^{-1}$ with the mean value of 0.02 $dscm^{-1}$ which is below the FAO critical water conductivity standard (Table 1). An indication of this values shows that the water sources were free from salinity problems as the electrical conductivity gives a good indication of the extent of the dissolved salts (Table 2).

The chloride analyzed ranges between 0.1 to 9.02 mg/l with the mean value of 2.19 mg/l (Table 2). The chloride level at Omi main canal is 9.02 mg/l which is above the FAO standard of 4 mg/l. This could lead to accumulation of chloride on the leaves of the crop to be planted, which can result in leaf burns. The values at other points were below FAO critical value that can result into toxic absorbed by roots and also damage sensitive ornamental plants. The value of CV 132.42% which is an indication of great variation of irrigation water between the points.

The total dissolved solids (TDS) in water is one of the essential parameters to be determined in relation to irrigation level because many toxic solid materials may be imbedded in the water which may cause harm to the plants (Masoudi, 2006). TDS for the water samples range from 0.01 to 0.5 mg/l (Table 2), the values do not exceed the FAO critical level of 2000 mg/l (Table 1). The usage of the water will have no salinity problem if applied to plant. However, the CV is 85.71% which implies that there is variation in TDS between the points.

Phosphate levels ranged from 20.64 to 75.33 mg/l. The FAO critical level for irrigation is 2 mg/l (Table 1). This implies that the phosphate levels are high and beyond the FAO standard for irrigation at all the points which can be hazardous for irrigation because there was no presence of phosphate at the inception of the scheme. The CV value is 1.52 % which indicates there are no variation in phosphate levels within the points.

Sulphate salts affect sensitive crops by limiting the uptake and increasing the adsorption of sodium and potassium, resulting in a disturbance in the cationic balance within the plant (Fipps, 2003). The sulphate levels ranged from 0.15 to 2.80 me/l. The highest value was recorded at the seepage water from distributory canal while the lowest was at the Omi reservoir. The current sulphate levels of the scheme shows that there has been an increase as compared with the baseline data but still within the safe range for normal irrigation according to the FAO standard.

Nitrate occurs most frequently in irrigation water. The most readily available forms of nitrogen are nitrate and ammonia. Ammonia-nitrogen is seldom present in excess of 1mg/l unless ammonia fertilizer or waste water is being added to the water supply. Sensitive crops may be affected by nitrogen concentration above 5mg/l. Most other crops are relatively unaffected until nitrogen exceeds 30mg/l (FAO, 1994). However, these problems can be easily overcome by good fertilizer and irrigation management (Bauder *et al*., 2011). The result of nitrate levels ranges from 0.004 to 0.009me/l. This shows that the current nitrate status of all the points is suitable for irrigation.

Boron is another element that is essential in low amounts, but toxic at higher concentrations. In fact, toxicity can occur on sensitive crops at concentrations less than 1.0 ppm (Bauder *et al.,* 2011). The boron levels range from 0.58 to 1.19 mg/l (Table 1). This implies that boron levels at all the sampling points are within the FAO acceptable standard of 2mg/l (Table 2). Potassium is one of the natural occurring in the groundwater and surface water (Biswas, 2002). Potassium value ranges from 1.40 to 4.00 mg/l with the mean value of 2.61 mg/l. However, potassium levels at the distributory canal, borehole at elejiba's compound and borehole at the Lower Niger River Basin Office are 3.60, 3.60 and 4.00 mg/l respectively which are above the FAO standard for irrigation water while other points remain within the acceptable limit of 2 mg/L. Furthermore, CV value is 37.93 % which indicates variation within the points.

The sodium adsorption which relates the sodium content with the dicationications calcium and magnesium ranged from 0.2 to 2.32 me/l in the study area (Table 2). It is a significant parameter for determination of suitability of irrigation water. High sodium in water produces the undesirable effects of changing soil properties and reducing soil permeability. In the study area, the SAR values obtained fall within the FAO standard and acceptable for irrigation (Biswas, 2002). The high CV value of indicates variation of SAR between the points.

Table 1: FAO Guidelines for interpretation of water quality for irrigation

Water parameter	**Symbol**	**Unit**	**Usual range in irrigation water**
SALINITY			
Salt Content			
Electrical Conductivity	EC_w	ds/m	0-3
Total Dissolved Solids	TDS	mg/l	0-2000
Cations and Anions			
Chloride	Cl^-	me/l	0-30
Sulphate	SO_4^-	me/l	0-20
NUTRIENTS			
Nitrate-Nitrogen	NO_3-N	mg/l	0-10
Phosphate-Phosphorus	PO_4-P	mg/l	0-2
Potassium	K^+	mg/l	0-2
MISCELLANEOUS			
Boron	B	mg/l	0-2
Acidity/Basicity	pH	1-14	6.0 – 8.5
Sodium Adsorption Ratio	SAR	me/l	0-15

Table 2: Physio – chemical properties of irrigation water of the study area

Parameters	Symbols	Units	O.M.C	O.M.R	D.C	S.W	B.E.C	O.R	B.L.N.R	Mean	STD	CV (%)
pH			7.1	7.2	7.2	6.6	7.3	7.1	6.5	7	0.29	4.14
Electrical conductivity	EC_W	ds/cm	0.01	0.03	0.03	0.02	0.01	0.01	0.02	0.02	0.00	0
Chloride	Cl	mg/l	9.02	1.4	0.9	0.1	0.6	2.8	0.5	2.19	2.90	132.42
Total Dissolved Solid	TDS	mg/l	0.5	0.01	0.13	0.15	0.4	0.15	0.1	0.14	0.12	85.71
Phosphate	P	mg/l	21.00	21.14	20.64	21.18	75.33	25.58	49.78	20.99	0.32	1.52
Sulphate	S	mg/l	53.37	122.85	274.56	21.99	75.33	25.58	49.78	89.07	82.02	92.08
Nitrate	N	mg/l	0.007	0.005	0.007	0.009	0.007	0.009	0.004	0.007	0.002	28.57
Boron	B	mg/l	1.19	0.64	0.75	0.58	0.68	0.78	0.74	0.77	0.18	23.38
Potassium	K	mg/l	1.40	1.80	3.60	2.00	3.60	1.90	4.00	2.61	0.99	37.93
Sodium Adsorption ratio	SAR	me/l	0.2	0.34	0.38	0.30	0.70	0.43	2.32	0.67	0.69	102.99

Key: O.M.C = omi main canal, O.M.R = omi main reservoir, D.C = distributory canal, S.W = seepage water from distributory canal, B.E.C = borehole at elejiba's compound, O.R = oyi river, B.L.N.R = borehole at Lower Niger River Basin Office

4. Conclusion

It can be concluded that pH, chloride, total dissolved solid (TDS), Nitrate and Sodium Adsorption Ratio (SAR) levels at all the points are within the acceptable FAO standard for irrigation. Boron levels were within the recommended levels at all the points except for the distributory canal and Oyi river which are slightly above the acceptable standard. Similarly, potassium levels recorded are higher than the recommended levels at the distributory canal, borehole at Elejiba's compound and borehole at the Lower Niger River Basin Office while other points are within the required standard. Furthermore, phosphate levels recorded at all the points are extremely higher than the acceptable FAO standard of 2mg/l. It is therefore recommended that proper monitoring of the scheme by the Lower Niger River Development Authority should be conducted by analyzing the water and soil in the area. There should be monitoring of farming activities in the area to reduce the accumulation of fertilizers which could be washed downstream there affecting the water quality. Leaching should be carried out regularly to reduce the accumulation of toxic elements.

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DESIGN OF A SOLAR-POWERED INTELLIGENT DRIP IRRIGATION SYSTEM FOR GARDEN EGG *(solanum melongena)* and TOMATO (*Solanum esculentum*) IN MINNA, NIGER STATE – PART I

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Abstract

The trend in the advancement of irrigation system in developed nations is rapidly progressing, but reverse is the case in some developing countries with Nigeria inclusive. Irrigation has gone beyond only applying water to plants, but applying good quality water, of the right quantity and at the right time. This can only be achieved when proper design is prioritized. This research paper focuses on the design of a solar-powered intelligent drip irrigation system, which was designed to supply exact water for a small garden egg research plot. Study showed that soil in the study area have higher composition of clay particles, and are therefore classified as clay soil. This was also confirmed by its slow intake rate. The plant water requirements were approximately 4 mmday^{-1}, time of irrigation is around 40 minutes with an average irrigation interval of 5days. The drip laterals, submain and mainline were designed as 0.40cm, 1.50cm and 1.7cm respectively. The pump capacity in kilowatt was computed as 0.046kW, which is approximately 0.1kW. The system is designed to be powered by 4 deep cycle batteries of 808Ah rating that will be charged by 8 mono-crystalline solar panel of 250W rating and a charge controller of 83.33A. It is recommended that selection of items for installation/construction should not be less in capacity compared with the designed ones.

Keywords: Charge controller, Drip irrigation system, Nominal battery voltage and photovoltaic energy.

1. Introduction

There is an urgent need to scale up agricultural production in order to meet the needs of both industries and domestic users, especially in less developed countries and poverty-stricken regions, such as Sub-Saharan Africa and Latin America (Molden *et al.,* 2007). Increasing crop water productivity means more crops should be produced per every drop of water (Thakur *et al*., 2018). This has been the genesis of advancement in irrigation systems from the Stone Age manual watering technique to the present-day automated drip system.

Drip irrigation is a system of irrigation in which water is applied at a very low rate to individual plant, and such rates are accomplished through the use of specially designed emitters or porous tubes (Jibril, 2005). Khan *et al.,* (2014) stressed that drip irrigation system is a method with frequent, slow application of water either directly on the land or into the crop root zone rather than the entire land surface, which ensures optimum water content in the root zone. High water use efficiency, precision in water and fertilizers application are features of drip irrigation systems (Ko *et al*., 2009; Bracy *et al.,* 2003).

The design of a drip irrigation system is in two phases: agronomic design and hydraulic design (Egharevba, 2009). In the agronomic design, some specific data are needed (i.e. crop water demand, type of soil and data of drip emitters, among others). The hydraulic design is based on several data (characterization of chosen emitter, field topography, etc.). In order to design an irrigation subunit (drip line and sub main pipes), it is necessary to combine the hydraulic calculation (flow, diameters and pressure of drip line and sub main pipes) with the irrigation net distribution plan. Drip line calculation is the first part in the hydraulic design of a drip irrigation system. The number and the distribution of the emitters are the results of the design (Gyasi-Agyei, 2007). Most of these outlined specifications are lacking in most designs, leading to either over or under-design. This study therefore intends to design a drip irrigation system for eggplants and tomato, as well as the power requirement for the system.

2. Research Methodology

The research took place at the horticulture farmland of the Department of Crop Science, Federal University of Technology, Gidan Kwano Campus, Minna, Nigeria. The study area falls under the Guinea Savanna (i.e., comprising short grasses and scattered trees) of the tropical climate vegetation belt of Nigeria, having two (2) distinct seasons (rainy and dry seasons). The rainfall commences mostly in the months of March-April and terminates around October-November, with an annual rainfall amount of 1229 mm. Average maximum and minimum monthly temperatures are 34 and 27 ºC respectively. The lowest temperature is experienced in the month of August, while the highest is experienced in the month of March. The average daily sunshine hours recorded is 7.0. The geolocation of Minna is on the north and east hemisphere, stationed on Latitude $9^{o}\,36^{I}\,54.86^{II}$ N and Longitude $6^{o}\,32^{I}\,51.94^{II}$ E.

2.1 Design Procedures

2.1.1 *Agronomic design*

The site measurement was done using measuring tape and demarcation was aided with wooden pegs. The soil textural class was determined by the method of particle separation by suspension in accordance with (Globe, 2005). The water infiltration rate into the soil at the two selected points was accomplished by the use of double ring infiltrometer as described in Michael and Ojha (2006). The rate of infiltration was determined using equation 1:

$$I = \frac{d}{t} \qquad 1$$

Where I = infiltration rate in (*cm/min*), d is intake in (*cm*) and t = time taken in (*min*).

The wetted perimeter was determined by field planimetry method using the bucket type LPDI on the experimental plot with a single lateral line as described in (Awe *et al*., 2017). The wetted volume was obtained using equation 2.

$$V = \frac{\pi}{12} d^2 \left[2z + h - \frac{h^3}{(z-h)^2} \right] \qquad 2$$

Where, maximum diameter achieved of the wetted soil ellipsoid is denoted as (d) and maximum depth achieved is denoted by (z). Distance from the soil surface up to the maximum diameter is denoted by (h). The total available water content (TAWC) was determined in the laboratory in accordance with (Palada *et al.,* 2011). A known quantity of soil sample was first oven dry at 105 ºC and the weight noted. It is then wrapped in a light clothing material, socked in water until no visible bubbles seen. The sample was then removed and hanged; re-weighing was done after free water has completely drained. The difference in weight is determine and values recorded. Then total available water content (TAWC) in a gravimetric form is determined using equation 3:

$$\theta_g = \frac{(M_w - M_d)}{M_d} \quad 3$$

Where, θ_g is gravimetric water content of the soil in g/g, M_w is the mass of moist soil, and M_d is mass of oven dried soil. Culturally, readily available water content (RAWC) is usually 50% of the total available water content (TAWC) (Doorenbos and Pruitt, 1977; Allen *et al.,* 2006; Palada *et al.,* 2011 and Dukes, 2012). The submissions of the above quoted authors were also utilized in this study. The plant water requirement was determined using the Modified Penman Monteith Equation as described in FAO (56) Manual (Allen *et al.,* 2006; Ighadun, 2012 and Alebachew, 2017):

i.e. $ET_c = ET_o\, X\, k_c$ 4

But,

$$ET_o = \frac{0.408\Delta(R_n G) + \gamma\frac{900}{T+273}U_2(e_{s-e_a})}{\Delta + \gamma(1+0.34U_2)} \quad 5$$

Where, *ETo* is reference evapotranspiration [mm day^{-1}], *Rn* is net radiation at the crop surface [MJ m^{-2} day^{-1}], *G* is soil heat flux density [MJ m^{-2} day^{-1}], *T* is mean daily air temperature at 2 m height [°C], U_2 is wind speed at 2 m height [ms^{-1}], e_s is saturation vapour pressure [kPa], e_a is actual vapour pressure [kPa], e_s-e_a is saturation vapour pressure deficit [kPa], Δ is slope vapour pressure curve [kPa °C^{-1}], *γ* is psychometric constant [kPa °C^{-1}], *ETc is* crop water requirement [mm day^{-1}] and K_c is crop coefficient.

The time of irrigation was determined using equation 6 as presented by (Khalifa, 2006):

$$T_i = \frac{V_w}{Q_e} \quad 6$$

Where; T_i is time of irrigation in hours, V_w is volume of water applied in liters, and Q_e is emitter discharge in liters per hour.

The irrigation interval was determined as (Doorenbos and Pruitt, 1977; Richard *et al.,* 2006, Michael and Ojha, 2006) using equation 7:

$$I = \frac{d}{ET_c} \quad 7$$

Where, d is depth of application at a defined time, ET_c is the crop water requirement of the specific plant under study; and I is the irrigation interval or irrigation frequency.

2.1.2 *Hydraulic design*

This is one of the most important aspects of drip irrigation system design, as it has to do with pipe sizes, their networking and water carrying capacities at a given time as well as the pumping unit that will provide the needed pressure required by the entire system. The drippers selected for this study are the button-necked pressure compensating type with a design discharge rate of 4 litres per hour, and was only one dripper per plant. Drippers of this discharge rate are chosen considering the soil type (clay loam) with slow intake rate, as well as volume of water held in the plant root zone. The expected number of dripper per lateral length of seven (7) meters was determined using equation (Palada *et al.,* 2011 and Naglic, 2014).

$$N_{dl} = \frac{L_l}{P_s} \qquad 8$$

Where, N_{dl} is the number of drippers per lateral line, L_l is the length of lateral line in meters (m), and P_s is the spacing between laterals in centimeters (cm). The lateral line diameter was designed using the Williams and Hazen Equation according to (Dasberg and Bresler, 1985) as presented by equation 9. However, lateral line spacing was maintained at 1m in accordance with the work of (Wondatir, Belay and Desta, 2013).

$$\Delta H = 14.03 \left[\frac{Q^{1.852}}{D^{4.871}}\right] L \qquad 9$$

Where; Q is the total flow into the lateral pipe *l*/s; D is the inside diameter of the lateral pipe, cm; L is the length of lateral pipe, m and; ΔH is total energy drop at the end of lateral or submain pipe, m.

The number of lateral line per submain line was determined using equation 10:

$$NL_s = \frac{L_s}{S} \qquad 10$$

Where, NL_s is the number of lateral line per submain line, L_s is the length of submain in meters, and S is the spacing between laterals in meters. The size of submain and mainline were also determined as the lateral line.

The system is expected to be the drum type Low Pressure Drip Irrigation System (LPDI), consisting of a 1000liters capacity drum with a major supply from a 2000liters capacity thermoplastic reservoir tank as shown in Figure 1. Water from the 2000liters on the surface will always be pumped to the 1000liters drum at a static head of 4 m.

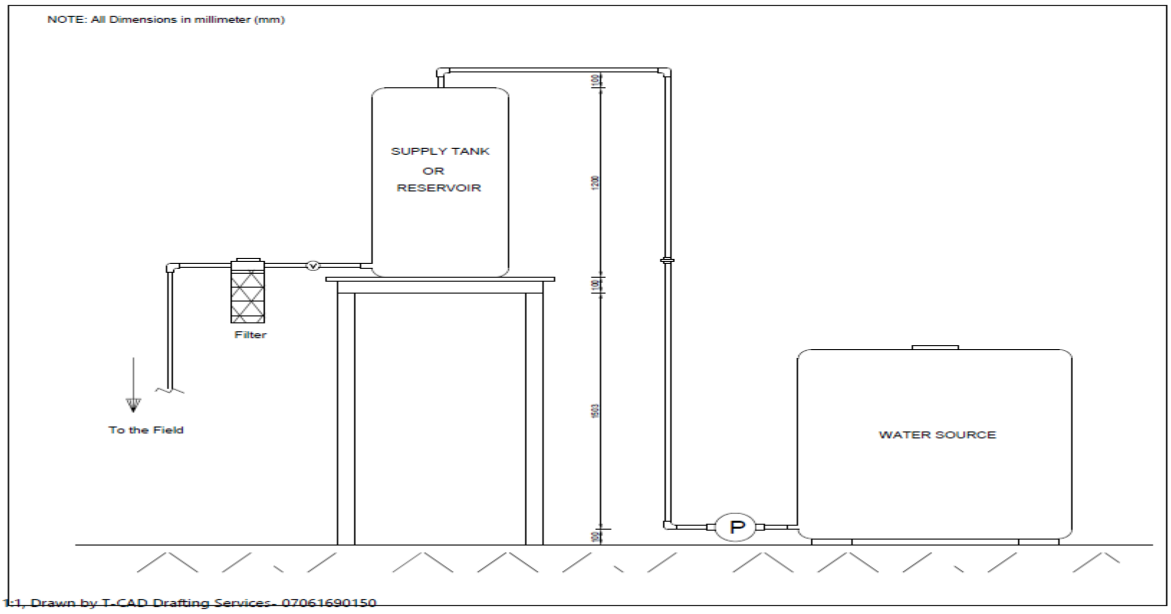

Fig. 1: System Reservoir Set-up

For this study, the pump capacity was determined using equation 11:

$$P_e = 9.81\frac{QH}{\eta} \qquad 11$$

Where; P_e is power required by the pump, Q is volume of water that must be lifted by the pump in a given time, and H ($H_{st} + H_L + H_v$) is total dynamic head. However, H_v is usually very small and could be neglect (Punmia *et al.,* 2002). This submission was also obeyed in this study. Also, the volume (Q) of water that must be lifted in a given time is determined using Lea equation presented as equation 12.

$$D = a\sqrt{Q} \qquad 12$$

Where, D is conveyance pipe diameter (m), and a, is constant which ranges between 0.97 and 1.22.

2.1.3 ***System power requirement***

Automation simply implies replacing manual irrigation scheduling, which basically depends on human efforts with the smart system (i.e. machine-based). Items that will be connected together to accomplish all these functions of scheduling with little or without human aid are collectively termed hardware component of the system. For this study, the hardware components used include: Micro controller boards (i.e. Arduino board), soil moisture sensors, temperature and humidity sensors, automatic valves, water meters, relays and water level sensors.

The system power design was obtained by first determining the total load on the individual units of the system (Emmanuel, 2009; Al-Shamani, Othman, Mat, Ruslan, Abed and Sopian, 2017). They include the D.C pump, the arduino boards and its connected accessories, and solenoid valves. The D.C pump capacity is 0.37kW, and is expected to work for at most, one hour a day. The daily wattage-hour determined was noted and documented. The power to be consumed by the 40 solenoid valves was also determined by multiplying the power rating of each board by the time of usage. Power rating of each board is 10W, and since it is like the brain box of the system, it is expected to work 24hours each day. The solenoid valves are also 40 pieces, their total power rating was determined to be 200W, and are expected to work for one hour in every 5 days (that is, 0.2hour in a day). Daily wattage-hour for all was determined and documented. Total load connected was determined according to (Geofrey *et al.,* 2015) using equation 13:

$$L_T = L_P + L_A + L_S \quad 13$$

Where, L_T is the total load on the system, L_P is the load by the pump, L_A is the load by the Arduino boards and L_S is the load by the solenoid valves. The total PV energy was determined by multiplying the total load connected by the losses as in Dhanne *et al*., (2014). Since PVs are not 100% efficient, a factor of 1.3 was considered in accordance with the solar energy best practices (Dhanne *et al.,* 2014). Total wattage of PV capacity was determined by dividing the total PV energy by the illumination per day. The average illumination per day was 7 hours (NiMet, 2015). Total panels required was determined by dividing total PV wattage by PV rating. However, the PVs are assumed to be of 250W rating. The power bank sizing was determined using equation 14:

$$B_c = \frac{T_L * D_a}{B_L * D_d * NB_V} \quad 14$$

Where, B_c is the battery capacity in (Ah), T_L is the total load on the system in (Whr), D_a is the days of autonomy in (days), B_L is the battery losses (%), D_d is the depth of discharge in (%), and NB_V is the nominal battery voltage in (V). The charge controller sizing was determined by first dividing the PV wattage by its voltages and multiplying by the total number of PVs in parallel (Emmanuel, 2009). This was as presented in equation 15. The battery specifications and charge controller size determined were noted and included as the design requested.

$$CC_S = \frac{P_{Wt}}{P_V} * NP_p \quad 15$$

Where, CC_S is charge controller size in (A), P_{Wt} is panel wattage rating in (W), P_V is panel voltage rating in (V), and NP_p is number of panels to be connected in parallel. For this study, the panels are rated 250W, 24V and all 8 panels are expected to be connected in parallel.

3. Result and Discussions

3.1 Result of Agronomic Design

The preliminary soil test indicated that samples obtained from points A and B, as well as their composite contain clay in higher proportion compared to other fractions of sand and silt, and therefore are classified as clay loam soils based on textural triangle. The dry bulk densities of the three (3) samples were found to be 1.48gcm^{-3}, 1.51gcm^{-3} and 1.46gcm^{-3} respectively. Gravimetric moisture content at saturation was 0.39gg^{-1} and by implication, every 1g of the soil sample has a void of 0.39% to be occupied by air or water when dry and wet respectively. This was in line with the submissions of Palada *et al.* (2011) that all soils culturally have an average of 55% solid composition and 45% space for either air at dry states or water when saturated.

The result of the infiltration rate indicates an infinitesimal intake rate in both points A and B, even as the test was carried out in late December. This also authenticates the result of the soil classification test which confirmed the soil to be clay loam. The rates of infiltration in the two (2) points are as low as 0.75cm/min and 1.0cm/min respectively as in Figures 3.1a and 3.1b. These low infiltration rates give an idea of selection of drippers with very low discharge that fits the soil water intake rate, in order to avoid runoff. The chart also indicates that after 40minutes, the water intake was almost zero. That is, there was stagnancy in water movement into the soil after this time, and any continues application will lead to wastage.

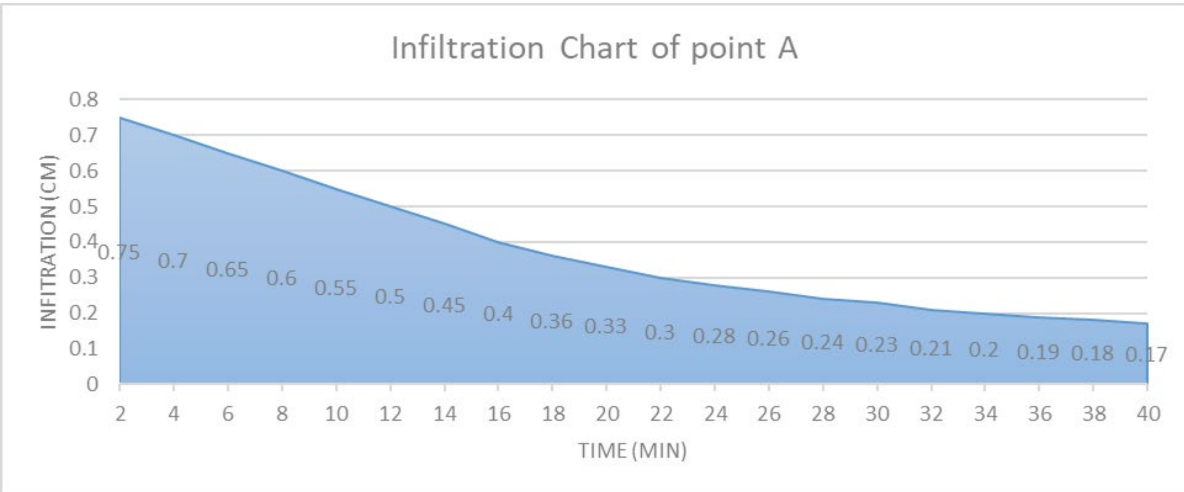

Fig. 2: Infiltration in (cm) by time (min)

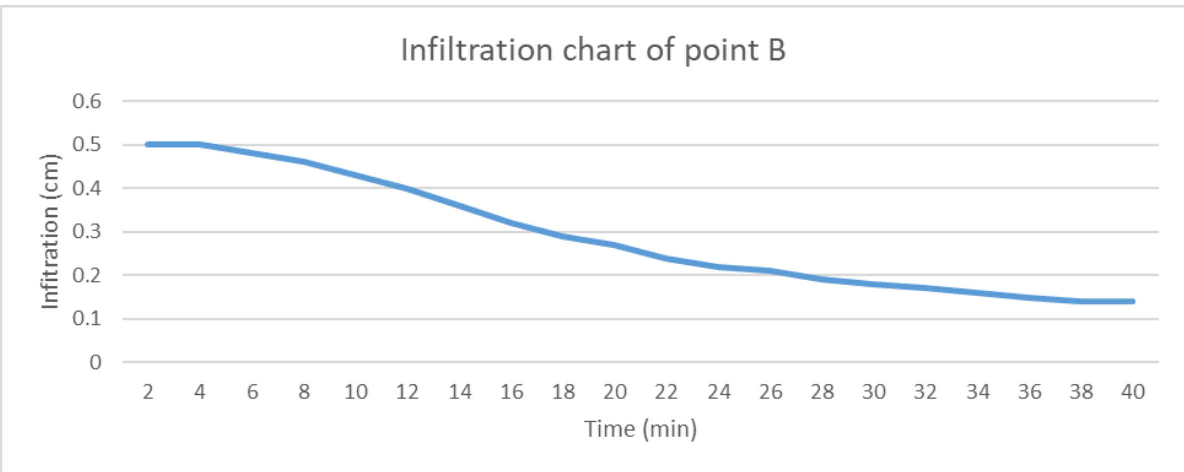

Fig. 3: Infiltration rate (cm) by time (min)

The soil pH was found to be 6.9, which is just slightly (about 0.1) above the recommended pH (between 5.5 and 6.8) for tomato and eggplant as in (NRC, 2006). Also, the concentration of available phosphorus was found to be 10.3mgg^{-1}; while concentrations of sodium, potassium, magnesium and calcium are 0.16, 0.13, 2.3 and 4.0 cmolkg^{-1} respectively. The average wetted perimeter and wetted depth are 37cm and 26cm respectively, this result also confirmed the fact that the soil in the area is a clay, as horizontal movements of water into clay soils in a given time intervals are always more than the vertical movements (Michael and Ojha, 2006).

3.1.2 ***Result of crop water requirement***

The crop water requirement was for the intended growing periods (109 days) within the dry months of November, December, January and February as presented in Tables 1 and 2. It could be seen from Table 1 that the highest water requirement computed in (mmday^{-1}) for tomato is 6.45 mmday^{-1}, in the month of December, which is the mid-season stage of its growing period. The least is 3.33 mmday^{-1}, which is the harvesting period.

Also, the highest crop water requirement computed for the eggplant is 5.95 mmday^{-1} in the month of December, which was the development stage as presented in Table 2. The minimum water required is in the month of January with the value 3.60 mmday^{-1}. However, the research does not captured crop water requirement at the initial growing stages of both crops because all are expected to be first raise in nurseries and seedlings be transplant after one month (after the emergence of five true leaves). In all, seasonal (total growing period) water requirements for both crops are above 400 mmday^{-1}, this is in line with the work of (Wondatir *et al.,* 2013; Brouwer and Heibloem, 1986), which submits that seasonal water requirement of the crops is between 400 and 800 mm.

Table 1: Water requirement of tomato for the entire growing period in Minna

S/no	**Months**	**ETo determined**	**ETc for Tomato**	**Growth Period**	**Monthly ETc**
01	November	5.17 mmday^{-1}	4.40 mmday^{-1}	Development	131.84
02	December	4.96 mmday^{-1}	6.45 mmday^{-1}	Mid-season	193.50
03	January	4.50 mmday^{-1}	4.50 mmday^{-1}	Late season	135
04	February	5.12 mmday^{-1}	3.33 mmday^{-1}	Harvest	-
TOTAL					460.34mm

Table 2: Water requirement of eggplant for the entire growing period in Minna

S/no	**Months**	**ETo determined**	**ETc for Tomato**	**Growth Period**	**Monthly ETc**

01	November	5.17 $mmday^{-1}$	4.13 $mmday^{-1}$	Development	124.08
02	December	4.96 $mmday^{-1}$	5.95 $mmday^{-1}$	Mid-season	178.5
03	January	4.50 $mmday^{-1}$	3.60 $mmday^{-1}$	Late season	108
04	February	5.12 $mmday^{-1}$	-	Harvest	-
TOTAL					410.58mm

3.1.3 *Result of irrigation scheduling*

Result obtained as shown in Tables 3 and 4. The clay soil in the sample occupies more than 15cm of the total sample, and its readily available water (RAW) of 30mm was multiplied by the depth (26cm) in accordance with (Palada *et al.,* 2011), which gives a value of 7.8mm. This value was then multiplied by the wetted perimeter to obtain 3.36litres as volume of water held at the root zone of plant. The time of irrigation was about 45 minutes. Irrigation frequencies in days for tomato are computed to be 6days, 4days and 5days at the development, mid-season and late season stages respectively. Table 4 also showed similar outcome except for the irrigation frequencies. Unlike for the tomato, irrigation frequencies for eggplant are computed to be 7days, 5days and 7days at the development, mid-season and late season stages respectively. However, the average irrigation frequencies computed for tomato and eggplant are 5days and 6days respectively. This outcome was in line with the findings of (Dewidar, Ben Abdallah, Al-Fuhaid and Essafi, 2015).

Table 3: Irrigation Scheduling for Tomato throughout the growing season

Crop	**Soil Type**	**Depth of Water**	**Readily Available Water (litres)**	**Time of Irrigation (hours)**	**Irrigation Frequency**		
					Dev. Stage	Mid Stage	Late Stage
Tomato	Clay Loam	26cm	3.36L	40min	6days	4days	5days

Table 4: Irrigation Scheduling for Eggplant throughout the growing season

Crop	**Soil Type**	**Depth of Water**	**Readily Available Water (litres)**	**Time of Irrigation (hours)**	**Irrigation Frequency**		
					Dev. Stage	Mid Stage	Late Stage
Eggplant	Clay Loam	26cm	3.36L	40min	7days	5days	7days

3.1.4 *Result of hydraulic design*

Considering the slow water intake rate of the soil, a pressure compensating dripper was selected for the experiment. The dripper has an orifice of 0.0018mm, and a manufacturer's design discharge of 2litres/hour. Based on this discharge, a dripper is expected to discharge at most, approximately one litre of water at the base of a plant after every elapse time. For each lateral length of 7m, a total of six drippers was computed, thus making a total volume of 6litres ($6.0 \times 10^{-3} m^3$) per lateral line. Lateral line, submain line and mainline internal diameters were computed as 0.40cm, 1.50cm and 1.70cm respectively.

3.1.5 *Result of pump design*

For the pump capacity, it was assumed that diameter of pipe through which water will be lifted by the pump equals the selected mainline diameter (i.e., 0.022m). The Lea formula for determination of most economic diameter of pumping mains was utilized to determine the discharge as contained in Punmia *et al.,* (2002). Then the velocity of water was determined as 1.35m/s. Friction head losses through the pipe length and other fittings was computed as 0.57m, and the overall dynamic head was determined as 4.57m. The pump capacity in kilowatt was computed as 0.046kW, which is approximately 0.1kW. However, the smallest commercial electric powered pump for irrigation available was about 0.37kW (0.5HP), and therefore it is selected for the study.

3.1.6 *Result of system power requirement*

Table 5 presents the hardware used in the research, their power rating and total load on the entire system. The power requirement of the system was determined based on the total load of the system hardware in accordance with Geofrey *et al.* (2015). The load by the pump, by the Arduino board and the solenoid valves are 185Whr, 9600Whr and 100Whr respectively. The total load on the entire system was determined to be 9,885Whr/day.

Table 5: The hardware used in the research, their power rating and total load

Items	Quantity	Power rating (W)	Total power rating (W)	Time of Usage (hrs)	Energy Required (Whr)	Total Load (Whr/day)
Arduino Board	40	10	400	24	9600	
Pump	01	370	370	0.5	185	
Solenoid Valves	40	5	200	0.5	100	
Total Load						9,885 Whr/day

The total PV energy needed was determined as 12,850.5Whr/day, total PV wattage needed is 1,835.79W, and number of PV panels needed was determined to be 7.34 at a rating of 250W. Based on the solar energy best practices (Al-Shamani *et al.,* 2017), a total of 8 panels is selected for this research work. The battery bank size was determined as 807.60Ah, and the number of batteries needed to power the entire system were 4.04 (approximately 4 batteries). Based on this result, the four (4) batteries needed should be rated 808Ah, 12V in order to properly take care of the 12 hours (0.5day) day of autonomy. More so, since the panels are rated 250W, 24V, all the 8 panels must be connected in parallel, this will make expected current passing through as 10.42A. Based on these specifications therefore, the size of solar charge controller required for this research work is rated 83.33A.

4. Conclusion and Recommendations

The study concentrated on design of a solar-powered smart drip irrigation system to irrigate garden egg and tomato in Minna. Study showed that soil in the study area have higher composition of clay particles, and are therefore classified as clay soil. This was also confirmed by its slow intake rate. The plant water requirements were approximately 4 $mmday^{-1}$, time of irrigation is around 40minutes with an average irrigation interval of 5days. The drip laterals, submain and mainline were designed as 0.40 cm, 1.50 cm and 1.70 cm respectively. The pump capacity in kilowatt was computed as 0.046 kW, which is approximately 0.1 kW. The system is designed to be powered by 4 deep cycle batteries of 808Ah rating that will be charged by 8 mono-crystalline solar panel of 250W rating and a charge controller of 83.33A.

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AN ASSESSMENT ON THE EFFECT OF SEASONAL RAINFALL VARIABILITY ON WATER QUALITY IN EDE TOWN, OSUN STATE, SOUTHWESTERN NIGERIA

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Abstract

Rapidly increasing human populations and expanding agricultural activities have brought about extensive land use changes throughout the world. Certain kinds of land use can change the hydrology of the watershed, altering the way water and pollutants move through the drainage basin. The effect of land use on watershed in Ede town was analyzed using ArcGIS. Ede is located in Osun state between latitude 7º 31' and 7 º 55' North and longitude 4 º 15' and 4 º 40' East. The region is drained by Rivers Shasha and Osun along with their tributaries. It has a total land area of 330 sq. km. The main occupation of the inhabitants of Ede is Farming. Cotton, cocoa, yam, cassava and corn are the predominant crops grown in Ede. The SRTM DEM was used to generate the Land use map for 1986 and 2002 of the study area. It was observed that there was a sharp decrease in vegetation from 216.3744sq.km in 1986 to 94.2885sq. km in 2002 showing 129.48% changes and this may have a negative impact on the environment around this area, increasing surface runoff of water. In addition, water body increased from 41.6 sq. km in 1986 to 69.1614 sq. km in 2002 which gives 66.25% change while settlement increased drastically from 85.5647 sq. km in 1986 to 188.455508 sq. km in 2002 with 120.24%. Generally, this has shown that water body in the study area has increased due to population influx. Continuous GIS monitoring of land use changes has been recommended, noting relative percentages of developed and undeveloped land. High impact land use such as logging in areas of high slope and easily eroded soil must be avoided. Protection of areas of land use that benefit watershed is advocated.

Keywords: *Assessment, Rainfall, Variability, Water Quality, Populations.*

1. Introduction

Water is a prime natural resource, a basic human need and a precious national asset. Periodic scientific assessment of the ground water potential, taking into consideration the quality of water and economic viability shows that for many years, impervious surfaces have been recognized as an indicator of the intensity of the urban environment (Espy *et al.* 1966; Stankowski 1972). With the advent of urban sprawl, impervious surfaces have also become a key issue in growth management and watershed planning due to their impact on habitat health (Arnold and Gibbons 1996). Increasing urbanization has resulted in increased amounts of impervious surfaces-roads, parking lots, roof tops, and so on. However, it has now been realized that the objective of supplying safe water would not be achieved to the extent and satisfaction expected unless the pollution aspects of water supply, as well as the issue of sanitation were addressed simultaneously. The focus has now shifted from water to water and sanitation. The most common assessments were found to be the measurements of basic physical parameters (such as pH, temperature, dissolved oxygen and conductivity) and chemical parameters, specifically nutrient concentrations (such as total nitrogen and phosphorus). These are demonstrated by basic physical and chemical measurements of water quality in Indonesian (Ong et al. 1987; Whitten et al. 1987), Malaysian (Ong et al. 1987), Singaporean (Sien and Huay 1987) and Taiwanese (Kao et al. 1978) rivers. Hart et al. (2001) recognizes that physical and chemical methods are mostly used to assess water quality while the assessment of river health using biological methods appeared more uncommon. Not with standing some impressive records in activities related to the UN Drinking Water and Sanitation Decade (WHO 1990), the provision of water at affordable cost and of acceptable quality is emerging as a major environmental challenge. In particular, the all dependence of future food security on the availability of irrigation water, as well as growing awareness of water resources for conservation purposes has created widespread concern. Lamparski (2004) suggested that assessing the quality of water resources is an essential process in the development of water resources.

Water quality may be defined in terms of specific characteristics of water that are important concerning a certain service (Tchobanoglous and Schroeder 1987). These characteristics are usually defined as physical, chemical and biological parameters. Examples are, heavy metal concentrations in a river intended for drinking water or levels of dissolved oxygen in a lake used for fishing. A number of various techniques, ranging in complexity and sophistication, may assess water quality. When planning to conduct any scientific assessment it is usual to consider what techniques are most appropriate with respect to: how expensive it is to perform (including both the setup and repetition of the technique); how simple it is to conduct and thus how much error may be incurred in the process. Pollution of reservoirs that serve as locations of both domestic and industrial effluent and runoff and as receiving bodies is also a common motivation for water quality studies and improvement programs (Kao et al. 1978; Hart et al. 2001; Papista *et al.* 2002). The high quality of water discharged from forested watersheds is well known and increasing deforestation of tropical forests in south East Asia has been found to worsen incoming riverine pollution (Food and Agriculture Organization of the United Nations Forestry Department 2003). Riparian forests improve dissolved oxygen levels in water by maintain cooler water temperatures (Brooks et al. 1997). Thus, forests help to decrease nutrient release into the water column and also cycle nutrients and chemicals reducing nutrient pollutants and some heavy metals. They also help to stabilize stream banks and reduce runoff, which may contain pollution into water bodies from upland areas (Brooks et al. 1997). Some of the major issues related to pollution of tropical rivers include; the quality of drinking water, excessive growth of floating plants, algal blooms, fish kills and organic and heavy metal contamination (Palupi et al. 1995; Hart et al. 2002; Manan and Ibrahim 2003). The biological health of a river catchment can be used as an indicator of water quality (Tchobanoglous and Schroeder 1987). Assessment of river health using biological methods is uncommon in developing countries, where physical and chemical methods are mostly used to assess water quality (Hart et al. 2001).

Runoff from rainfall can significantly contribute to variation in the quality of surface waters (Olaoye *et al.,* 2013). Recent hydrological reports in Nigeria indicate significant increase in the average annual rainfall. Ground water, surface water (rivers, streams and ponds), atmospheric water (rainwater, snow and hail) and springs are the main source of water available to the people in general. The qualities of these water bodies vary widely depending on the location and environmental factors (Tay, 2007). The major source of ground water is precipitation that infiltrates the ground and moves through the soil and pore spaces of rocks. Other sources include water infiltrating from lakes and streams, recharge ponds and wastewater treatment system. As ground water moves through soil, sediment and rocks, many impurities such as disease-causing micro-organisms are filtered out. (Freeze and Cherry, 1979). Many water resources in developing countries are unhealthy because they contain harmful physical, chemical and biological agents. To maintain a good health however, water should be safe to drink and meet the local standards and international standards to taste, odour and appearance (Chessbrough, 2000). In order to monitor the water resource and ensure sustainability, national and international criteria and guidelines established for water quality standards are being used according to (WHO, 1993; 2005). The water quality variation is often reflected as changes in the water quality indicator parameters, in addition to bacteriological load, which is frequently interpreted as an indication of microbial contamination. According to Kistemann *et al.,* (2002), who investigated three tributaries of different drinking water reservoirs and showed significant presence of total microbial loads in the watercourses, resulted from rainfall and extreme runoff events. In addition, Van Vliet and Zwolsman (2008) compared water qualities during different seasons and established varying deteriorating trend in the water quality with varying rainfall intensity.

2. Methodology

2.1 Study Area

The study area is Ede town. Ede is located in Osun state, Southwestern Nigeria. It has her coordinates as $7^0$44'20"N 4026'10"E. It has an elevation of 269 m (883 ft) and an area of 330km^2 (130 sq mi). Its joint operation graphics reference is NB31-03. It lies along the Osun River at a point on the railroad from Lagos, 112 miles (180 km) southwest, and at the intersection of roads from Osogbo, Ogbomoso and Ife. The area is underlain by metamorphic rocks of the basement complex which outcrop over many parts. Rocks found here are schists which, associated with quartzite ridges. The land surface is generally undulating. Soil erosion and soil degradation are not serious in the area.

2.2 Data Collection

The data for this research work were collected from both secondary and primary sources. The secondary sources of data include published textbooks, journals and periodicals, while some unpublished theses and dissertations were consulted as well. The land use pattern, ground surface slope of the study area was generated using GIS (Geographic information systems). The water quality index using the water quality parameters such as pH, colour, turbidity, total alkalinity and appearance was obtained.

The data used in this project were Land use/Land cover of the study area (three digital elevation models (DEM); and Landsat images from Landsat TM and ETM+ was obtain at various time intervals) which was used to determine the Elevation, Flow length, Flow accumulation and Flow direction.

2.3 *Criteria for Selection of Data*

The data used in this study were selected based on the following criteria: Landsat TM and ETM data acquired had cloud cover of less than 20%. The SRTM DEM data acquired had a 90m resolution and were geometrically processed. All Landsat images were either terrain corrected (L1T), systematic corrected (L1G) or systematic terrain corrected (L1GT) (USGS, 2011b). This meant that all images were radio metrically and geometrically accurate (USGS, 2011b).

2.3.1 *Data Type and Acquisition*

Satellite imagery (Landsat ETM) and the digital elevation model (EDM) were acquired from the global land cover facility archive. The land sat and DEM imported into ArcGIS software where the study area was extracted by using the slipping the clipping process in the Raster processing function of the Data management toolbox. The DEM was used to generate the Flow direction, Flow accumulation and the Flow Length using the hydrology function in the spatial analyst tools. Elevation of the map was derived from the DEM using the 3D analyst. The Land use classification was done using the Natural breaks classification method. The Slicing method was used to reclassify Elevation, Flow direction, Land use, Flow accumulation, Flow length into three categories.

2.4 *Software*

The software that was used in data processing and analysis is ArcGIS 9.3.

2.4.1 *Data processing*

This involved a stepwise arrangement and organization of acquired data in a manner that was appropriate for analysis (Figure 1).

2.4.2 ***Composite band formation***

The different bands in the five Landsat images were composited in ArcGIS to produce an image with seven bands.

2.4.3 ***Panchromatic sharpening***

Panchromatic sharpening involves the fusion of the high-resolution (15 m) panchromatic band/image with the lower-resolution Landsat images (USGS, 2011). The four Landsat 7 ETM+ composite images were pan-sharpened with their respective panchromatic images.

2.4.4 ***Clipping of study area***

Each of the composite images was clipped to the extent of the study area. Map of the study area was also clipped.

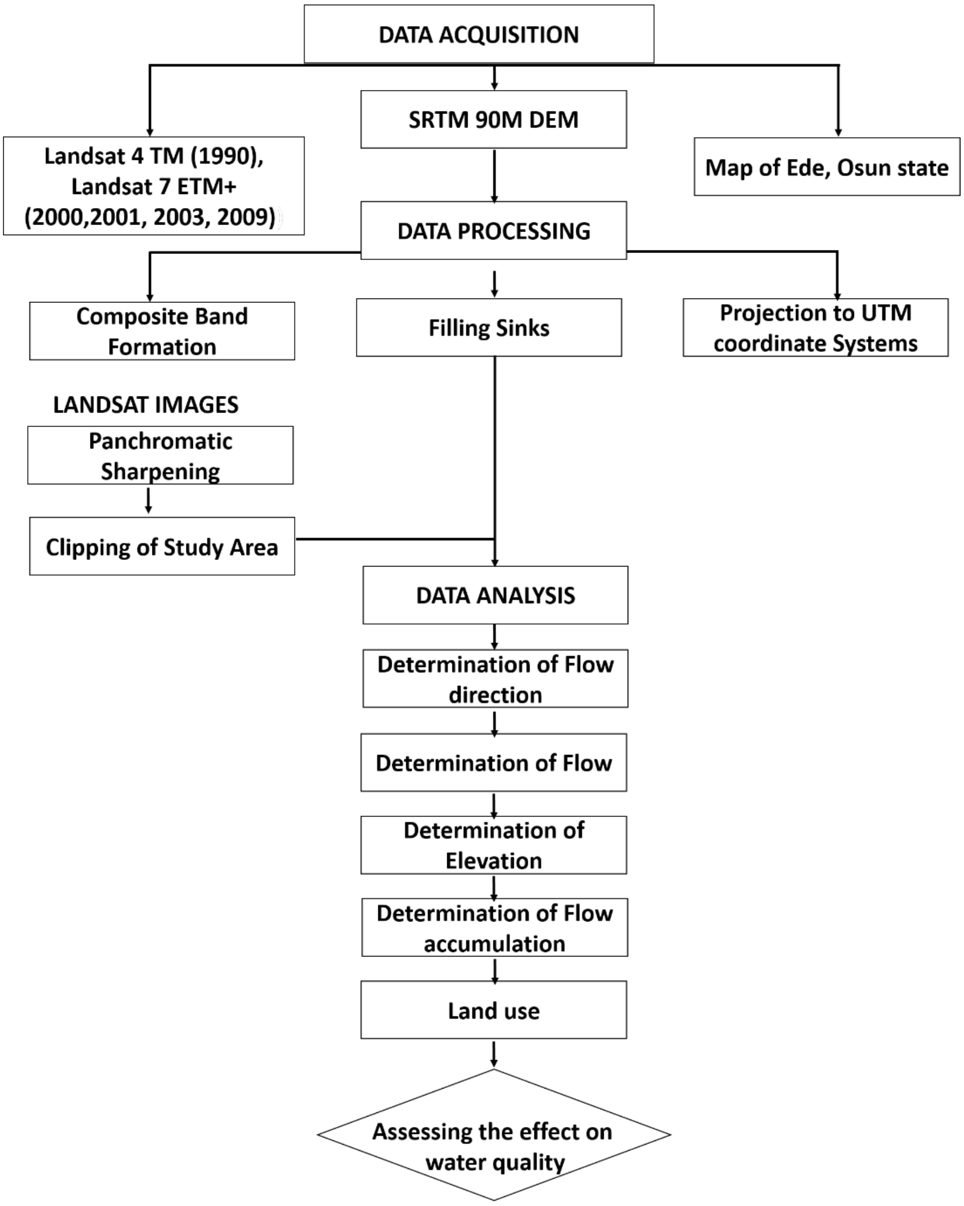

Figure 1: Methodology Flow Diagram

2.5 ***SRTM 90m DEM***

2.5.1 ***Filling of sinks***

In order to carry out hydrology analysis on DEM, all depressions have to be filled. Such depressions are called sinks (ESRI, 2009a). The SRTM 90m DEM sinks were filled using the 'Fill' tool in ArcGIS.

2.5.2 ***Data analysis***

Series of analysis were performed on the processed Landsat images, SRTM 90m DEM

2.5.3 ***SRTM 90M DEM***

Operations were performed on the DEM to get the parameters for analysis.

2.5.4 ***Determination of flow direction***

The depression less DEM was used to generate a flow direction raster. The flow direction shows the possible direction of water run-off on the elevation model. This analysis was performed using the flow direction tool in Arc Toolbox's Spatial Analyst tools.

2.5.5 ***Determination of flow accumulation***

Determination of flow accumulation is the next step after flow direction and it shows the cells within the study area where water accumulates as it flows downwards. Thus, settlements around these cells will receive much water during an event of rainfall or any sudden release of water.

3. Results and Discussions

The connection between rainfall and the runoff in a watershed is influenced by the physical characteristics of the watershed. The parameter of physical characteristic of the watershed influencing the surface runoff coefficient can be analyzed through parameter of relief, land infiltration, vegetation cover, and surface retention. The hydrology process in a watershed relates to the physical characteristic of the watershed, like morphometric (area, slope, flow pattern density, elevation difference, river span, etc), vegetation cover, land usage and soil. The overall effect of rainfall water on water quality can be primarily due to the Land use. Seeing that the major occupation of the inhabitants of the study area is Farming, the effect of fertilizer and other constituents of the soil cannot be neglected in the project. The satellite images have helped in citing the areas of vegetation and settlement of the study. Land development typically introduces impervious surfaces that lead to increased runoff during rainfall. Development usually requires the removal of native vegetation and the leveling of land, which reduces rainwater retention time. Native vegetation intercepts rainwater in its foliage and plant root uptake. Un-even surfaces increase surface friction, which results in an increase in retention time, which then allows rainwater to infiltrate for a longer period before runoff can occur. Thus, with more development comes less surface infiltration and an increase of impervious surfaces.

Groundwater recharge is reduced by impervious surfaces. Impervious surfaces increase the amount of runoff, which fills our waterways and may lead to flooding during storm events. Filth (oil, lead, trash, fecal matter) from roads is directly washed into storm drains that empty into rivers, stream and the ocean. Low Impact Development (LID) implements ways to offset this by incorporating infiltration within the development or improvement project and protect water quality. The atmospheric condition is another factor that influences the quality of water apart from the soil and topographical conditions. Environmental pollutions also have effect on the quality of water in the area. A chemical constituent in the atmosphere reacts with rain water and thus changes the product. Areas with high vegetation and areas where agricultural activities are carried out tends to have greater impact and effects (physical, biological and chemical) on water quality as the presence of fertilizers and other soil constituents influences the composition of the water.

3.1 ***Elevation***

The elevation of Ede varies between 231m and 380m where 380m represents the highest elevation and 231 represents the lowest elevation in the study area. The range being 99 m, which happened to be the lowest elevation. Therefore, water flows from the area of highest elevation to and through the location of the dam. The Figure 2 below is the map of the study area showing the elevation

3.2 *Flow accumulation*

Flow accumulation of Ede varies between 0 and 38106. The 0 representing the area (region) of lowest water accumulation while 38106 representing area (region) of highest water accumulation. It is represented with a grey scale with areas of highest accumulation being white and the area of lowest elevation being the darkest. The dam falls within the area of highest accumulation (38106).

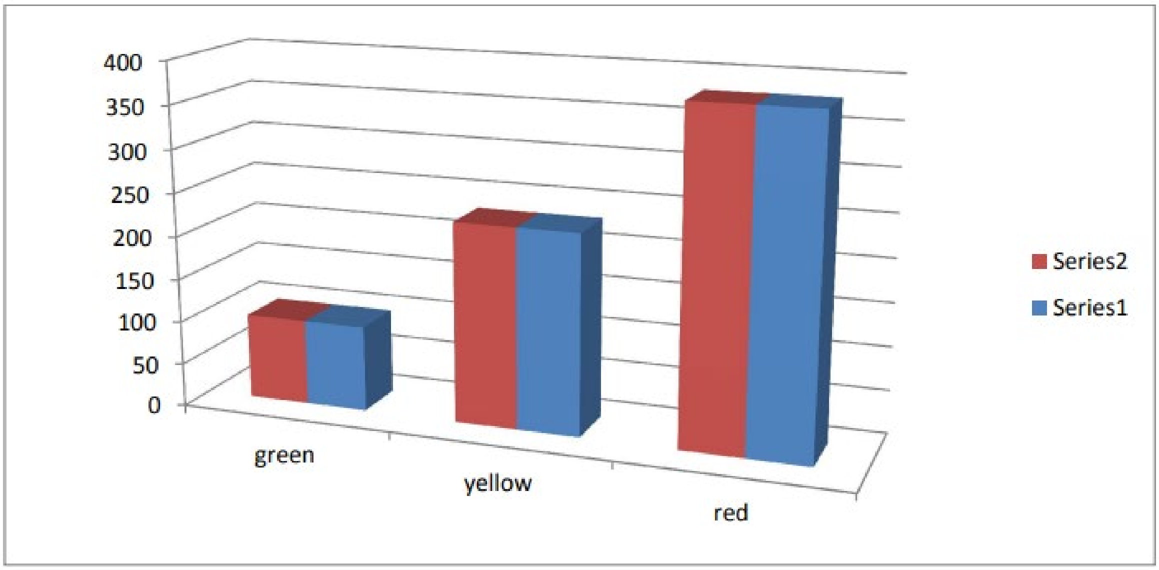

Figure 2: Map of the study area showing the elevation

4. Conclusion

In this study, effects of rainfall events on water quality in Ede were investigated focusing on Ede dam. The amount of rainfall events and rainfall frequency is the key issue to effect on the dam's water quality. Certain amount of rainfall should occur to bring pollutants from surface to water body. Rainfall events after a long-term dry season accelerated water quality degradations since pollutants may be accumulated on surface areas during dry season. On the other hand, degradations of river's water quality which experienced several previous heavy rainfall events were little with following rainfall events. In addition, watershed characteristics should be carefully considered since water contaminations may be greatly dependent on types of adjacent areas' land cover or land use. As results, the changes of water quality due to rainfall events were dependent on the amount of precipitations as well as patterns of rainfall event. For proper management of water quality in Ede, plans for early rainfall events after long-term dry season should be established. Therefore, water managements for rainfall events right after long term dry season and considering watershed characteristics should be established to have a proper management for river's water quality.

List of Abbreviations

DEM	Digital Elevation Model

ESRI	Environmental Systems Research Institute
ETM+	Enhanced Thematic Mapper Plus
ENVI	Exelis Visual Information Solutions
FAO	Food and Agricultural Organization
FGN	Federal Government of Nigeria
FME	Federal Ministry of Environment
GIS	Geographic Information Systems
GLCF	Global Land Cover Facility
NDVI	Normalized Difference Vegetative Index
RS	Remote Sensing
SRTM	Shuttle Radar Topography Mission
TM	Thematic Mapper

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GEOSPATIAL ANALYSIS AND MAPPING OF ANNUAL WEATHER VARIATION EFFECT ON SORGHUM YIELD

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Abstract
Agricultural production in Nigeria like other developing countries is highly vulnerable to climate variability. Taking the effect of weather variability on the yield of sorghum into consideration and the difficulties attached to it, there is the need for an integrated method of GIS modeling system to allow agricultural producers as well as policy makers to know the impact of spatial temporal variation of weather on sorghum yield for better profitability, management and productivity. The study analyzed rainfall and temperature variations with sorghum yield data covering the period of 1991-2012 in seven states in North Central Nigeria namely Benue, Kogi, Kwara, Nasarawa, Niger, Plateau State and The Federal Capital Territory Abuja. Data on sorghum yield, rainfall and temperature covers only 22-year period. This study used GIS (geographical information system) to examine the impacts of temperature and rainfall variation on the production of sorghum in North Central Nigeria. The results revealed that sorghum production correlated highly with rainfall amount, climatic variables examined have impact to a certain limit on the selected crop yield in the study area. The GIS revealed that sorghum production and yield could be explained by the climatic variables examined. Nasarawa State recorded the highest correlation with value of 1.59 and Niger state had the lowest correlation with the average value of -0.27 the highest record of rainfall occurred in 1993 with the volume of 1930.4 cm with highest temperature in 2005 reading 68°C. The implication of the findings for sustainable agricultural development is discussed in the concluding part.

Keywords: Climate change, Crop yield, GIS, temperature, rainfall

1. Introduction

All life on Earth, water and energy resources, agriculture, vegetation, air quality and sea level are significantly influenced by climate change and variability (US Geological Survey, 2007). Geologically, life has existed on planet Earth for approximately four billion years. During this time, climate has swung between ice ages and warm periods. The Earth's atmosphere has generally been in chemical balance. The increasing global demand for energy and natural resources to meet the need of the ever-growing population is believed to be upsetting this atmospheric balance (Warner, 2007), and thus giving rise to climate change. Various studies by the Intergovernmental Panel on Climate Change (IPCC) suggest a discernible human influence on global climate change. Thus, climate change and variability has received increased global attention in the last three decades. This is largely due to the risk it poses to the environment and hence the global community.

Africa is distinctive in the combination of climate-change effects. Agriculture is the largest single economic activity in Africa, accounting for around 60 per cent of employment and, in some countries, more than 50 per cent of GDP. However, over the past half-century, Africa's economies have not displayed a high degree of adaptability. Although households have considerable experience of coping with temporary shocks, such defensive flexibility has not been combined with sustained ability to adapt to new circumstances or adopt new technologies. The temperature trend in Nigerian since 1901 shows increasing pattern as the increase was gradual until the late 1960s and this gave way to a sharp rise in air temperatures from the early 1970s, which continued until date. The mean air temperature in Nigeria between 1901 and 2005 was 26.6°C while the temperature increase for the 105 years was 1.1°C. This is obviously higher than the global mean temperature increases of 0.74°C recorded since 1860 when actual scientific temperature measurement started (Spore 2008; IPCC 2007). Should this trend continue unabated, Nigeria may experience between the middle (2.5°C) and high (4.5°C) risk temperature increase by the year 2100. Climate variability influences weather elements such as temperature, rainfall, relative humidity, wind speed and direction. Rainfall trend in Nigeria between 1901 and 2005 shows a general decline within the 105years, rainfall amount in Nigeria dropped by 81mm. The declining rainfall became worst from the early1970s, and the pattern has continued until date (Odjugo, 2007). This is a clear evidence of climate change because a notable impact of climate change is, increasing rainfall in most coastal areas and decreasing rains in the continental interiors (IPCC 1996; NEST 2003). According to Odjugo (2007), it was observed that the number of rain days dropped by 53% in the Northeastern Nigeria and 14% in the Niger-Delta Coastal areas. These studies also showed that while the areas experiencing double rainfall maximal is shifting southward, the short dry season (August Break) is being experienced more in July as against its normal occurrence in the month of August prior to the 1970s. These are major disruptions in climatic patterns of Nigeria showing evidences of a changing climate Rainfall which has been seen as the most important factor in crop production in Nigeria. Some of the important factors guiding rainfall in relation to crop include number of rainy days, time of fall, total amount of fall and the type of soil. According to Olaoye (1999), regular occurrence of drought because of erratic rainfall distribution and/or cessation of rain during the growing season reduce Nigeria's capability for increased crop production. Temperature affects cereal production by controlling the rate of physio-chemical reaction and rate of evaporation of water from crops and soil surface (Ismaila *et al.,* 2010).

Sorghum (*Sorghum bicolor L moench*) is one of the most important staple crops in Nigeria, and is the most important cereal food in the Northern states that covers the guinea savannah ecological zone (FAO, 2003). Sorghum is the major cereal consumed by the majority of the population (NAERLS, 2007). Its morphological and physiological characteristics contribute to its adaptability to drought conditions, including an extensive root system, waxy brooms on the leaves that reduce water loss, ability to stop growth in periods of drought and to resume when conditions are favourable, and tolerance to water-logging (Oyedipe, 2001). Effects of heat stress on sorghum include reduced tile ring, reduced height, reduced spikelet number, sterility and reduced grain filling (Nguyen, 2006). Lack of basic knowledge on the effect of climate change and variability on crops still exist in Nigeria. This study assessed the effect of climatic variation (temperature and rainfall) on the yield of sorghum in North central Nigeria geospatial tools.

The objectives of the study were to assess and analyze rainfall and temperature variation data in relation to sorghum yield from 1991 to 2012 in North Central Nigeria in order to evaluate the effect of the rainfall and temperature variation on the yield of sorghum in North Central, Nigeria and thereafter develop yield maps of sorghum for the study area.

2. Materials and Method

2.1 Description of Study Area

The North-central zone of Nigeria has a land area of 296, 898 km^2 representing nearly 32 percent of the country's total land area (NBS, 2008). There are six states in the zone and the Federal Capital Territory, Abuja. The States include Benue, Kogi, Kwara, Nasarawa, Niger and Plateau. Situated between latitudes 6° 30" – 11° 20"N and longitude 7° – 10°E, the zone has 20.36 million people with the rural population constituting 77 percent (NPC, 2006). The position of the study area in the map of Nigeria is shown in Figure 1 while Table 1 shows the coordinates of this zone (Benue, Kogi, Kwara, Nasarawa, Niger, Plateau, and the Federal Capital Territory, Abuja).

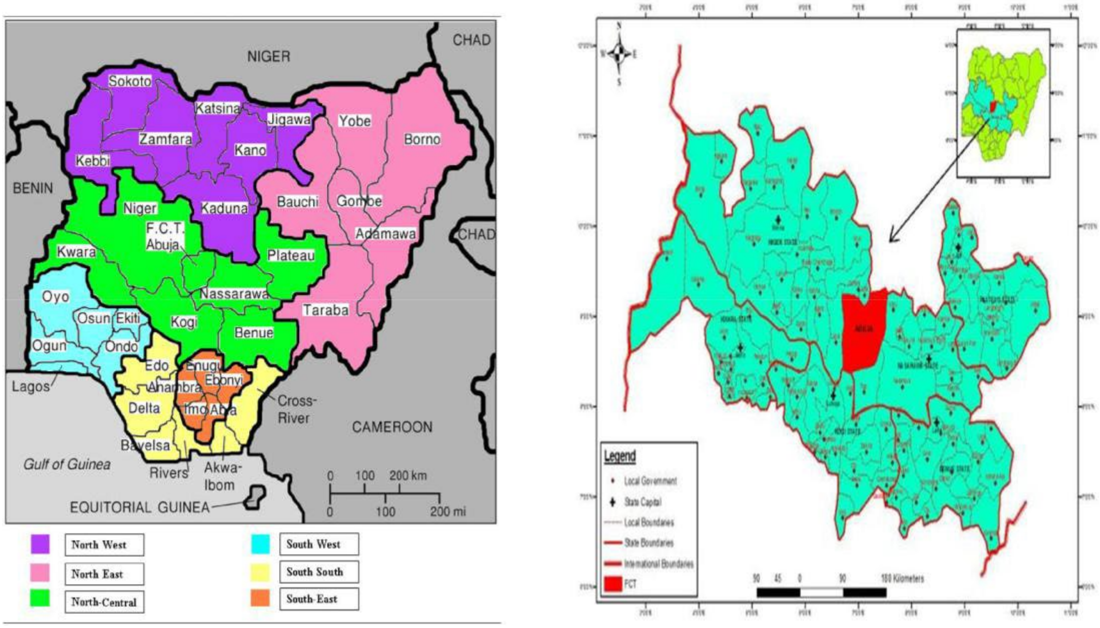

Figure 1: The position of the study area in the map of Nigeria (Adopted from Sklar, 2006)

Table 1: The coordinate of North Central states

S/N	Name of State	Longitude (Degree, Minute, seconds)	Latitude (Degree, Minute, seconds)
1	Benue	10°00’00”E	8°08’08”N
2	Kogi	6°45’00”E	7°45’00”N
3	Kwara	4°32’32”E	8°29’48”N
4	Nassarawa	8°31’10”E	8°28’60”N
5	Niger	3°30’00”E	8°20’00”N
6	Plateau	100°38’00”E	80°24’00”N
7	FCT Abuja	8°00’00”E	9°00’00”N

2.2 Data Collection

The annual temperature and rainfall data of each state in the North Central of Nigeria are the climate data used for this study. The data used for the analysis were obtained from Nigeria Meteorological Agency (NIMET) from the year 1991 to the year 2012 and the crop yields on the other hand were collected from Federal Ministry of Agriculture Nigeria on annual basis.

2.3 Data Manipulation

The crop yield, temperature and rainfall data for the North Central states was inputted into a Microsoft excel worksheet and the data was imported into ArcGIS software where it was converted into an ArcGIS file format. The imported data was then analyzed using the geographically weighted in the spatial analyst tools using crop yield as the dependent while rainfall and temperature were used as the explanatory variables.

2.4 Geospatial analysis

ArcGIS version 11 was used to analyze annual temperature, rainfall and sorghum yield data geo-spatial variation using kringing interpolation method. After importing the Nigerian map into the GIS interface, it was the pre –processed by geo-referencing, rectifying, updating and digitizing it. Geo-referencing was done by assigning the right coordinates to the Nigerian map. Changing the coordinates of a map from old to the newly assigned correct coordinates to register the map into Arc GIS version 10 internal environment is known as rectification and updating is re-adding the registered map. Digitizing which is the last phase in map processing is the act of craving out necessary features from an existing map. North-central map of Nigeria, its states, states capital, local governments and boundaries were carved out from the existing maps. Temperature, rainfall and sorghum yield values were recorded in the state capital attribute table on the software. ArcGIS version 10 was the used to develop the interpolated maps depicting the variation of annual temperature, annual rainfall and annual crop yields at a year interval within the North-central part of Nigeria using the kringing method of geospatial interpolation on the temperature, rainfall and crop yield data values. The interpolated maps that serve as the major outputs were then reclassified and post-processed by laying-out and exporting them. Legend, scale bar, north arrow, grid lines, title and other map characteristic feature were derived through the laying outprocess. The interpolated maps were exported in TIFF format figure 3.1 is a flow chart describing map interpolation process using kringing method of interpolation.

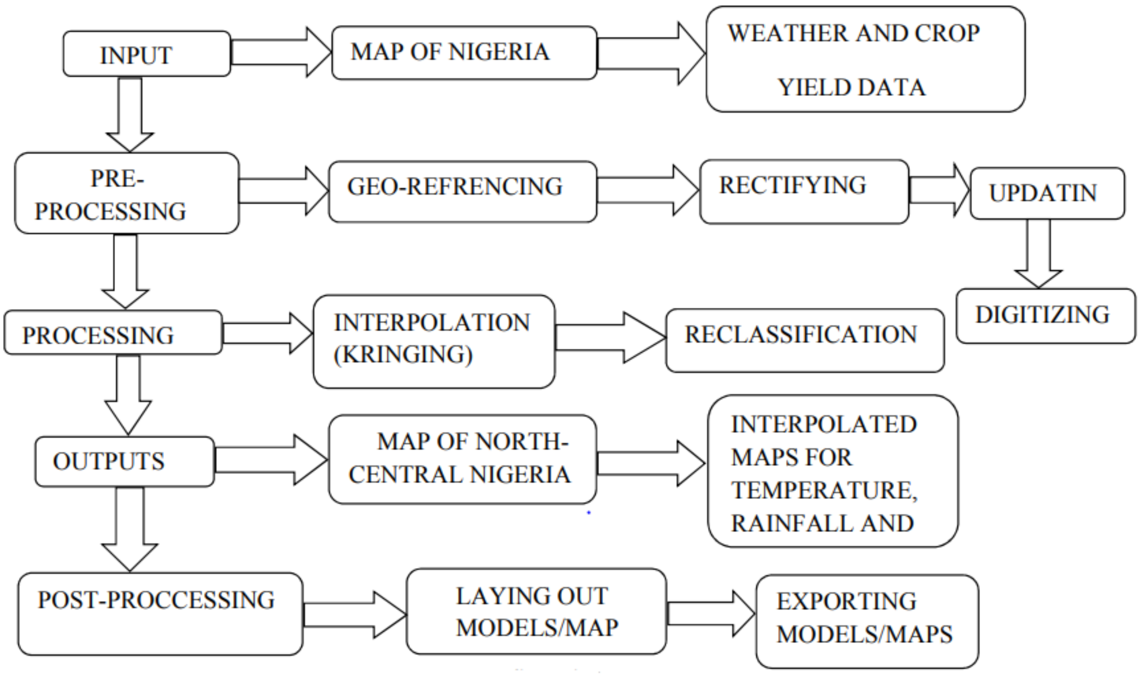

Figure 2: Kriging method of interpolation flow chat

3. Results and Discussion

This project work includes the production of bar chats using the climatic data and sorghum yield, production of geo-spatial variation maps depicting annual rainfall, annual temperature and annual sorghum yield in the study area using GIS version 10, the correlation of annual temperature and annual rainfall on the annual yield of sorghum in north-central Nigeria. Predictions of future annual sorghum yield.

3.1 Annual Rainfall and Annual Sorghum Yield Maps

Annual rainfall and sorghum yield maps of 1991, 1992, 2000, 2005, 2009, and 2012 are taken into consideration. Figure 3 shows the annual rainfall and annual sorghum yield of north central states for the year 1991 for annual rainfall variation, the map area with deep forest green indicates highest seasonal rainfall with values ranging between 1438.8 cm – 1844.3 cm and its visible in Kogi and Nassarawa state while the area with tinted blue shows the area with lowest seasonal rainfall with values ranging between 944.9 cm – 1227.1 cm which is visible in the F.C.T Abuja. For annual sorghum yield variation map the area with deep orange indicates high yield rate, which is visible in Kwara state and plateau state. The high yield of sorghum in Kwara state and plateau state is because of moderate rainfall in the two states and other favorable factors such as farm mechanization, and irrigation contributing to the increase in the yield of sorghum.

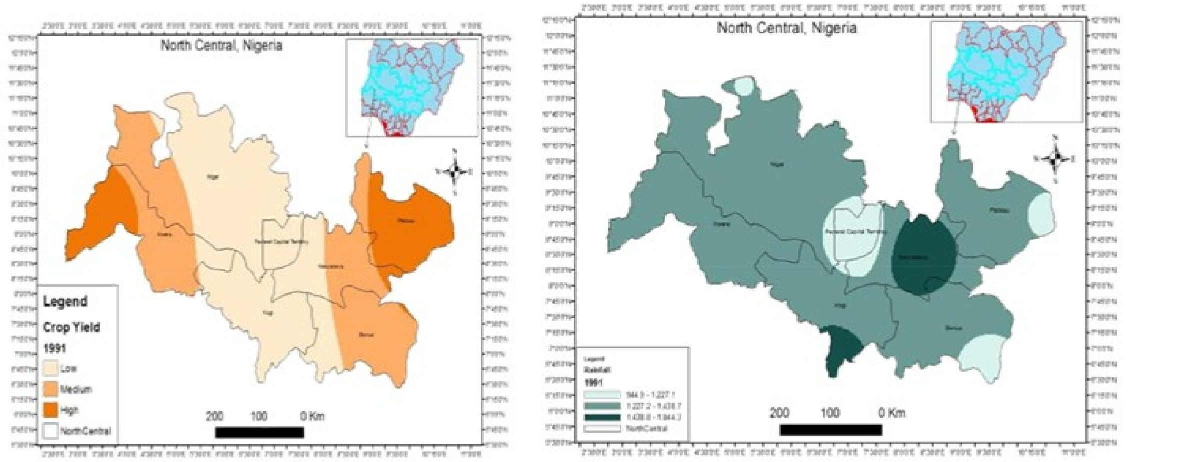

Figure 3: Geo-spatial variation map of annual rainfall and annual sorghum yield for 1991

Figure 4 shows the annual rainfall and sorghum yield for north central Nigeria in the year 1992. For annual rainfall variation map, the area in deep blue color shows area with the highest rain fall which ranges between 25 cm – 47.5 cm and the area with the lowest rainfall is indicated by tinted blue ranging from 0.05 cm – 11.2 cm Niger, Kwara, Kogi, Nassarawa, and Plateau fall under this category. From the yield map light orange represent medium yield, deep orange represents high yield while tinted orange represents low yield. High yield in plateau state and Kwara state is because of the moderate rainfall in the area.

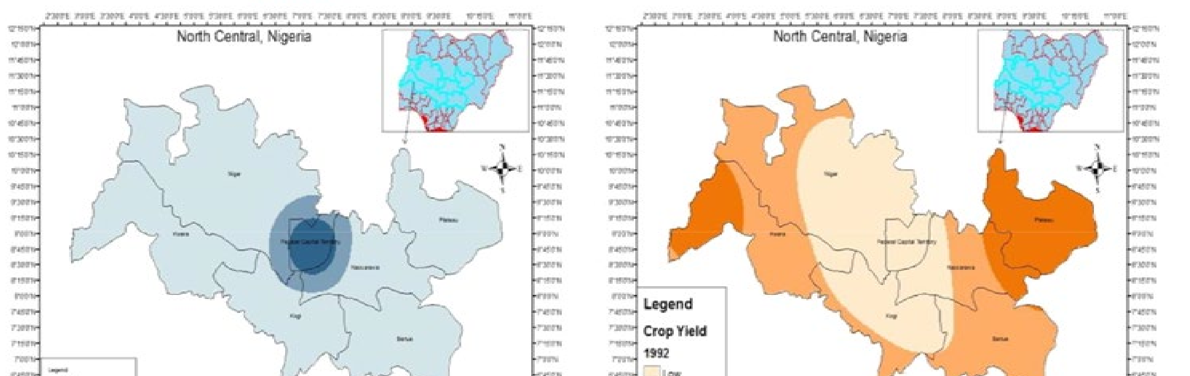

Figure 4: Geo-spatial variation map of annual rainfall and annual sorghum yield the year 1992

The annual rainfall and annual yield variation map for year 2000 is shown in Figure 5 with deep blue representing a high rate of rainfall ranging from 1101.2 mm – 1269.4 mm which can be seen in Niger state while low rainfall with tinted blue color ranging from 848.7 mm – 980.7 mm which can be seen in Nassarawa, Kogi and Abuja. Annual yield is the highest as indicated with deep orange in Plateau, Kwara and Benue state; this is because of the moderate rainfall in the respective states.

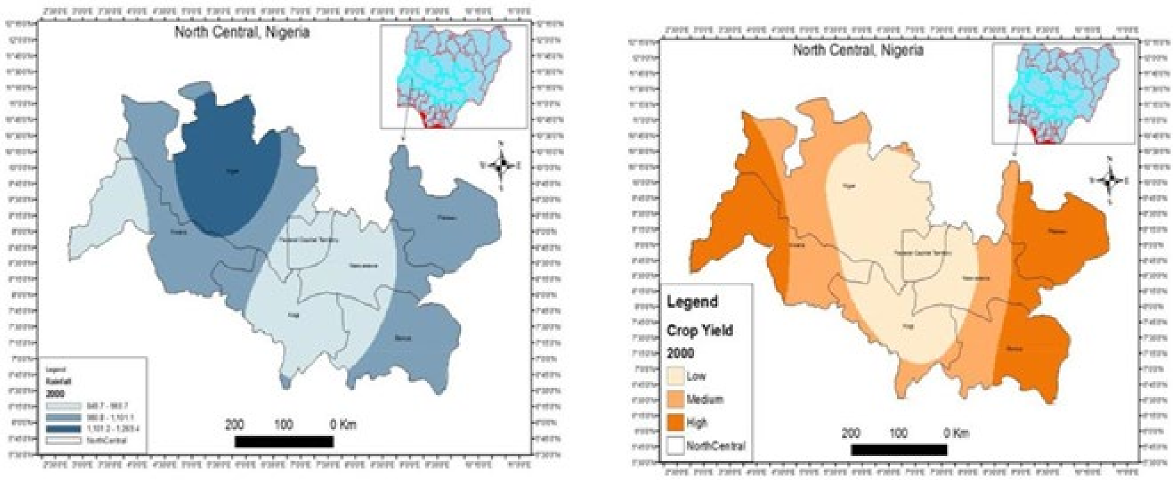

Figure 5: Geo-spatial variation map for annual rainfall and annual sorghum for year 2000

Figure 6 shows the annual rainfall and temperature variation maps of the north- central states of Nigeria. In 2005 Kwara, Niger, and plateau records the highest range of rainfall which ranges from 945.4 mm – 1015.5 mm while the lowest annual rainfall ranges from 822.9 mm – 890.9 mm. the yield map shows that plateau Nassarawa and Benue are having the highest yield while Abuja with the lowest amount of rain fall has the lowest yield.

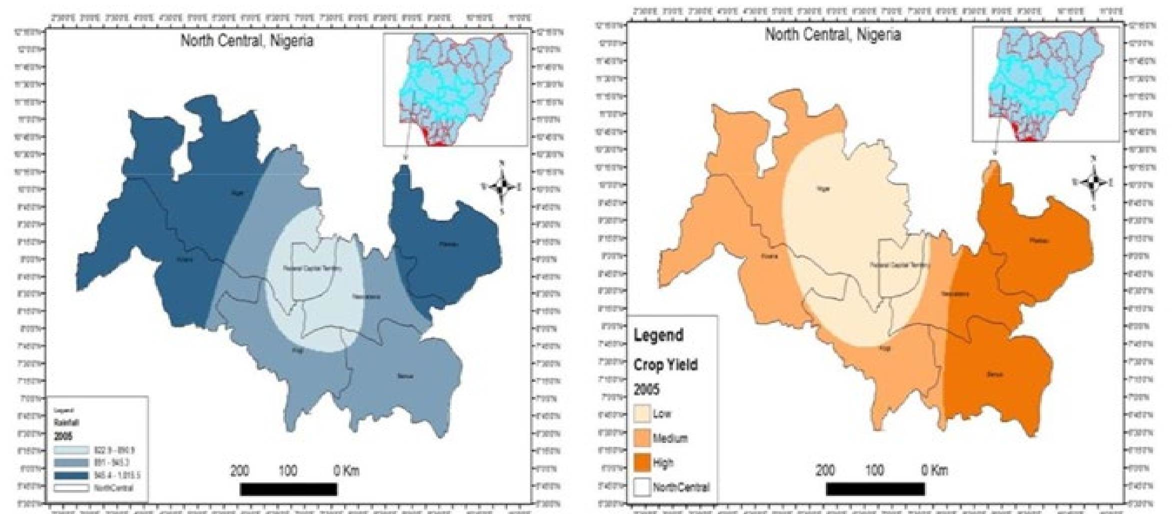

Figure 6: geo-spatial variation map of annual rainfall and sorghum yield of the study area for the year 2005

The annual rainfall and yield variation map for 2009 is shown in Figure 7 with Abuja, Benue state and Niger state having the highest rate of rainfall in deep blue color ranging from 1170.8 mm – 1330.3 mm and lowest rate in tinted blue ranging from 903.6 mm – 1,075 mm and the yield variation showing plateau and Benue having the highest yield with deep orange color as indicator due to the moderate rainfall in the area.

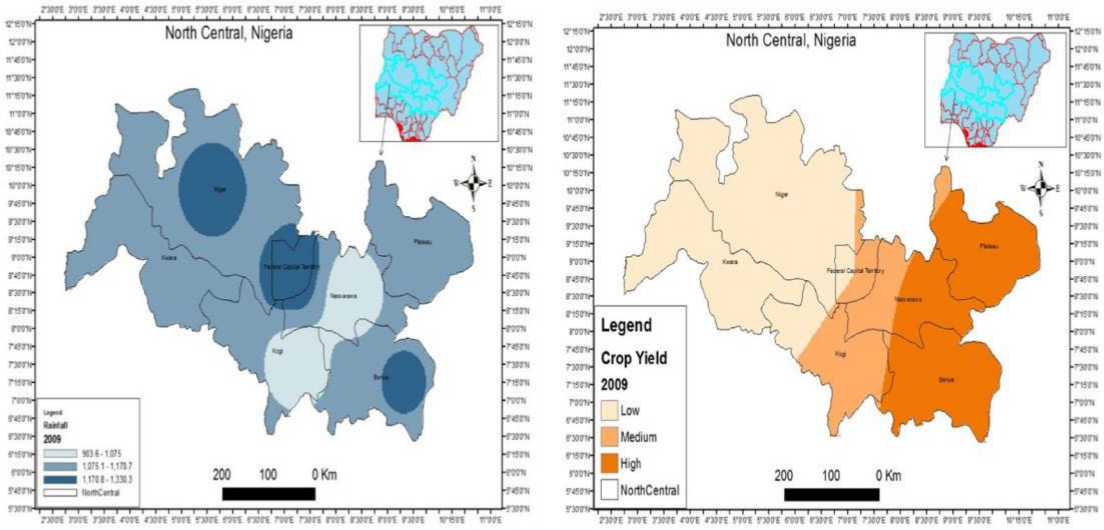

Figure 7: geo-spatial variation map of annual rainfall and sorghum yield for the year 2009

Figure 8 shows the annual rainfall and cowpea yield for north central Nigeria in the year 2012. For annual rainfall variation map, the area in deep blue color shows area with the highest rain fall which ranges between 1106.1 mm – 1336.7 mm and the area with the lowest rainfall is indicated by tinted blue ranging from 683 mm – 931.7 mm Niger, Kwara, Kogi, Nassarawa, and Plateau fall under this category. For the yield light orange represent medium yield, deep orange represents high yield while tinted orange represents low yield. High yield in Nassarawa state and Benue state is because of the moderate rainfall in the area.

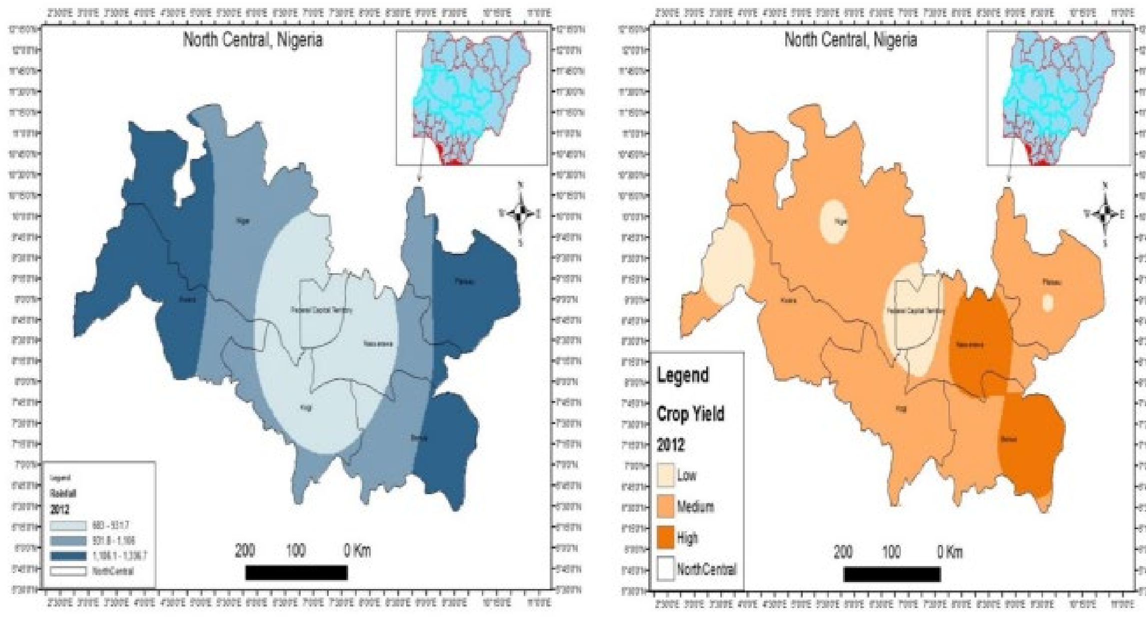

Figure 8: Geo-spatial variation map of annual rainfall and sorghum yield for the year 2012

Figure 9 to Figure 13 show the variation in annual temperature and annual yield of sorghum of the north central states of Nigeria. Deep red color signifies the highest temperature while tinted red indicates the lowest temperature. Studying the maps shows that change in temperature does not affects the yield of sorghum for example Figure 9 indicates that Abuja has the highest temperature and has a lowest yield for year 1991 and Niger state has a lowest temperature and still a lowest yield.

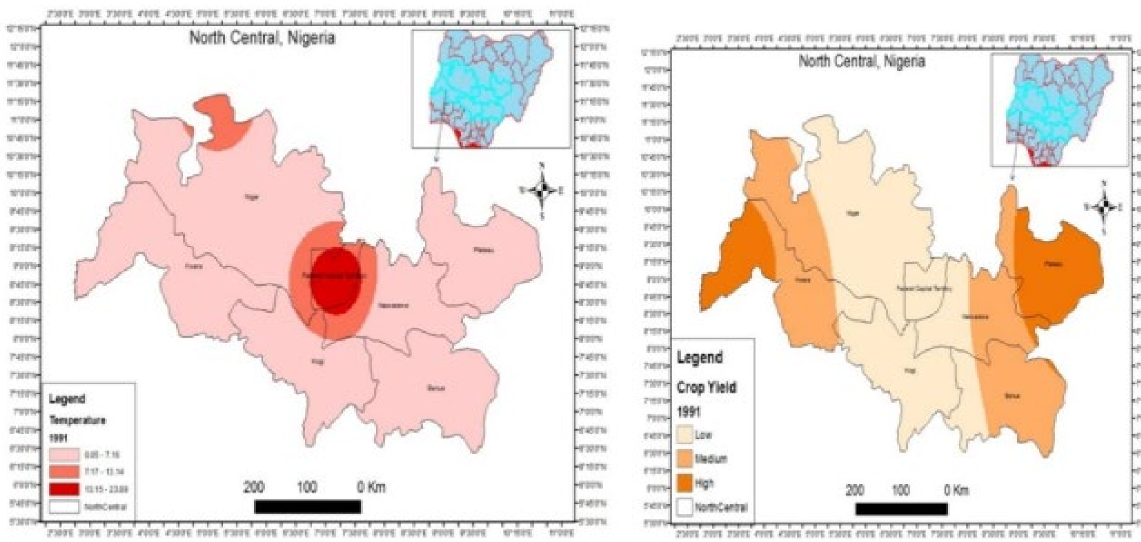

Figure 9: geospatial variation map of annual temperature and annual sorghum yield for1991

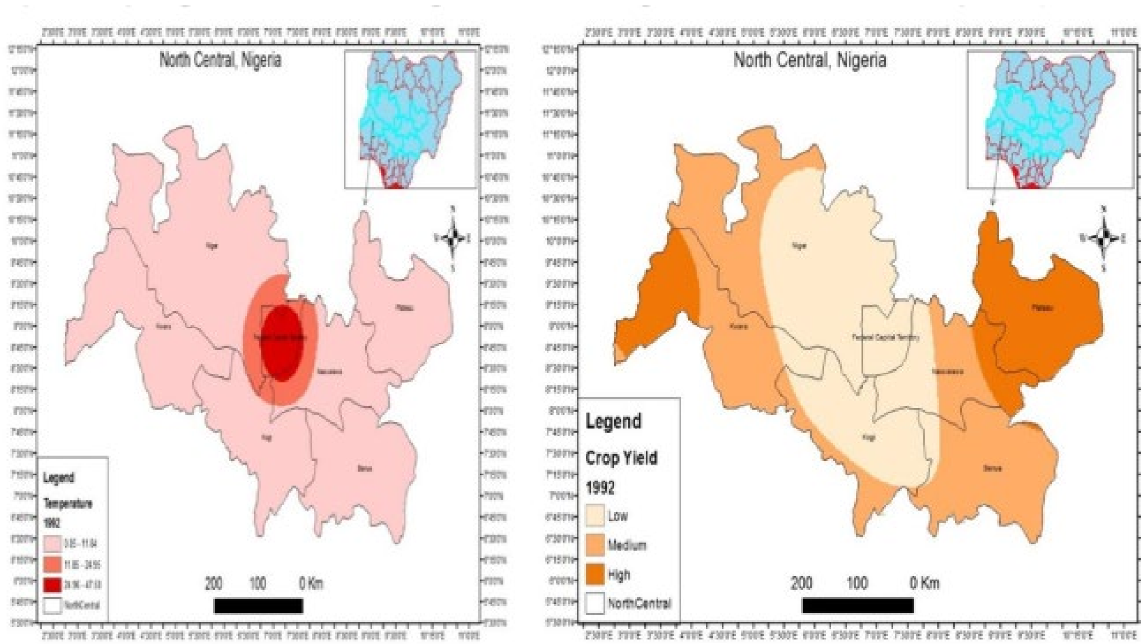

Figure 10: Geo spatial variation map of annual temperature and annual sorghum yield of the study area of year 1992

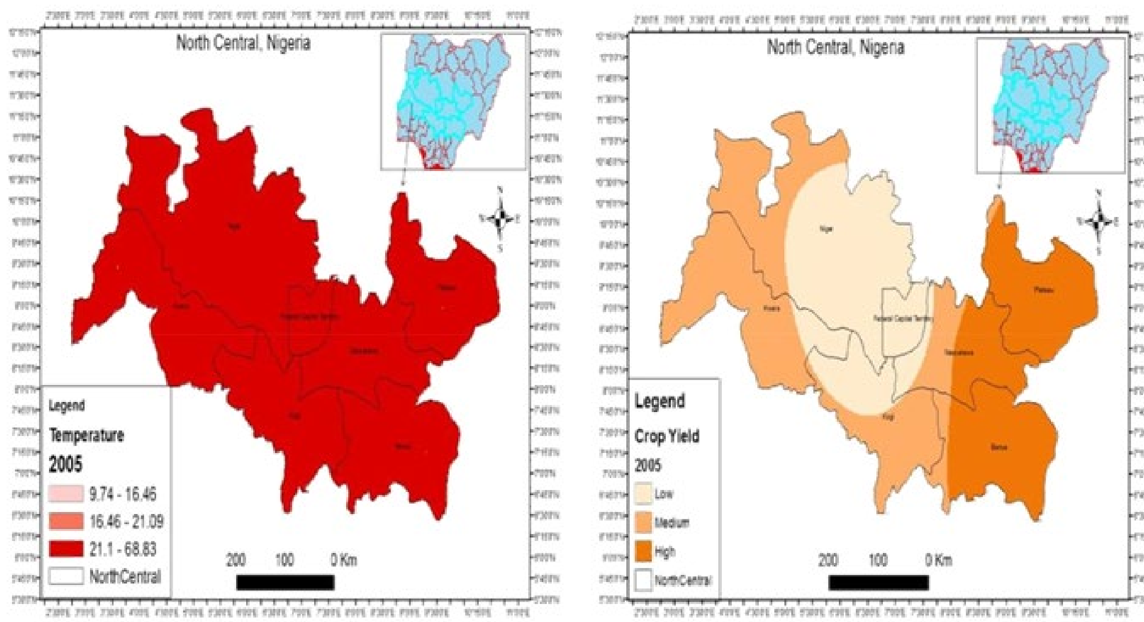

Figure 11: geo-spatial variation map of annual temperature and sorghum yield for 2005

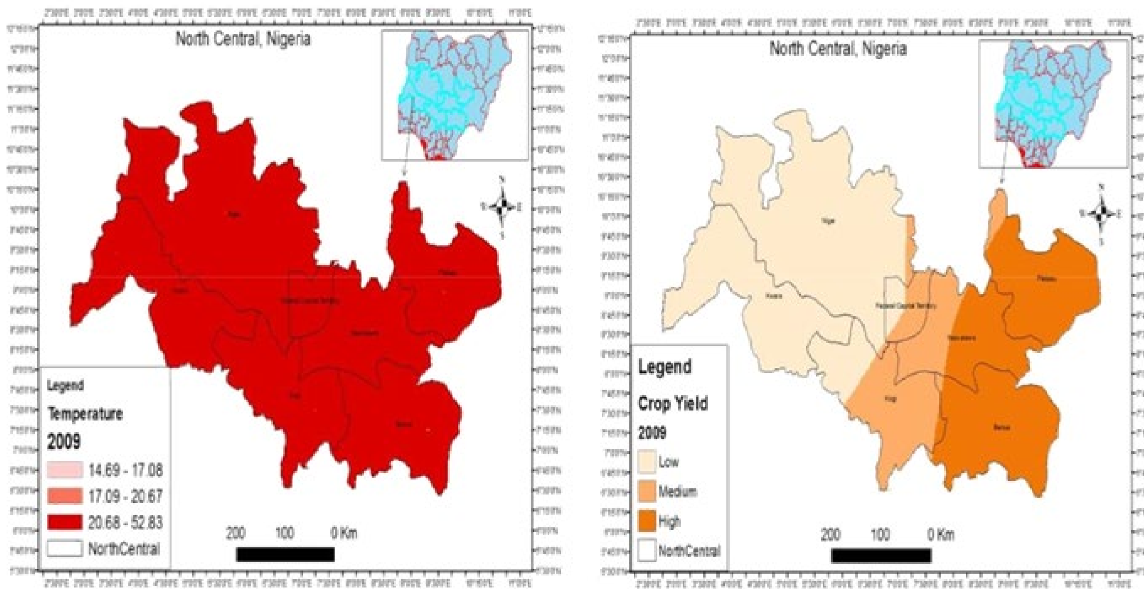

Figure 12: Geo-spatial variation map of annual temperature and sorghum yield for 2009

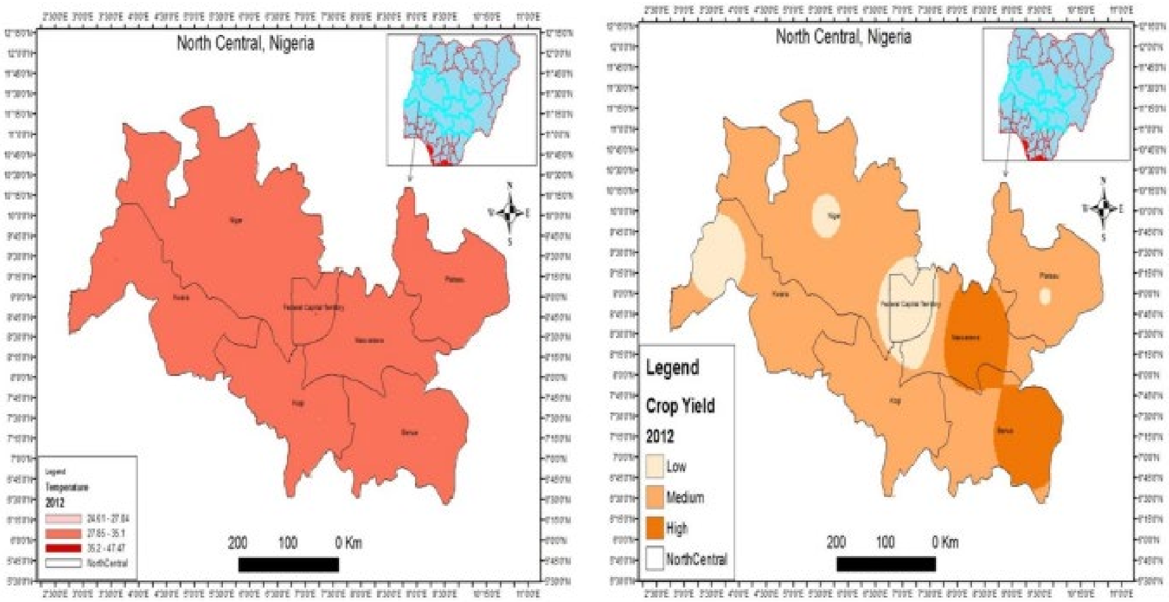

Figure 13: Geo-spatial variation map of annual temperature and sorghum yield for 2012

3.2 Geospatial Projection Values

Table 2, Table 3 and Figure 14 showed the prediction values of annual temperature and annual rainfall and average prediction values of annual rainfall and annual temperature for year 1991 – 2012 respectively. The standardized residual values ranging from <-2.5 to -1.5 indicates that the climatic variables (temperature and rainfall) under-predict the yield of sorghum in the study area it shows that these climatic variables has little or no effect on the yield of sorghum indicating that other factors are the main determinant of the yield rate. Values ranging from -1.5 to 1.5 indicates that temperature and rainfall contribute effectively on a normal basis to the crop's yield showing that they have a visible effect on the crop's yield with other factors alongside. Values from 1.5 to >2.5 over-predicts, indicating that rainfall and temperature are the major determinants of the yield. Nassarawa states has the highest mean prediction value with a value of 1.59 , the variation in annual rainfall and annual temperature affects to a great extent the yield of sorghum in this state while Niger state with -0.25 has the lowest prediction values.

Table 2: Projected values of rainfall and temperature variation on sorghum yield

S/N	Year	Kwara	Niger	FCT Abuja	Kogi	Plateau	Nasarawa	Benue
1	1991	1.5	-1.5	2.5	0.5	1.5	1.5	0.5
2	1992	-1.5	-0.5	2.5	0.5	1.8	1.9	-0.6
3	1993	0.3	0.5	1.7	-0.5	2.8	1.5	-2.5
4	1994	0.5	2.3	-1.6	0.5	2.4	2.5	2.5
5	1995	0.6	0.5	0.3	0.4	1.2	-0.4	0.4
6	1996	-1.5	1.5	1.3	1.2	1.5	1.5	0.5
7	1997	0.5	0.5	-0.3	-0.7	-0.3	-0.3	-1.5
8	1998	1.5	0.5	2.8	0.5	2.4	2.3	0.5
9	1999	1.5	-0.5	-0.5	2.5	-0.5	0.5	1.5
10	2000	0.5	-1.5	2.5	-1.5	0.4	0.5	0.5
11	2001	1.5	-3	2.8	-0.5	0.5	0.5	0.5
12	2002	2.5	-2.8	2.5	0.5	1.4	0.5	2.3
13	2003	-1.5	-0.5	-0.6	0.5	1.5	2.5	2.5
14	2004	0.5	2.8	1.5	-0.5	2.5	0.4	1.5
15	2005	0.5	-1.5	0.5	0.5	2.5	2.4	0.5
16	2006	0.5	0.6	1.5	-1	0.5	2.4	1.5

17	2007	2.4	-1.8	-3	-0.5	-0.5	2.5	2.3
18	2008	0.5	-1.5	2.5	-1.5	0.5	2.5	1.5
19	2009	1.5	1.5	2.5	-0.5	-0.5	2.5	1.5
20	2010	-1.5	-1.5	1.5	0.5	0.5	2.5	1.5
21	2011	-0.5	-0.5	1.5	-0.5	0.5	2.5	1.5
22	2012	1.5	-0.4	-2.5	-0.5	-0.5	2.5	1.7

Table 3 shows that Kwara, Nassarawa, FCT Abuja, and Benue state have values within the range of 0.5 and >1.5 which indicates that variation in temperature and rainfall have a good prediction on sorghum yield in the study area. Leaving out only Niger and Kogi state with - 0.27 and 0.13 respectively.

Table 3: Projected values of rainfall and temperature on sorghum yield (mm)

Kwara	Niger	FCT Abuja	Kogi	Plateau	Nassarawa	Benue
0.60	-0.27	0.99	0.13	1.00	1.59	0.94

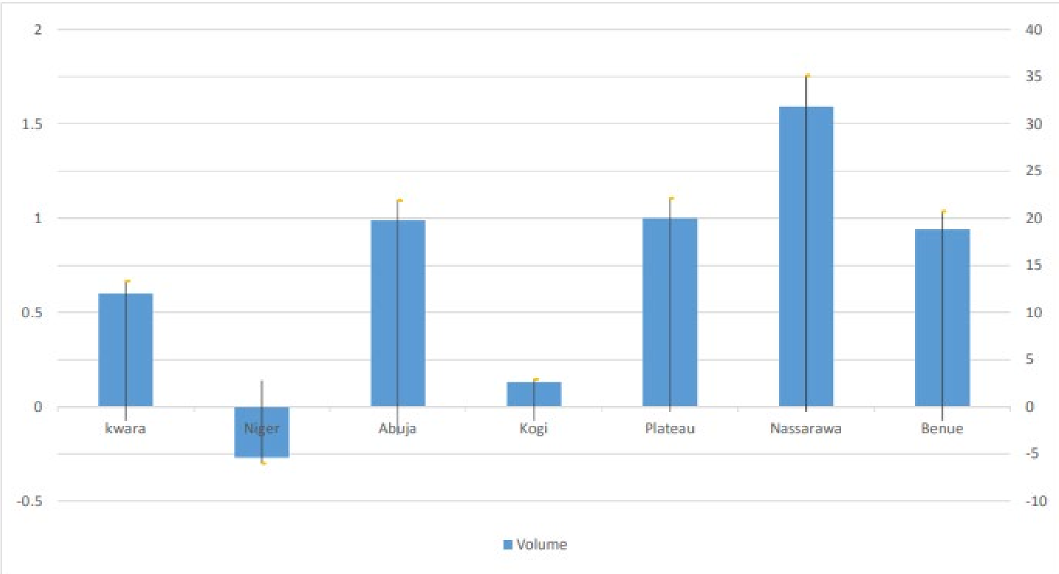

Figure 14: the mean projected values of annual rainfall and annual temperature variation effect on yield of sorghum for the year 1991 – 2012.

4. Conclusions

The climatic (rainfall and temperature) variation within the period under consideration have impact on the yield of sorghum in the North-Central states of Nigeria. Enlightenment campaign and short-term training by Government extension workers is recommended to be made available for farmers to educate them on the effect of climate change on their farming activities and crop yield. It is highly recommended to substitute fossil fuel with alternative source of energy to reduce the global atmospheric gas emission contributing to global warming which in turn leads to climate instability. Forestation and planting of trees is recommended to reduce effect of global warming thereby enhancing a stable climate. Introduction of changes in current farm management practices is recommended because this study shows that climatic conditions affect crop yield for relatively long period.

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ASSESSMENT OF THE USE OF BERMUDA GRASS (*CYNODON DACTYLON*) AND BROADLEAF CARPET GRASS (*AXONOPUS COMPRESSUS*) IN CONTROL OF SOIL EROSION BY WATER

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Abstract

Soil erosion by water is associated with environmental degradation, decline in soil fertility resulting into low crop and animal productivity. This research studied the effect of two types of vegetation (C. dactylon and A. compressus) as compared to bare land conditions on runoff generation and sediment yield. The results showed that the vegetated plots produced an average runoff volume of 95.93 ± 44.64 L and 92.09 ± 41.77 L respectively for C. dactylon and A. compressus while the bare land generated runoff 1.53 times more than those of C. dactylon and 1.63 more than that from the A. compressus plots. However, the difference in the runoff volume and sediment load from the vegetated plots were not significantly different from each other though significantly different from those of the bare land. Correspondingly, the eroded soil from C. dactylon and A. compressus vegetated plots were 1.72 ± 0.87 kg and 1.60 ± 0.91 kg and the bare land produced 4.32 ± 2.23 kg resulting into a soil loss of 4.48 and 2.98 times greater than the soil loss from the vegetated plots (C. dactylon and A. compressus plots). The average soil loss from the vegetated plots and the bare plots were estimated as 2.34×10^2 ± 251.59 kg/ha, 2.07×10^2 ± 218.0 kg and 8.08×10^2 ± 441.26 kg/ha. The study showed that A. compressus gave better soil protection, reducing sediments production and runoff volume by 61.61% and 37.41% while C. dactylon gave 60.51% and 34.82 % reduction compared to bare land plot. Thus, land cover management is found to have a great influence on soil erosion under the prevailing environmental conditions found at Gidan Kwano, Nigeria.

Keywords: Control measures, Management practice, Sediment yield, Soil loss, Vegetation, Water erosion.

1. Introduction

Erosion is a natural occurrence, shaping sand dunes, creating river deltas, or carving out enormous rock features like the Grand Canyon. Humans have, however, intensely accelerated the processes of erosion through agricultural expansion and land mismanagement (Hussein, 1998). Thus, accelerated erosion can cause detrimental effects on the environment such as loss of productive topsoil, sedimentation of waterways, limiting water infiltration, flooding and pollution with chemicals in the runoff (Norton, Ventura, & Dontsova, 2003) as well as affecting the physical, chemical and biological properties of the soil (Lobo, Lozano, & Delgado, 2005), thereby increasing both runoff and erosion resulting into land degradation (Pandey, Himanshu, Mishra, & Singh, 2016). McCool & Renard (1990) reported that only under the gentlest climatic, topographic, and soil conditions that accelerated erosion has no potential for damaging the natural resource base. Vegetative cover can protect the soil against the impacts of raindrop and improve its physical and chemical properties (Lima, Silva, Curi, & Quinton, 2014). Furthermore, the use of grasses as a water erosion management tool is a more effective conservative measure than reforestation in the sense that it needs relatively less time to cover the ground surface as well as it is also low cost (Saidi & Adrinal, 2019). Thus, sustainable development programs that do not negatively affect soil and water resources should be a paramount concern globally because climatic events will continue to occur and humans will continue to utilize these resources for its benefits (Norton, Ventura, & Dontsova, 2003).

Thus, this study is aimed at assessing the influence of two types of vegetation (*C. dactylon* and *A. compressus*) and non-vegetation (bare land) conditions on runoff generation and sediment yield to enhance productive capacity of the environment.

2. Materials and Methods

The experimental site was located on the premises of Federal University of Technology, Minna, Gidan Kwano Campus at latitude 8° 10°N and 11°30°N, longitude 3° 30°E and 7°30°E in the Southern Guinea Savanna of Nigeria. The climate alternate with both dry and wet season. The rainy season begins in April and ends in October. The mean monthly rainfall record from 1998 to 2008 ranges from 0.26 mm to 269.5 mm with November and March having the minimum and September having the maximum occurrence. The dry season is marked by the influence of harmattan (tropical continental air mass) which blows across from the Sahara. It usually lasts from December to February (Iyanda, 2008). The mean monthly temperature ranges from 26.01˚C to 34.68˚C with August having the minimum record and March having the maximum record. The soil of the research site is classified as sandy loam according to textural class. The vegetation of the experimental site consists of scattered trees such as mango (*mangiferas indica*), shrubs: *vililaria paradox, vitex donian* and short grasses such as *Andropogon gauyanus*, *Brachairia bizantha, Stylosanthes guyanensis, Mucuna pyruieris, Axonopus compressus Canajus cajas* and *Cynodon dactylon*.

Fig. 1. (a) Layout of the plots, (b) Layout of the plots showing the collector and the collecting tank and (c) Picture of the Broad-leaf carpet grass

The experimental site consisted of three treatment plots (A - *Axonopus compressus* (Broadleaf carpet grass) plot, B - *Cynodon dactylon* (Bermuda grass) plot and and C - non-vegetation (bare land) condition plot). *A. compressus* and *C. dactylon* were chosen because of their ability to produce vegetal cover and they are weeds commonly found in the experimental site. Plot C is the control plot, bare of vegetation. This was maintained by treating the soil with herbicide (Glyspring).

The plots were prepared in April, 2009. The plots were made up of 4 m × 1.5 m each on a 3 % slope (Fig. 1). Plywood that extended 20 cm above the ground surface and 10cm below the ground surface were placed around the experimental plots to avoid leaks and direct only runoff delivery and sediment within the experimental plot. A broad collector 1.2 m long and 30 cm wide was placed at the base of each of the plots to collect all the runoff and sediment produced during the rain event. On the collector are spouts (3 cm in diameter) through which runoff delivery empties into a collecting tank (120 litres) installed in pits just below ground level. Placed over the spout is a mesh to collect the sediment. Records of rainfall depth for each storm even was taken using a locally constructed rain-gauge.

After each rainfall event, runoff and sediment load produced are channeled through the collector placed at the lower end of the plot. The sediment loads trapped on the collector by the mesh placed over it were scooped off into a soil bag. Sediments channeled into the tank were allowed to settle after which the runoff volume was determined. The clear water was collected with a bucket and measured with a graduated container. The sediment collected at the bottom of the tank plus the sediment collected on the collector were taken for oven drying to a constant weight. The sediment weights were determined after oven drying using a weighing balance. The sample weight divided by the area of the experimental plot gives the total soil loss from the plot.

The physical properties of soil of the experimental site was done by collecting composite soil samples from each plot using a hand auger. The samples were taken at a depth of 20 cm. The samples were labelled before taking the next sample point to determine particle size using hydrometer method, textural class was determined from the particle size analysis and double ring infiltrometer was used to determine the rate of infiltration. Also, bulk density (using undisturbed soil samples by gravimetric method), moisture content and total porosity were calculated using standard formulas.

3.1 Rainfall depth

The average rainfall depth for the experimental site is presented in Fig. 2. There were no rainfall events in the months of January to March and November to December, 2009. Meanwhile, measurable rainfall depths occurred in the rest of months with the highest and lowest rainfall depths occurring in the months of August (392 mm) and April (35 mm), respectively. April being the onset of the raining season.

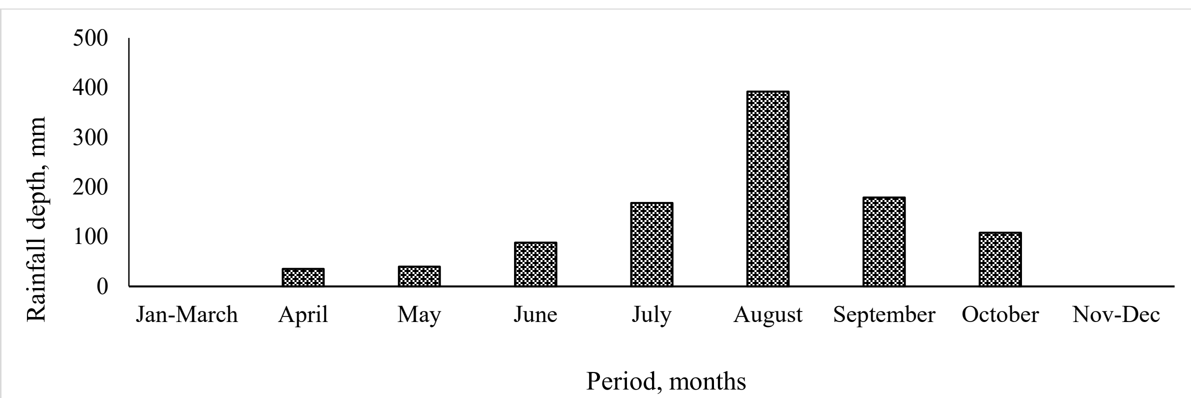

Fig. 2. Average rainfall depth during natural rainfall events at the experimental site

3.2 Runoff and Sediment Yield

The result of surface runoff and sediment yield for the different treatment plots are presented in Table 1. The ANOVA table did not show any influence of vegetation cover over non vegetated cover treatment, although there was variation in the runoff depths among the treatments, these were however, not significantly different from each other. Sediment yield and soil loss from the different plots showed a different effect from runoff depth. The vegetated treatment plots (*C. dactylon* and *A. compressus*) were not significantly different from each other, they were however different from the non-vegetated treatment plots.

The average sediment yields were 1. 66 kg for *A. compressus* plot, *C. dactylon* produced an average quality of 1.72 kg, whereas the bare soil plot produced 4.32 kg of sediments.

Table 1. ANOVA Table for the experimental site showing conservation treatments and its effects of natural rainfall events on sediment yield

Treatment	Runoff depth, L	Sediment yield, kg	Soil loss, kg/m^2
Cynodon dactylon	95.96+44.64a	1.72+0.87a	0.025+0.02a
Axonopus compressus	92.09+41.77a	1.66+0.91a	0.023+0.02a
Bare land	147.14+77.71a	4.32+2.33b	0.081+0.05b

Fig. 3 presents soil loss from the water erosion control treatment plots. The soil loss from *C. dactylon* and *A. compressus* vegetated plots were lower than the bare plot. The *C. dactylon* plot showed a range of 0.039 to 0.0017 kg/m^2, the *A. compressus* ranged from 0.0492 to 0.0018 kg/m^2 while the bare plot ranged from 0.125 to 0.0422 kg/m^2.

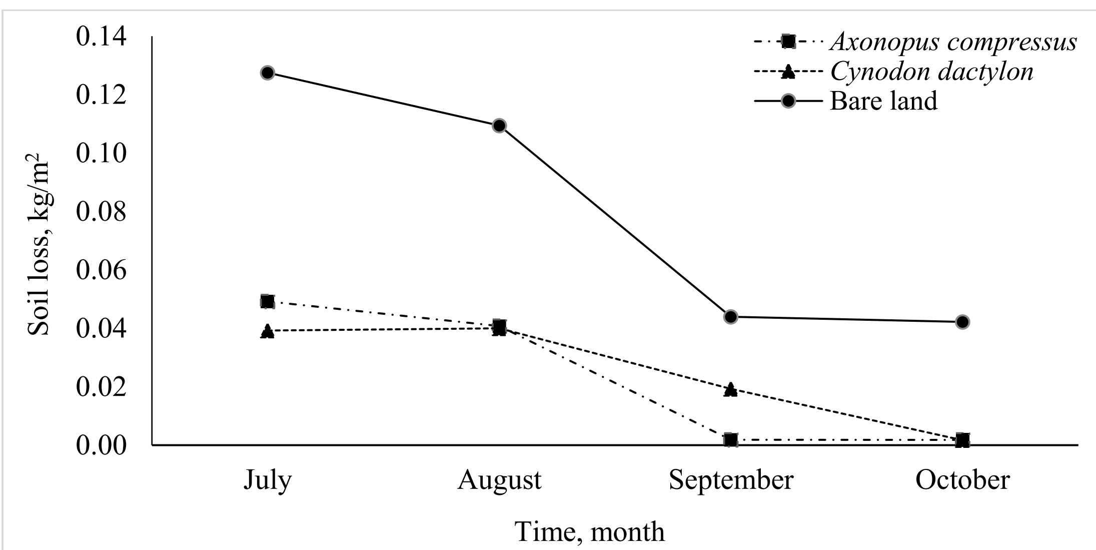

Fig. 3. Soil loss under vegetative and non-vegetative cover during natural rainfall events

Table 2 presents soil properties of the experimental site with the different treatments applied. The results showed averaged moisture contents of 4.49 %, 4.25 % and 4.08 %, respectively for plots A (*C. dactylon*), B (*A. compressus*) and C (bare soil) and the three plots were classified as sandy loam with very high erosion risk. On the contrary, the results of bulk density analyses for plots A, B and C were 1.57 g/cm³, 1.52g/cm³ and 1.40 g/cm³, respectively showed low values of bulk density on the vegetated plots indicating that there is greater water infiltration on the vegetated plots which minimizes run-off volume.

Table 2. Soil physical characteristics for experimental study site during natural rainfall

Plot	MC (%)	BD (g/cm³)	Porosity (%)	IR (cm/hr)	TC	Soil structure degree	Erosion risk
A	4.49	1.52	0.42	212.20	Sandy loam	Weak	Very high
B	4.25	1.40	0.45	228.50	Sandy loam	Weak	Very high
C	4.08	1.57	0.37	248.10	Sandy loam	Weak	Very high

KEYS: A= *C. dactylon*, B = *A. compressus*, C = Bare soil, MC = Moisture content, BD = Bulk Density, IR = Infiltration Rate, TC = Textural Class

The infiltration rates for both the vegetated and non-vegetated plots exhibited the same pattern of flow. This is presented in Fig. 4. The infiltration rate increased at the beginning, and reached its maximum point before decreasing downwards. This showed that, the infiltration of water into the soil was initially low, and then increased to a saturation point before decreasing. The saturation depth, for the bare soil, *C. dactylon* and *A. compressus* plots were 268.02 cm/hr, 236 cm/hr and 258.0 cm/hr, respectively. The cumulative infiltration curve on the other hand increases with increase in time. The low infiltration rate of the vegetated plots may be due to high humidity of the soil.

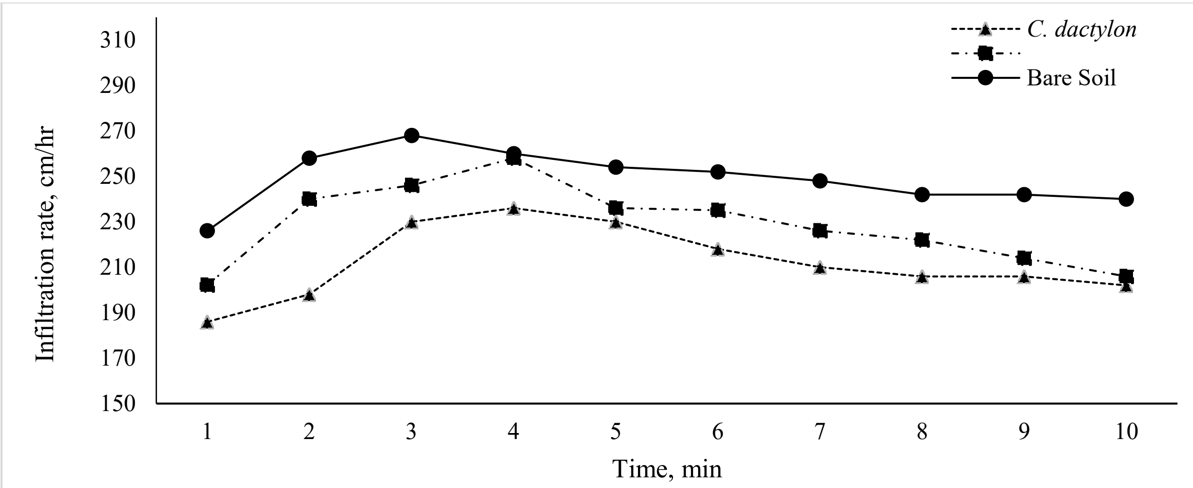

Fig. 4. Infiltration rate for C. dactylon, A. compressus and bare soil plots

3.3 Discussions

In respective of the type of conservation measures applied to reduce the effects of soil loss, sediment yield is highly dependent on hydrological properties, this is illustrated in this present study and also confirmed by Wang et al. (2009). They agreed that the accuracy of sediment yield result was especially dependent on surface runoff during soil erosion and sediment transport stages. The sediment yield was observed to increase with increase in rainfall intensity and run-off depth (Figs. 2 and 3). The quantity produced varied for each plot, for the vegetated surfaces, sediment yield was not excessively high compared with the bare soil plot. This may be due to the favourable soil structure and good stability of the soil with the protective action of the vegetation (Saidi & Adrinal, 2019). Though, based on Lobo et al. (2005) erosion risk classification, the soil of the experimental site are at high risk (Table 2), hence, soil erosion by water can enhance degradation process and limit vegetation growth (Moreno-de las Heras et al., 2010). The effects of lack of vegetative cover has been reported by several authors (Lima et al., 2014, Saidi and Adrinal, 2019). Thus, the importance of soil cover to reduce the menace of soil erosion cannot be overemphasized.

The vegetative effects of *C. dactylon* and *A. compressus* on sediment yield compared to the bare soil plots is illustrated in this present study with lower soil loss from the vegetated plots (Table 1 and Fig. 3). This is indicative of reduction in the effects of raindrop energy absorbed by the plants as well as ability of plant roots in reducing surface runoff and soil erosion (Saidi & Adrinal, 2019). This is also demonstrated by Lima et al. (2014) in their study on the effects of vegetation cover on soil loss. They reported an adequate soil protection due to rapid growth from intercropping, better soil surface protection against raindrop impact, thus resulting into runoff reduction. Furthermore, proper distribution of vegetal cover over the ground surface has positive impact on the effects of sediment yield. This is in agreement with the studies by Moreno-de las Heras et al. (2010), who reported that the amount and spatial organization of vegetation cover strongly influences the pattern and extent of water and sediment redistribution.

Over the entire study period, sediment load was shown to be greatly affected by run-off depth, the decrease in sediment and run-off production from the *A. compressus* plot was 61.63% and 40.15% respectively whereas, the decrease from *C. dactylon* vegetated plot was 60.73% and 37.62% respectively compared with the bare plot. The *A. compressus* plot had the lowest runoff depth, thus producing lower quantity of sediment whereas the bare soil had the highest run-off depth and sediment load indicating that run-off favoured removal of particles, which is a function of rainfall characteristics. Also, sediment yield from the bare soil plots was higher than the vegetated plots due to impacts of raindrop which contributed to sediment delivery into the runoff (Neave & Rayburg, 2007).

The infiltration process is a key factor in sediment yield/soil loss estimation, it can determine the runoff rate, thus affecting the rate of occurance of soil erosion (Wang et al., 2009). Vegetation cover can increase infiltration, soil permeability, organic matter thus reducing soil erodibility (Saidi & Adrinal, 2019) while surface sealing and crusts can decrease infiltration, and increase runoff and impact of erosion (Pandey et al., 2016) especially in areas of low vegetation cover. Thus, the low infiltration rate measured in this present study is due to a number of processes such as physicochemical processes and densely vegetated surfaces which can reduce the impact of raindrops (Norton et al., 2003). Also, rainfall duration and surface runoff play a significant role in infiltration processes (Moreno-de las Heras et al., 2010).

4. Conclusions

This study estimated runoff and sediment yield from natural rainfall events from *C. dactylon* and *A. compressus* vegetation plots and bare soil plots. Vegetation is an effective means of water erosion preventive measure where the *A. compressus* plot had the lowest runoff depth, thus producing lower quantity of sediment compared with the *C. dactylon* plots. Soil properties, runoff rates and infiltration rates are important parameters in soil loss estimation with the bare plots showing more rate of occurance of soil erosion.

Recommendations

Detailed soil analysis consisting of soil types, soil structure, soil carbon content, chemical properties of the soil of both experimental site and the sediment yield and plant analysis including growth rate, density, root length, root length density are areas of further research considerations.

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COAGULATION EFFICIENCY OF OKRO SEED AND LEAF EXTRACTS ON FISHPOND WASTEWATER

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Abstract

This study examined the natural coagulation efficiencies of okra seed and leave extracts as replacement for chemical coagulant like alum in wastewater treatment for possible reuse. The extracts were obtained from okra seeds and leaves using distilled water. The coagulation power of the extracts was examined on fishpond wastewater (FPWW) samples obtained from a popular fish farm in Minna, Niger State. The parameters examined were turbidity, total dissolved solid (TDS), Biochemical Oxygen Demand (BOD) and electrical conductivity (EC). The results show that with addition of different dosages of the okra extracts, the turbidity of the FPWW was reduced from 160 to 53 NTU, EC was reduced from 3166 to 1094 µs/cm while TDS was brought down to 205 from 2154 mg/l. The extracts have no statistically significant effect of the BOD of FPWW. The coagulant however introduced a particular odour into the wastewater and this will make deodorization inevitable before the wastewater reuse but this does not in any way invalidate the coagulation potentials of okra leaves and seeds extracts.

Keywords: Coagulation, fishpond wastewater, okra extracts and wastewater reuse

1. Introduction

Potable water availability has become a problem nowadays due to mismanagement and anthropogenic activities on the land. Surface water is being polluted daily by sewage discharge and effluent from different sources. While ground water is polluted by various human activities and leachates from dumping sites

(Bratby, 2006). The existence of some contaminants in water usually lead to health issues, like gastrointestinal illness, reproductive problems, and neurological disorders. Children, pregnant women, adults and those with low immunity may be especially at risk of becoming ill after drinking water with compromised quality. For instance, accumulation of lead in human body system can cause serious health problems, especially for pregnant women and young children (Muyibi and Okufu, 1995). The polluted water will have to go through treatment processes before it can be used by domestic purpose. One of such processes of water treatment is coagulation (Yarahmadi *et al*., 2009).

Coagulation is the addition of certain coagulant to water to destabilize particles in suspension and it is one of the cheapest processes of water treatment. Aluminum sulphate, an example coagulant, is soluble in water and is used as a flocculating agent. The salt (Al_2SO_4) can however become poisoning factor in dialysis (Lukman *et al*., 2015), and also one of the factors which might contribute to Alzimer disease. The use of natural coagulants may therefore remain a more sustainable and economically viable alternative in physical water treatment.

In many developing countries, water treatment techniques include, among others, coagulation, and sedimentation (which main aim is turbidity reduction). Disinfection, another treatment technique, though very efficient, can be a costly process because of high costs involved purchasing the needed chemicals. Chemical coagulants when combined with lime have been popularly used for turbidity removal from water samples. The sludge resulted from such treatment process comes with a disposal problem because it contains aluminum and can accumulate in the environment in large volume (Sc'iban *et al.,* 2009). Therefore, it is pertinent that other better and more environmental - friendly alternative coagulants be developed to augment if not to replace chemical coagulants.

Natural coagulants are usually assumed safe for human health. These include *Moringa oleifera*, from which Bhuptawat and Folkad, (2007) and Camcuic *et al*, (1998) have reportedly experimented on and have been found to be viable replacement coagulant for chemicals coagulants. Raji *et al,* (2015) studied the flocculating tendencies of fresh stems of mucilage of Gumbo (*Hibiscus esculents*) and was used to reduce the turbidity of municipal wastewater to acceptable standard. Many researchers have also reported *Moringa oleifera* various uses have come reported that Moringa *oleifera* seed is non-toxic and good coagulant in water treatment. It specially recommended for developing countries to be used as a coagulant. Encouraged by the results of these studies, many developing countries have explored the use this plant as a viable coagulant in water and wastewater treatment on a small scale (Diaz *et al,* 1999).

Muyibi and Okufu, (1995) also reported *Moringa oleifera* powder as having the capability to reduce high turbidity values in water samples. Anastasakis *et al.,* (2009) while explaining steps for water treatment, proposed a settling time of two to three hours for all the particles to settle. Bratby, (2006) and Raji *et al,* (2015) while studying the use of sand filtration technique on river water flocculated with *Moringa oleifera* used a settling period of 1hour to two hours for low, medium and high turbid water. In the present project, okra seeds and leaves were chosen and used as coagulants. Their effectiveness was evaluated for reduction of turbidity and total dissolved solid in fishpond wastewater.

2. Materials and Methods

Okra *Abelmoschus esculentus L.* is an important vegetable crop grown in tropical and sub-tropical parts of the world. The okro seed used was obtained from an ultra-modern market in Minna, Niger state. The okro seeds were washed thoroughly and dried in the oven at 35^0C for 18 hours to reduce its moisture content. The seeds were then ground with mortar and pestle, sieved with 250µm pore sized sieve to obtain soluble active ingredient contained in the seed. The okro leaves were obtained from a farm in Gidan kwano village, they were washed thoroughly and dried in the oven at 30^0C for 24 hours and was then ground and sieved using 250µm pore size sieve.

One hundred grams each of the okro seeds and leaves powder was collected and placed in two different beakers and 1000ml of distilled water was added into each beaker. Magnetic stirrer was used to mix the mixture thoroughly for 30minutes to extract the active components. This was followed by filtration of the solution through a piece of clean white cloth. The filtrate was then centrifuged at 30 rpm for 5 min, followed by filtration using Whatman filter paper No 41 (Sc'iban *et al.,* 2009). The obtained stock solutions from each of these methods were preserved at - 4°C and was used within four days after the extraction to prevent ageing process.

2.1 *Collection of Wastewater and Experimental Runs*

The fish pond wastewater was collected from Musgola fish farm located at Lapai-gwari in Minna Niger state. The wastewater sample was collected in a 25liters gallon and analyzed for some physiochemical properties. The jar test was then performed to evaluate the effect of coagulant dosage on turbidity removal efficiency. The experiments were carried out using different dosages of coagulant. Eight 1000 ml beakers were used for each experiment. The dosage of the coagulants used were from 0, 20, 40, 60, 80, 100, 120 and 140 mg/l each for seeds and leaves extract. The experiments were performed in three replicates. The beakers were initially filled with some quantity of wastewater samples and were placed in the slots of jar tester and were then agitated at 150 rpm. Doses of coagulant were added into each of the beaker during agitation and the process was left for 2 minutes. The mixing speed was changed to 30 rpm and the agitation was continued for 30 minutes. After agitation process, all samples were made to remain at ambient temperature for one hour. A 30 mL of the water samples were collected from the middle of the beaker and was taken for laboratory analysis.

The turbidity of samples was measured in Nephelometric Turbidity Units (NTU) by using turbidimeter model HACH 2100N series with USEPA Method 180.1. The pH, TDS and EC were measured using Hanna H98150 multimeter as recommended by Raji *et al,* (2015).

3. Results and Discussions

The results of the jar test experiment were as presented below:

Table 1: Physical Parameters of the Fish Pond Wastewater at different Dosage of Coagulant (Seeds)

Dosage (mg/L)	Turbidity (NTU)	pH	EC (µS/cm)	TDS (mg/L)	BOD (mg/L)
0	$160^{a} \pm 1.2$**	$6.74^{c} \pm 0.3$	$3166^{gg} \pm 4.6$	$2154^{hj} \pm 4.2$	$4.0^{ff} \pm 0.8$
20	$151^{b} \pm 2.9$	$6.51^{c} \pm 0.2$	$3152^{gg} \pm 5.6$	$2062^{hc} \pm 3.8$	$3.8^{ff} \pm 0.5$
40	$143^{c} \pm 3.2$	$6.53^{c} \pm 0.1$	$2863^{gh} \pm 5.9$	$1739^{hr} \pm 6.3$	$3.9^{ff} \pm 0.6$
60	$102^{d} \pm 2.6$	$6.89^{c} \pm 0.1$	$2419^{gj} \pm 3.3$	$1030^{hl} \pm 4.5$	$2.6^{ff} \pm 0.6$
80	$78^{e} \pm 2.5$	$6.51^{c} \pm 0.0$	$2032^{gk} \pm 6.9$	$908^{hl} \pm 8.9$	$2.6^{ff} \pm 0.6$
100	$69^{e} \pm 4.2$	$6.51^{c} \pm 0.3$	$1344^{gl} \pm 7.0$	$589^{hb} \pm 2.4$	$1.9^{ff} \pm 0.4$
120	$56^{f} \pm 3.2$	$6.88^{c} \pm 0.4$	$1167^{gz} \pm 3.6$	$380^{hm} \pm 9.4$	$1.6^{ff} \pm 0.3$
140	$53^{f} \pm 2.6$	$6.70^{c} \pm 0.3$	$1094^{gz} \pm 3.9$	$205^{hm} \pm 8.3$	$1.6^{ff} \pm 0.3$

** *Values are means of triplicate reading ± standard deviation.*

Values on the same columns with the same superscript are not significantly difference ($p<0.05$) while values with different superscript are significantly different at $p<0.05$.

3.1 *Turbidity Removal Efficiency*

Turbidity, which is the measure of the degree of water transparency due to the presence of suspended particulates could also be used to provide an estimation of the Total Suspended Solids (TSS). Concentration of a particular water sample. It is essential to reduce the turbidity of water in order to effectively disinfect it. From figure 1, it was observed that turbidity of fishpond wastewater decreases with increase of coagulant dosage both for seed and leaves extract.

Table 2: Physical Parameters of the Fish Pond Wastewater at different Dosage of Coagulant (Leaves)

Dosage (mg/L)	Turbidity (NTU)	pH	EC (µS/cm)	TDS (mg/L)	BOD (mg/L)
0	$160^{a} \pm 1.2$	$6.54^{a} \pm 0.3$**	$3166^{ab} \pm 4.6$	$2154^{cd} \pm 4.2$	$4.0^{m} \pm 0.8$
20	$157^{a} \pm 2.4$	$6.51^{a} \pm 0.1$	$3159^{ab} \pm 6.5$	$2082^{ce} \pm 6.9$	$3.8^{m} \pm 0.6$
40	$153^{a} \pm 1.0$	$6.53^{a} \pm 0.2$	$2883^{ac} \pm 2.3$	$1840^{cc} \pm 4.5$	$2.9^{m} \pm 0.1$
60	$132^{b} \pm 3.3$	$7.10^{a} \pm 0.0$	$2439^{ad} \pm 7.5$	$1539^{cc} \pm 3.8$	$2.4^{m} \pm 0.3$
80	$98^{b} \pm 2.1$	$6.51^{a} \pm 0.6$	$2232^{ae} \pm 1.2$	$1008^{cg} \pm 6.7$	$2.6^{m} \pm 0.2$
100	$89^{b} \pm 2.0$	$6.82^{a} \pm 0.4$	$1864^{ae} \pm 9.2$	$789^{ch} \pm 4.1$	$1.8^{m} \pm 0.4$
120	$76^{d} \pm 0.9$	$6.49^{a} \pm 0.5$	$1769^{af} \pm 3.3$	$683^{ch} \pm 2.8$	$1.6^{m} \pm 0.0$
140	$63^{d} \pm 2.1$	$6.90^{a} \pm 0.6$	$1334^{ag} \pm 3.6$	$347^{ck} \pm 3.3$	$1.6^{m} \pm 0.0$

****Values are means of triplicate reading ± standard deviation.***

Values on the same columns with the same superscript are not significantly difference ($p<0.05$) while values with different superscript are significantly different at $p<0.05$.

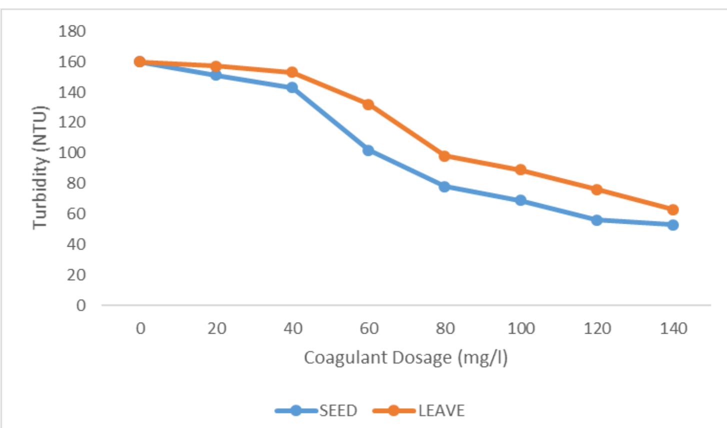

Figure 1: Turbidity removal efficiency of Okra on Fishpond wastewater

However, from tables 1 and 2, the ANOVA conducted revealed that there was no significant difference between turbidity values for leaves extract at a dosage of 0, 20 and 40mg/l. The effect of the coagulant addition started manifesting at 60 mg/l. What could be inferred form this was that, for extract from okra leaves to be used as coagulant, more dosage is needed than if seeds extract is to be used. It was however observed that, seeds extract introduced more odour to the resultant treated water more than leaves. Therefore, more coagulant dosage is required for leaves extract but deodorization is required if seeds extract is to be adopted. In previous study, Camciuc *et al.* (1998) discovered that the protein content in seed and leaf of Okra ranged between 23.8-25.5 % and 22.0-23.7 % a respectively. The result of turbidity removal in fishpond wastewater by the two sections of the plant indicated a strong correlation between the protein content and removal efficiency, which suggest that protein in Okra could potentially play a role as an active agent in coagulation process. Moreover, the result shows that Okra's seed has the potential advantage as natural coagulant for turbidity removal in comparison to other sections of the plant. However, Brasby, (2006) reported that okra seed is conventionally consumed by human being as protein riches vegetable, and may not economically feasible to be used as coagulant. The dried Okra leaf that is commonly considered as waste material could be proposed as a coagulant in water treatment process, due to its similarity in coagulation behavior.

3.2 Effect of Okra extracts on Total Dissolved Solid Concentration of Fishpond wastewater

Total Dissolved Solids is the total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water, expressed in units of mg per unit volume of water (mg/l) Muyibi and Okufu (1995). TDS is directly related to the purity of water and the quality of water purification systems. This includes anything present in water other than the pure water molecule and suspended solids. TDS removal efficiency is is shown in figure 2 for okra seed and leave extract while their effects on electrical conductivity of the wastewater is as shown in figure 3.

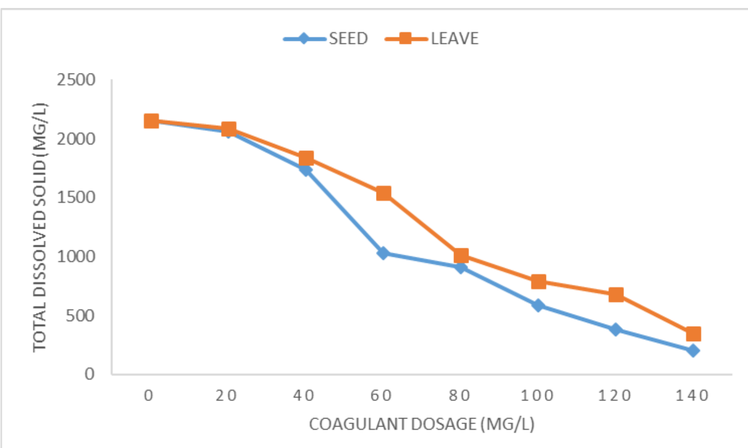

Figure 2: Effect of Okra extracts on Total Dissolved Solid Concentration of Fishpond wastewater.

ANOVA has revealed that both okra seed and leaves extract have no significant effect on pH and BOD of the fishpond wastewater but their effect on turbidity, EC and TDS is remarkable. Researchers, (Bratby, (2006) and Raji *et al,* (2015) have discovered strong relationship between these three wastewater parameters. Therefore, any treatment method that will have significant effect on one may also affect the other two but turbidity being the major factor that need to be considered in fishpond wastewater physical treatment.

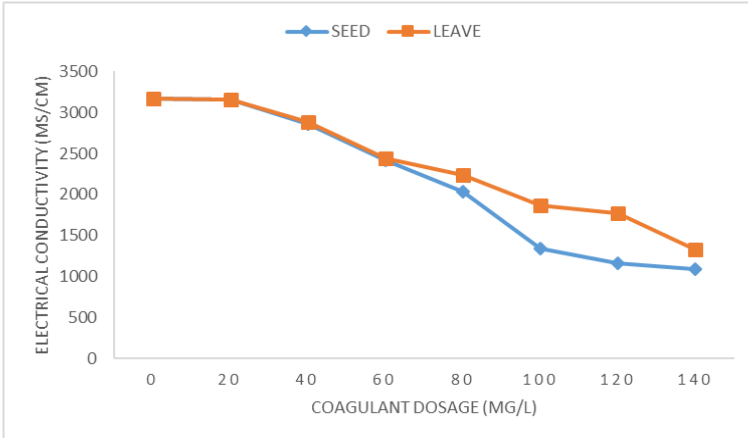

Figure 2: Effect of Okra extracts on Electrical Conductivity Concentration of Fishpond wastewater.

4. Conclusion

The increase in potable water demand for domestic uses occasioned by population growth and rising standard of living, has led to over utilization of renewable drinking water sources and depletion of water quality. Therefore, locally available materials can be used towards achieving sustainable potable water supply. This study was conducted to test okra seeds and leaves as new source of bioremediation in water treatment. A comparative study was made for okra seeds, and leaves extract at different dosages and effect on turbidity, TDS, EC, pH and BOD was studied. It was discovered that seed extract reduced turbidity and other parameters more than leave extract but the seed introduced an offensive odour into the wastewater. While the sludge obtained from seed extract was higher than that of okra leaves. It can be thus suggested that we can use locally available material to treat low turbid waste water which is environmental - friendly as well as cost effective. Natural coagulants are therefore sustainable and economical viable way of water treatment process.

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VARIABILITY OF RESIDUAL SALT CONTENT IN SELECTED FARM SITES OF GIDAN KWANO, NIGERIA

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Abstract

In order to meet the expectation of farmers which is to have a bountiful harvest, various crops need to be cultivated commercially, but soil salinity which is affecting most part of the world, pose serious threat to plant production and the expectation of farmers. So, it seems valuable, to test the salinity and analyze the chemical parameters of the soil from different farm sites selected for this study. In the present research, experiments were conducted to assess the seasonal variability of residual soil salt content of selected sites in the university farm at Gidan Kwano, Minna, the soils were analyzed, and some chemical parameters were found to be more, which may be due to the type of fertilizers used at the various sites. The values of the chemical parameters analyzed are pH (which ranges between 6.25 to 6.88), EC (which ranges between 41 to 70µs/cm), Mn (which ranges between 0.13 to 0.33mg/l), Cu (which ranges between 0.10 to 0.23mg/l), Pb was not observed form the various study locations, P (which ranges between 8.00 to 14.00mg/kg), Na (which ranges between (0.12 to 0.18mol/kg), K (which ranges between 0.04 to0.16mol/kg),Mg^+ (which ranges between 1.10 to2.30mol/kg), Ca^+ (which ranges between 1.90 to3.10mol/kg), CEC (which ranges between 1.8 to 4.3) and Fe (which ranges between 0.06 to 0.18). It is therefore recommended that more *research be carried out on the chemical applied to the soil and the water used for irrigation. Also, maximum amount of water should be applied to the farmland to assist in leaching excess salt forms in the soil.*

Keywords: Crop, farm, food, root, soil, salt content

1. Introduction

A farm is an area of land devoted primarily for various agricultural activities for the purpose of food production. These activities include crop planting, animal husbandry and processing of their products. The farm is traditionally believed to facilitate food production (Pearce, 2015). On the other hand, agriculture simply means the production of crops and livestock either for sale at local, national and international markets. Some of these crops include rice, wheat, yam, cassava; tropical fruits such as mangoes, cashew, citrus, bananas, and livestock's, such as poultry, piggery, diary and fisheries (Mohammed *et al.,* 2010). Thus, it is clear that agriculture continues to be the key pillar of most African economy. They further stated that agriculture plays an important role in Nigeria economy, as it contributes to the Gross Domestic Profit (GDP) with crop production at an estimate of about 85 percent, livestock at about 10 percent, and about 5% for fisheries and forestry.

Soil is an important factor which is very relevant for agricultural activities. Soil simply refers to that top most part of the earth crust which constitutes water, mineral particles, air, organic matter and living organisms. It is a very complicated living medium which can also be seen as a non-renewable resource as its formation is an exceedingly gradual process, therefore much care and attention must be given to it in order to avoid soil degradation which in turn affects the crops grown on it. One of such problems that could lead to soil degradation is salinization, which has become a worldwide threat that inhibits crop growth or leads to low crop yield crops, destruction of soil structure and erosion eventually (Yang *et al*., 2011). They observed that the salinity is so severe across the world and the region affected grew wider than expected and therefore requires more attention to avoid it adverse effects. Salinity has the tendency of destroying the soil structure by making fine particles clog into aggregates, (flocculation) which could inhibit plant growth and prevent proper root penetration. They stated that a soil that has high salt concentration also has a significant amount of sodium present in it which could hinder the germination of seedlings. They further stated that salt stress usually have effect on the growth of plants, and high salts content is due to chemicals added to the soil in form of fertilizers and animal waste. This tends to pose negative effect on the soil rather than boosting the soil nutrient if not carefully checked.

The presence of certain elements in high concentration may prevent the absorption or utilization of other elements. Such condition results in retarded growth, low yield, or even complete destruction of the plant (Jaleel *et al.,* 2007). For instance, the quantity of certain elements such as sodium, potassium, etc. if increased in soil when added artificially as an input may lead to the adverse effects on the soil, by increasing the salinity of the soil. Jaleel *et al.,* (2007) stated that numerous soils become less productive each year due to salt buildup which has a significant role to play in soil degradation thus affecting approximately twenty percent of farms that are irrigated and about twelve percent of dry land. The earliest reaction to salinity in most plants is a tremendous decrease in the tendency of expansion of leaf surface, then by a cessation of expansion as the stress increases (Parida and Das, 2005**)**. The greatest danger of salinity on the germination of plant is linked to the reduction in the osmotic potential of the growth medium, especially the ion toxicity and nutrients insufficiency which could lead to retarded growth and eventually the destruction of the plant (Luo *et al*, 2005). Therefore, it is of great importance to study the problem of salinity which is caused by diverse factors such as the chemicals applied to the soil as fertilizer, pesticide and herbicides, the water for irrigation, waste from animals such as urine and dung, and seek ways of avoiding further threats of salinity on the soil.

This study is aimed at identifying the effect of seasonal variability of residual soil salt content of selected site farms in Gidan Kwano Minna that has been operated upon in the last fifteen years, and to evaluate the impact of salts on the soil properties in the farmland during the period of irrigation and rain feed agriculture.

2. Materials and Method

2.1 Study Location

Gidan Kwano, a growing agricultural commercial farming community, has been actively involved in agricultural activities in the last fifteen years. This is as a result of the sudden increase in population of one of the major cities in Niger State that is Minna. Situated along Kilometer 11Minna – Bida Road, South – East of Minna in the Bosso Local Government Area of Niger State. The land lies at about longitude of 06^0 28^1 45^1E and latitude of 09^0 35^1 26^1E. The site is surrounded Northwards by the Western rail line from Lagos to the northern part of the country and the eastern side by the Minna – Bida Road and to the North – West by the Dagga hill and river Dagga (Musa and Egharevba, 2009).The soil type found in this area is sandy-loam which is characterized as Alfisol (USDA, 2002). The major crops planted are yam, Guinea corn, Maize, Rice and Cassava.

Figure 1: Google Map of the study locations in dotted blacks.

2.2 *Climate*

The climate of the area is sub-humid tropical; Minna has an average relative humidity of 48.9% and average monthly relative humidity ranges between 21% in February to 73% in August. The yearly precipitation within the study area ranges between 1600mm in the south and 1200mm in the north. The pattern of precipitation is monomial and is characterized by a lengthy mean yearly precipitation of about 1284mm. Precipitation commences in May and ends in October (Adeboye *et al.,* 2009).It is known to attain its peak between the months of July and August. The highest temperature in this region is usually between the months of February to April which gives a standard minimum temperature record of 21℃ and maximum temperature of 41℃ (Musa and Egharevba, 2009). The temperature normally falls to 23℃ during the raining period.

2.3 Sample Collection

Soil samples were randomly collected from different farm locations based on the type of farming operations. Table 1 shows the coordinates of the farms considered for the study and the various crops grown while figure 1 shows google earth locations of the various study areas.

Table 1: Distribution of various farms and their coordinates.

S/No	Type Farm Practice	Co ordinate Longitude	Co ordinate Latitude
1.	Eucalyptus plantation	9^0 52.856^1 N	6^0 46.322^1E
2.	Fallow Land	9^0 52.818^1 N	6^0 46.308^1E
3.	Yam Farm	9^0 52.838^1N	$6^0 46.307^1$E
4.	Afforestation site	9^0 31^1 217^{11}N	6^0 27^1 604^{11}E

2.4 Soil Analysis

The soil samples were first air-dried at room temperature for 48 hours. After which some quantity of the samples were collected and placed inside a 1000 ml cylinder to determine the percentage composition of the various soil particles. This is in accordance with the works of Oguike and Mbagwu (2009). The remaining soil samples were analysed for pH, EC, organic carbon, available Phosphorus, Exchangeable Bases (Na^+, K^+, Mg^{2+} and Ca^2), Cu, Pb, Ca^{2+}, CEC, Fe and Salinity. This was carried out according to Haluschak (2006).

3. Results and Discussion

The various crops grown on the various study areas is presented in Table 2. It can be observed that eight different types of crops are grown on the randomly selected study area which is based on the popularity of the crops. The soil texture classification for the study area is in conformity with the works of Musa and Adeoye, 2010; Musa *et al*., 2012; and Musa *et al*., 2013. These studies explained that there are basically five types of soils most commonly available for agricultural purposes. These include sandy loam soil, sandy clay soil, loam soil, clay soil and loamy clay soil. The values of the particle size analyzed ranged between 78.84 to 82.67 % for sand, 6 to 13.11 % for silt and 4 to 14.1% for clay. From the results obtained, sand has the maximum percentage followed by clay and silt respectively. The values obtained showed that a large fraction of the farm land where samples were collected are sandy in nature and mainly falls into the loamy sand textual class. This is similar to the works of Lawal *et al*., (2014) on the impact of gradient positions on some properties of soils under a Tectona Grandis Plantation in Minna, Southern Guinea Savanna of Nigeria. Table 3shows the most commonly farmed soil type (sandy loam) within the study area. It is known to support the growth of cereal crops which is one of the predominant crop types in this part of the country.

Table 2: Crops planted on the various site

Location	**Crops Grown**									
	A	B	C	D	E	F	G	H	I	J
Farm 1	A	B	C	D	NG	NG	NG	NG	NG	NG
Farm 2	NG	NG	NG	NG	E	F	G	NG	NG	NG
Farm 3	NG	NG	NG	NG	NG	NG	NG	H	I	J

NG Crops not grown, A: Yam, B: Rice, C: Pepper, D: Maize, E: Okra, F: Pawpaw, G: Potato, H: Eucalypsus Plantation, I: Fallow Land, J: Yam Farm

Table 3: Textural classification of soils for the various locations

S/No.	**Locations**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Textural class**
	Farm 1W.S				
1.	A	78.84	7.06	14.1	Loamy sand
2.	B	79.86	7.03	13.11	Loamy sand
3.	C	79.82	6.09	14.09	Loamy sand
4.	D	78.88	8.04	13.08	Loamy sand
	Farm 1 D.S				
5.	A	79.98	9.02	11.0	Loamy sand
6.	B	79.86	13.11	7.03	Loamy sand
7.	C	80.02	11.85	8.13	Loamy sand
8.	D	81.0	11.0	9.0	Loamy sand
	Farm 2 W.S				

9.	E	81.0	7.04	11.96	Loamy sand
10.	F	80.0	6.0	4.0	Loamy sand
11.	G	82.67	9.56	7.77	Loamy sand
	Farm 2 D.S				
12.	E	79.98	6.0	14.02	Loamy sand
13.	F	81.02	6.02	12.96	Loamy sand
14.	G	80.0	8.04	11.96	Loamy sand
	Farm 3 W.S				
15.	H	82.09	6.03	11.88	Loamy sand
16.	I	78.03	9.01	12.96	Loamy sand
17.	J	78.86	8.01	13.13	Loamy sand
	Farm 3 D.S				
18.	H	81.95	8.84	9.21	Loamy sand
19.	I	78.804	10.02	11.176	Loamy sand
20.	J	79.501	8.46	12.639	Loamy sand

A: Yam, B: Rice, C: Pepper, D: Maize, E: Okra, F: Pawpaw, G: Potato, H: Eucalypsus Plantation, I: Fallow Land, J: Yam Farm

3.1 Chemical Analysis

Bouksila *et al*., (2010) reported in their study that a land that has a shallow water table in line with elevated soil salinity usually results to complete soil degradation. In arid and semiarid climates, soil salinization is the greatest problem affecting irrigated land sustainability. Weathering of rocks is one of the major ways of obtaining minerals and there exist a relationship between the salt present and chemical composition of rocks from which soils originated, the fertilizer applied and the farming system practiced (Chukwu and Musa, 2008). Table 4 presents the various chemical parameters available within the study areas. These parameters observed are associated with the various types of fertilizers applied to the farmlands.

3.1.1 Phosphorus (P)

Phosphorus is an important macronutrient which is mobile and has direct effect on the productivity of a soil in terms of quality and growth of the plant. The result obtained from this study as presented in Table 4 showed that the values of phosphorus for farm 1 ranged between 9 to 11 mg/kg and 11.5 to 14 mg/kg; for farm 2 it ranged between 8.5 to 11 mg/kg and 12.5 to 14 mg/kg while for farm 3 it ranges between 8 to 10 mg/kg and 10.5 to 14 mg/kg during the wet and dry seasons respectively. Phosphorus values obtained during the dry period were found to be higher than the values obtained during the raining period, this may be due to the organic manure and the inorganic fertilizer N:P:K which are added to the soil and are consequently reduced during the wet season through the process of leaching. The leaching process is much more intense during the wet season which is due to the rate at which rain falls within the study area. This is similar to the work of Kingshuk and Giichi (2014) who studied the salinity condition of 2011 Tohuku-Oki Tsunami affected agricultural lands in northeast Japan and found out that as a result of sufficient rainfall during the raining period, there was less problem of salinity in agricultural lands whereas during the dry period, the salt contents in the soil increased. This, they linked to high temperature rate which lead high rate of evaporation of the soil moisture content and insufficient rainfall to leach the excess salt ions present in the soils.

3.1.2 Potassium (K)

Potassium is one of the most relevant macronutrient needed by plants to activate enzymes and for the formation of protein (Temilola *et al.,* 2014). From the results in Table 4, it was observed that the value of Potassium in the soils analyzed during the wet and dry seasons ranged from 0.06 to 0.10 Cmol/kg and 0.11 to 0.14 Cmol/kg for fam 1; for farm 2 the value ranges between 0.04 to 0.10 Cmol/kg and 0.11 to 0.16 Cmol/kg during the wet and dry season while farm 3 had values ranging between 0.03 to 0.09 Cmol/kg and 0.10 to 0.12 Cmol/kg during the wet and dry seasons respectively. The values obtained indicates a higher potassium content during the dry period as compared to the values during the raining period might be due to high temperature and leaching of nutrient in the soil. This is similar to the works of Yavitt *et al*., (2004) and that of Schoonover and Crim (2015).

3.1.3 Magnesium (Mg)

Magnesium content of the soil samples during the wet seasons from farms 1, 2 and 3 ranged between 1.0 to 1.5 Cmol/kg; 1.2 to 1.5 Cmol/kg and 1.2 to 1.4 Cmol/kg respectively while that of the dry season for farms 1, 2, and 3 ranges between 1.4 to2.3 Cmol/kg; 1.7 to 2.3 Cmol/kg and 1.4 to 1.8 Cmol/kg respectively. The values of obtained during the dry period are quite higher than the raining period this might be due to the consistent rainfall which leads to leaching of nutrient and also due to high temperature (Nduka *et al.,* 2008).

Increased level of magnesium in soils has been described by several researchers (Novak *et al*., 2009; Bronick and Lal, 2005; Chen and Cutright, 2001; Huang *et al*., 1997) to cause high level of structural degradation which eventually leads to poor or lower infiltration rates and hydraulic conductivities. Magnesium is a divalent cation thus its excess in high level in soils either alone or in combination with sodium may lead to its deterioration in soil physical properties (Novak *et al.*, 2009). The hydration energy and radius of Magnesium is known to greater than calcium which weakens the attractive forces between individual soil particles thereby causing them to degenerate into smaller fragments (Novak *et al*., 2009; Bernasconi *et al*., 2006).

3.1.4 *Calcium (Ca)*

The values obtained for the various soil samples from the different farms ranged between 2.0 to 3.1 Cmol/kg and 2.0 to 3.2 Cmol/kg for farm location 1during the wet season respectively while farms and 3 ranges between 2.0 to 2.5 Cmol/kg. The obtained values during the dry seasons for the farm locations 1, 2 and 3 ranges between 2.0 to 2.8Cmol/kg; 2.3 to 2.6 Cmol/kg and 2.0 to 2.6 Cmol/kg respectively. The use of calcium as soils amendment is a common practice in Nigeria which increases its content in soils as most crops planted in this region are maize and corn. Excessive calcium uptake by a plant may lead to disturbances in ion balance, to the disadvantage of other nutrients (such as potassium and magnesium), or to changes in cytosol pH and a decrease in solubility of some ions, e.g. of iron (Giel and Bojarczuk, 2011)

Table 4: Various Parameters Analyzed in the Soils from the Various Locations.

Sample	pH in H_2O	Mn (mg/l)	Cu (mg/l)	Pb (mg/l)	Av. P (mg/l)	Exc. Bases Na+ (cmol/kg)	K+ (cmol/kg)	Mg+ (cmol/kg)	Ca2+ (cmol/kg)	EC (µS/cm)	CEC (cmol/kg)	Fe (mg/l)	% O/C	% O/M
Farm 1 W.S														
A	6.33	0.19	0.12	0	10	0.12	0.10	1.0	2.4	10	2.8	0.12	0.33	0.57
B	6.48	0.18	0.16	0	11	0.14	0.09	1.3	2	12	3	0.06	0.28	0.48
C	6.38	0.18	0.11	0	10.5	0.13	0.06	1.5	2.3	12.5	4	0.14	0.44	0.76
D	6.28	0.13	0.13	0	9	0.16	0.08	1.3	3.1	14	2.5	0.2	0.36	0.62
Farm 1 D.S														
A	6.63	0.33	0.21	0	11.5	0.16	0.11	1.8	2.8	13	3.5	0.13	0.37	0.64
B	6.47	0.28	0.23	0	12.5	0.18	0.12	2.3	2.7	13.2	4	0.16	0.28	0.48
C	6.88	0.21	0.20	0	12	0.18	0.12	1.7	2.0	14	4.3	0.11	0.34	0.59
D	6.74	0.27	0.18	0	14	0.16	0.14	1.4	3.2	14	3.5	0.21	0.35	0.61
Farm 2 W.S														
E	6.52	0.15	0.18	0	11	0.12	0.06	1.2	2.5	10	2.4	0.16	0.27	0.47
F	6.44	0.19	0.13	0	8.5	0.14	0.04	1.5	2.1	10.04	1.8	0.11	0.38	0.66
G	6.25	0.16	0.15	0	10.5	0.15	0.10	1.4	2.0	12	2	0.09	0.41	0.71

Farm 2 D.S														
E	6.36	0.22	0.10	0	14	0.18	0.11	1.9	2.6	11.8	3.2	0.15	0.39	0.67
F	6.45	0.20	0.17	0	12.5	0.16	0.14	1.7	2.4	12.5	3.8	0.18	0.26	0.45
G	6.33	0.22	0.16	0	12.5	0.18	0.16	2.3	2.3	13	2.5	0.2	0.47	0.81
Farm 3 W.S														
H	6.48	0.13	0.12	0	8	0.14	0.06	1.4	1.9	9	2.3	0.13	0.44	0.76
I	6.81	0.16	0.10	0	10	0.15	0.03	1.3	2.1	9.8	2	0.18	0.42	0.73
J	6.38	0.14	0.13	0	9	0.13	0.09	1.2	2.3	10.5	2.3	0.16	0.42	0.73
Farm 3 D.S														
H	6.85	0.18	0.19	0	10.5	0.18	0.10	1.8	2.0	12	3.1	0.16	0.37	0.64
I	6.37	0.19	0.18	0	11.5	0.18	0.12	1.4	2.6	12.5	2.6	0.11	0.33	0.57
J	6.44	0.18	0.16	0	14	0.16	0.10	1.6	2.4	13	2.4	0.18	0.36	0.62

A: Yam, B: Rice, C: Pepper, D: Maize, E: Okra, F: Pawpaw, G: Potato, H: Eucalypsus Plantation, I: Fallow Land, J: Yam Farm, EUC. Eucalypsus Plantation, Yam F. Yam farm, Fallow L. Fallow land. Av. P. Available Phosphorus, EC. Electrical Conductivity,CEC. Cation Exchange Capacity, % OC Percentage Organic Carbon, %OM Percentage Organic Matter, Exc. Bases Exchangeable Bases.

3.1.5 *Sodium (Na)*

The values obtained for the soil sample from the various farms land ranged from 0.12 to 0.16 (cmol/kg) and 0.16 to 0.18 cmol/kg for farm location 1 while 0.12 to 0.15 cmol/kg and 0.16 to 0.18 for farm location 2 and farm location 3 ranges between 0.13 to 0.15 cmol/kg and 0.16 to 0.18 cmol/kg during the wet and dry seasons respectively. The values of sodium obtained from the various farmland were observed to be relatively low and within permissible limits. This could be linked to the kind of soil improvement additives that are added to enhance crop growth. This further speculates that low amount of NPK fertilizer is been added to the soils. The low concentration of sodium in the study area indicates that the study area is free from the threat of salinization and in areas whereby sodium concentration in the soil is high, it may lead to high salt presence in the farmlands which will lead to turbidity of the soils and decrease in the osmotic activity of the soil (Getahun *et al*., 2014). The low concentration of Mg^+, Na^+, Ca^+, and K^+ have no detrimental effect on the soil because they are required in little amount in the soil but when in excess, would give rise to the problem of salinity which weakens plants as a result of the increase in osmotic pressure and the toxic effect of the soil, damage of soil structure due to lack of oxygen making it incapable of assuring plant growth. When the salt content of the soil is high, the rate at which percolation will take place in the soil will be reduced which will in turn give room to water logging thus reducing the growth rate at which root absorbs water from the soil. This is in conformity with the works of Patel and Pandey (2009).

3.1.6 *Organic Matter (OM)*

The presence of OM in soil is believed to be a very important factor in soil fertility as it is known to be a major source of plant nutritive elements with a great influence on the physical and chemical properties of the soil (Zornoza *et al*., 2015; Liu *et al.*, 2008). An understanding of the OM variation in soils is of great importance to salinized soils (Delal *et al*., 2011). The OM values for the various soil samples obtained from farm location 1 ranged between 0.48 to 0.76 % while that of farm location 2 and 3 ranges between 0.47 to 0.71% and 0.73 to 0.76% respectively. During the dry season, the OM content for farm locations 1, 2 and 3 ranges between 0.48 to 0.64%; 0.45 to 0.81% and 0.57 to 0.64% respectively. The result obtained shows that farm locations 2 and 3 had the highest organic matter content which may be due to the organic manure applied to the farms as compared to farm 1.Thus, the two farm locations may have high soil fertility rate as compared with other farms which is in conformity with the works of Yang *et al*., (2012). They studied the spatial distribution of soil moisture, salinity and organic matter in Manas River water shed, Xinjiang-china.

3.1.7 *Manganese (Mn)*

The values obtained for soil samples collected from farm location 1 ranged between 0.13 to 0.19 mg/l during the wet season while during the dry period it ranged between 0.20 to 0.33 mg/l, for farms locations 2 and 3 during the wet season the Mn values ranges between 0.15 to 0.19 mg/l and 0.10 to 0.13mg/l respectively while during the dry season it ranges between 0.10 to 0.17 mg/l and 0.16 to 0.19 mg/l respectively. This result indicates a low concentration of manganese content in farm 3 and a higher concentration in farm 1 respectively. These might be due to the organic and inorganic fertilizers that are applied in the farms and also the nature of the soil properties. This is similar to the work of Kingshuk *et al.,* (2014), they studied the Salinity status of the 2011 Tohoku-oki tsunami affected agricultural lands in northeast Japan and found out that due to inefficient and poor distribution of water by inadequate drainage management could lead to salinity.

3.1.8 *Copper (Cu)*

On the second and third locations during the wet season, the values ranged between 0.13 and 0.18 cmol/kg and 0.10 to 0.13 cmol/kg respectively. During the dry season farm locations 1, 2 and 3 had values ranging between 0.18 to 0.23 cmol/kg; 0.10 to 0.17 cmol/kg and 0.16 to 0.1 9 cmol/kg respectively. This result indicates a higher concentration of Cu in the various farms during the dry period as compared to the raining period this might be due to consistent rainfall which tends to leach away most of the available nutrient including Cu. The result also indicates that farm 1 and farm 2 has the highest concentration of copper compared to farm 3. This is similar to the work of Kingshuk *et al.* (2014).

3.1.9 *Iron (Fe)*

This result indicates a higher concentration of iron in the various farms during the dry season thus leading to a high concentration of soil nutrient at the soil surface. This is similar to the work of Getahun *et al.,* (2014) on the evaluation of irrigation water quality and suitability for irrigation in the Fincha'a Nile basin of western Ethiopia. It was observed that nearly all irrigation water contains dissolved salts and trace elements which when applied to the soil moves by capillary action and when these water evaporates due to intense temperature leads to the concentration of these salts at the soil surface giving rise to salinization.

3.2 *pH*

The pH of any substance can be defined as the degree of acidity or alkalinity of that substance. It can also be express as the negative logarithm of hydrogen ion concentration in the substance (Portjanskaja *et al*., 2004; Thanasoulias *et al*., 2002). The pH value obtained from this study ranges from 6.25-6.88 for the soil sample, which indicates that the soil is slightly acidic. These values as compared with international standards of FAO (1976) and were found to be within acceptable range.

3.3 Electrical Conductivity (EC)

Electrical conductivity is used to measure the degree of salinity of a given soil and also the rate at which a soil can conduct electricity. This is expressed in micro siemen per centimeters (μS/cm). It has been reported that the higher the value of electrical conductivity, the higher the salinity. The observed EC values from Table 5 for the wet season ranged between 9.00 and 12.50 μS/cm while that of the dry season ranged between 11.8 to 13.2 μS/cm. it was observed from the Table 5 that the dry season had highest values of EC. The low EC values during the wet season could be linked to the dilution of the various salt metals in the water which is consequently leached away from their present position. When the electrical conductivity of the soil samples was compared with standards obtained from World Health Organization (WHO) of 2004; it was discovered that the values were within the recommended standard. This clearly shows that the sampled soil does not contain enough salt concentration to conduct electricity which makes them suitable for farming purposes. The presence of the various salt metals determined in this study have no detrimental effect on the soil as they are required in small amount in the soil for effective crop growth. This is in conformity with the works of Patel and Pandey (2009) and that of Getahun*, et al*., (2014).

Salt can be defined as an inorganic mineral that has the tendency to dissolve in water, salt is usually linked with sodium chloride common table salt (Jaleel *et al.,* 2007). They also stated that in real terms, salts that affect both surface water and groundwater are usually a combination of sodium, calcium, potassium, magnesium, chlorides, nitrates, sulfates, bicarbonates and carbonates. These salts often originate from the earth's crust as they are formed through weathering processes, where small amounts of rock and other deposits are dissolved over time and transported by water (Chukwu and Musa*,* 2008). This slow weathering may cause salts to accumulate in both surface and underground waters. Salt content in soils are increased through the application of fertilizers and other organic amendments to the soil.

4. Conclusion

The United Nations estimated that the population projection by 2050 is expected to be about 8.9 billion inhabitants, which implies more agricultural activities to meet the food demands. Recently, the main aim is to increase the potential for food cultivation and its yield in the field which is to be accompanied by sustainable land management. This can be achieved through the various resource management with respect to human needs, sustenance of environmental quality, and the preservation of natural resources for the future. Soil salinity is extensively reported as the major agricultural problem, predominantly in irrigated agriculture. Approximately 20% of arable land and 50% of agricultural land in the world are under the stress of salinity. According to UNESCO and FAO estimated figures, the area of saline soils in the world is of 9.5 x 10^7 km^2. Salinity causes a direct or an indirect detrimental influence on the preservation of soil quality, since it affects the physical, chemical and biological properties of the soil.

This study has revealed that salinity of the soils that were identified within the study locations is gradually on the increase but still at a level that has no detrimental effect on the crops planted. Though identified as an age long farming practices, adequate management of the irrigation scheme and fertilizer application could improve the soil nutrient content irrespective of the soil condition. A proper management practices must be put in place to avoid the threat of salinity in years to come. Hence, the environment will be sure of a healthy soil which can sustain biological productivity, maintain environmental quality, and promote plant and animal health when best management practices are employed. Having the knowledge of the seasonality variation of residual salt content of these farmlands can provide useful indications of economic and environmental sustainability. Therefore, the revitalization of soils affected by salt has a considerable role in the sense of justifying the pressure, especially in agricultural areas. Salt affected soil is an important land resource for agriculture; therefore actions must be put in place to see that it is brought to minimum and if possible completely avoided.

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DEVELOPMENT OF A COMBINED FLOW NUTRIENT FILM HYDROPONIC TECHNIQUE

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Abstract

The objective of this research was to design and evaluate a Combined Flow Nutrient Film Hydroponics Technique (NFHT) using lettuce. Effect of plant population density on nutrient concentration absorption and dry biomass in the NFHT was studied. The NFHT was developed with an idea of reducing energy consumption incurred during cultivation of crops in nutrient film hydroponics. The study of the effect of plant population densities (2, 4, and 6 plant per meter square) to total dry biomass (TDB) production showed that there was a slight increase in it yield as the population density reduced, but this increase occurred at 3 weeks after planting, and as analyzed using ANOVA reveals a significant (P > 0.05). Whereas for the nutrient concentration absorption, there was also a slight difference for the population densities used, but the difference as also analyzed using ANOVA was significant at 3 weeks of harvest.

Keywords: Combine flow; Nutrient film; Hydroponic; total dry biomass; root dry biomass; dry plant aerial biomass; plant population density

1. Introduction

Cultivation of crops continuously has led to the reduction in soil fertility, which has resulted in the reduction of opportunities for natural soil fertility build up by microbes; this has led to reduction in yield and quality of produce (Usama, 2015). Rock wool, which consist of rock, coke and other materials, is liquefied at 1600 °C and spunned into fiber for a root substrate. A rectangular block manufactured with surfactant have been used in Europe as root substrate for vegetable production (William and Paul, 1990). The earliest record on hydroponics cultivation, was in Hanging Gardens of Babylon, where plants were cultivated in a steady stream water. Hydroponics have been adopted over the century, but not until 1929 where an experiment was conducted for its adaptability to commercial crop cultivation (Paul *et al.,* 2011). Hydroponics is a biotechnology of cultivating plants using mineral nutrients solutions in water without the use of soil under controlled culture conditions but does not oppose to customary methods of intensive agriculture (Vijendra and Preet, 2015; Dayadar, 2015). Plant cultivation on soil is subjected to so many risks, which includes; changes in temperature, disease and pest problems, root aeration, nutrient deficiency, poor soil moisture holding capacity, undesirable microbial activities and nematodes, poor drainage, changes in acidity levels, salinity which hydroponics alleviates (Paul *et al.,* 2011). Hydroponics systems helps in delivering water and nutrients to growing plants at a continuous and high relative water potential, which it nutrient levels and composition needs to be properly factored to prevent waste and increase the efficiency of the system (Scot *et al.,* 2014). One of the determining factors in crop biomass production in a hydroponics system is it population density; which is referred as the number of individuals or plants per unit surface area (Humberto *et al.,* 2016). Vegetable crops are grown in many parts of the world thus contributing to the income and the nutritive diets of many (Josephine, 2014). Mofeke *et al.* (2009) and Josephine (2014) reported that vegetable crops constitute 30-50% of iron and vitamins A in resource poor diet. Lettuce (*Lactuca Sativa*) has been recognized as one of the most cultivated vegetables in Nutrient Film Technique (NFT) hydroponics system; this is due to its high productivity, reduction in cycle in comparison to soil cultivation and it easy adaptation to the system (Singh *et al.,* 1997; Cometti *et al.,* 2013). Lettuce cultivation in an area of high temperature poses challenge to it cultivation, when the root zone temperature is not controlled, plant yield is reduced, because the solution temperature affects the oxygen content, causing root death and accelerated bolding process, it is recommended that the temperature does not exceed 20℃ (Cometti *et al.,* 2013; Singh *et al.,* 1997). There are six basic designs of hydroponic systems; water culture, Ebb and flow (flood and drain), wick, drip (recovery or non-recovery), aeroponics and NFT (Josephine, 2014). Based on the previous study of NFT hydroponic system, a combined flow NFT was developed, effect of population density on growth rate and concentration of nutrient absorption was studied in this paper.

2. Materials and Methods

2.1 Design Concept

The concept design of flow nutrient film hydroponic technique is shown in Figure 1. It was design taking into cognizance the environmental condition and the availability of basic requirement which will be required for its efficient performance. The design of the nutrient film hydroponic techniques (NFHT) took into account the following considerations;

Nutrient delivery control
Better timing and control of production
Continuous availability of nutrient in the system even in the absence of electricity
Less land consumption and drastic increase in output
Less expensive to develop
Easy usage and practice i.e., its adaptability both to urban and rural areas.
Automatic control of the electric pump
Movability and ease of detachment.

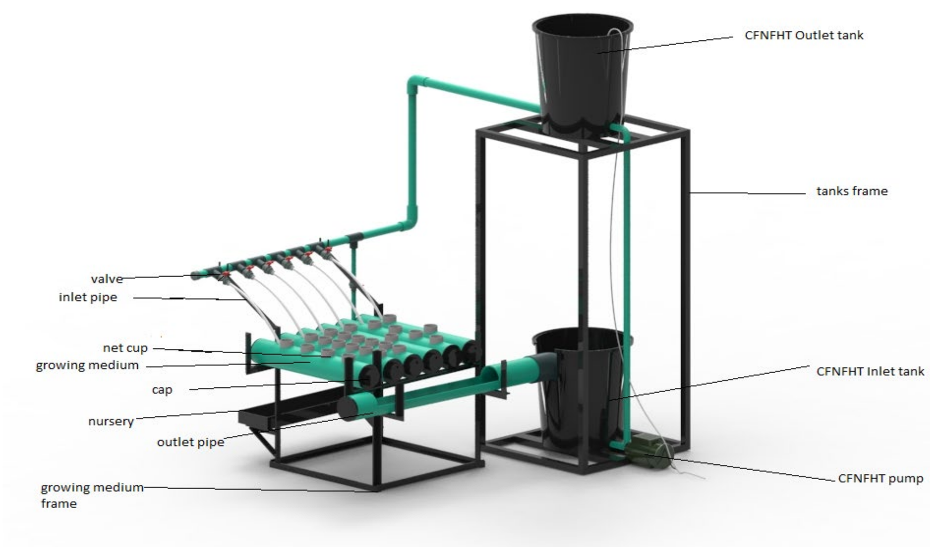

Figure 1. A 3-D View of the designed combined flow nutrient film hydroponics system

2.2 Design Analysis

2.2.1 *Design for the frame*

The NFHT growing medium frame

The diameter of a pipe is 0.1016m, 6 growing pipes will be used for each set up

Therefore; the sum total breadth of the pipe is 0.6096m

The length of the growing medium is 0.91m

2.2.2 *Frame for the tanks*

The tank frame is higher than the nutrient film frame which will enable nutrient to flow into the nutrient film by gravity.

The breadth = 0.75m, length = 0.82m, height = 1.54m

2.3 Nutrient Film Tank

Total nutrient in the growing medium when the outlet of the growing medium is closed.

Volume of a cylinder = $\pi r^2 h$ 1

$= 3.142 \times 5.08^2 \times 96.52$

= 7826.1996 cm^3 =7.82621 m^3 for a growing medium

Therefore, for six (6) growing medium = 46.9572 $liters$

When the outlet is been opened (i.e., the outlet valve from the growing medium)

Amount nutrient which will be in the growing medium will be = 5789.9205 cm^3

2.4 Determination of the Inlet and Outlet Opening

From the relation

$$Q_1 = Q_2 \quad (2)$$

Therefore

$$A_1V_1 = A_2V_2 \quad (3)$$

Also

$$Q = Re \times v \times A / D \quad (4)$$

Where;

Q= Discharge (m^3/sec), R_e= Reynolds number

For laminar flow R_e =2000, v= kinematic viscosity of water = $10^{-6}m^2$/sec

D = hydraulic diameter, A = cross sectional area, A_1 = Cross sectional area of the inlet

A_2 = Cross sectional area for the outlet, Q_1 = discharge for the inlet, Q_2= discharge for the outlet

Determination of the inlet

Using the formula form equation (4)

$A = \pi d^2/4$ 5

= $1.2669 \times 10^{-4} m^2$

Q = $2000 \times 10^{-6} \times 1.2669 \times 10^{-4} / 6.35 \times 10^{-6}$= 0.03990 m^3/sec

Determination of the outlet

Using the formula form equation (4)

A = $\pi d^2 /4$

= $7.855 \times 10^{-5} m^2$

Q = $2000 \times 10^{-6} \times 7.855\, x\, 10^{-5}/7.855$ = $1.571 \times 10^{-5} m^3$/sec

From the calculation above Q_1 is not equal to Q_2

Due to the materials available the inlet flow rate is slightly higher than the outlet flow rate, but with the help of the control valves the inlet flow rate is been adjusted to be equal to the outlet flow rate.

Determination of the inlet

A = $\pi d^2 /4$ = $7.855 \times 10^{-5} m^2$

$Q = 2000 \times 10^{-6} \times 7.855 \times 10^{-5} / 7.855 \times 10^{-5}$ = $1.571 \times 10^{-5} m^3$/sec

Determination of the outlet

A = $\pi\, d^2 /4$ = $7.855 \times 10^{-5} m^2$

Q = $2000\, x\, 10 - 6\, x\, 7.855\, x\, 10 - 5 / 7.855\, x\, 10 - 5$ = 1.571 X $10^{-5} m^3$/sec

Now $Q_1 = Q_2$

2.4.1 *Design for the centrifugal pump*

Flow rate (Q) = $Area\ (A) \times velocity\ (V)$ 6

Area = $\pi d^2/4$ = $5.06773 \times 10^{-4} m^2$

Velocity = speed of the liquid

The velocity for other applicant is 2m/s (dab water technology).

Therefore

$Q = 5.06773 \times 10^{-4} \times 2 = 1.0135 \times 10^{-3}$ m^3/sec $= 1.0135 \times 10^{-6}$ liters /sec

The flow rate for the pump will be 1.0135×10^{-6} liters /sec

Drop in pressure (Hp): This is the dynamic energy loss of water due to mainly friction divided by the loss of water due to friction against the water ways of the pipe and its accessories in a plant (dab water technology).

$$Hp = 20\% \; of \; Hg \tag{7}$$

Where Hg = geometrical height

Delivery head (Hi): is the maximum possible height between the delivery port of the pump and water outlet point (dab water technology).

$$Hi = Hs + Hg \tag{8}$$

Suction head (Hs): is the height between the water level on the sump and the suction port of the pump (m) (dab water technology).

Residual pressure (Hr): is the required pressure at most unfavorable water inlet (dab water technology).

Geometrical height (Hg): is the geometrical height pointing from the sump water level to the most unfavorable water inlet point (m) (dab water technology).

$$Hg = Hi - Hs \tag{9}$$

Total water pressure head (Ht) (dab water technology).

$$Ht = Hg + Hp + Hr \tag{10}$$

Hg =160cm, Hs = 199cm, Hi = 359cm

Hp = 20/100 x 160 = 32cm, Hr = 2000cm, Ht = 192 cm = 1.92m

Efficiency of the pump (%)

$E = P_W/P_s$ 11

Where; P_W = the water horse power = (Q x H) /3960

Q = 1.0135m^3/sec but using US gallon per minutes, 1 gallon US per minutes = 0.23 m^3/hr

= 15863.4783GPM, $P_W = 15863.4783 \times 6.2967 / 3960$ = 25.2241BHp

E= 25.2241/ 0.5= 50.4482%, the pump efficiency is 50.44

2.5 Timing of Returning Water

The rate in which water will be returned into the inlet tank for the growing medium must be determined before been pumped back in to the outlet tank at the trigger of the float switch sensor when the water level in the outlet tank is low.

Time at which the pumps work before triggering off = 167 secs

Time in which the pumps stop before been triggered on again = 268 secs

Therefore, in a day the pumps work for 1.11312 hours/day and the pumps rests (stops working) 22.886988 hours/day

Therefore, power is been conserved.

2.5.1 *Sizing the tank*

Volume of water required = height of the pump and volume of the tank, Height of the pump = 15cm, Area of the tank = $\pi d^2/4 = 3.142 \times 50^2 /4$ = 1963.75 cm^2, Minimum volume of nutrient solution needed in the tank = Total amount of nutrient in the growing medium without been circulated = 7378.6175cm, for the six-growing pipe = 7378.6175 x 6 = 44271.705 cm^3

Total amount of nutrient in the tank = 120 liters, Total amount of nutrient in the system during the shortage of power = 5789.9205cm^3

For the six-growing medium = 5789.9205 x 6 = 34739.523 cm^3

2.6 Design for the NFHT Nursery

Breadth of the NFHT frame = 60.9624 centimeters, breadth of the NHFT nursery = 60.9624 centimeters, since the nursery will attach directly to the NFHT frame

The height of the NFHT nursery = 5cm, length of the NFHT nursery = 26cm

The area of NFHT nursery = L x B = 60.9624 x 26 = 1585.0224cm^2

2.6.1 Design for the float switch

The height of the frame and the outlet tank = 218cm

The height from the center of the pump to the maximum height of the frame and the outlet tank =

The height of the outlet tank = 64cm Therefore the length of the float switch inside the outlet tank = 282cm

2.6.2 Nutrient film hydroponic system component

The combine flow nutrient film hydroponic techniques comprise of a table frame which carries the pipes in which the nutrient will flow through and/or temporary remain for the onward development of the plants. It also comprises of tanks in which nutrient will be stored. The tanks are of the two types, the outlet or the receiving tank and the inlet tank. The inlet tank is connected to a centrifugal pump which is electrically powered. The pump cycles nutrients from the inlet tank into the outlet tank and the outlet tank gives nutrient to the growing medium by gravity. From the bottom tank there are pipes connected to the centrifugal pump which act as outlet pipes which are connected to each primary inlet pipes which are connected to the growing pipe. One of the growing pipe ends is installed with a stopper which prevents the flow of nutrient out of it. At the other ends of the pipe an opening of 2.54cm, a semicircular pipe placed which collects excess water from the growing pipe and directs it back to the tank and the system continues over again.

2.7 Cultural Condition and Set Up of Study

This study was conducted under a greenhouse from the 7thMarch 2018 to 6th April 2018, at the Teaching and Research Farm of Landmark University, Omu-Aran, Kwara state, Nigeria, at the geographical coordinate latitude 8^{o} 9^{0} 0” N, longitude 5^{0} 61^{0} 0” E, located at the Southern Guinea Savannah zone. A maximum rainfall of 34.03599 mm was reported during the months of the research. The wind direction from the north to the south has an average annual temperature of 29.2793^{0}C, maximum temperature of 30.0998^{0}C, and a minimum temperature 28.9002^{0}C. A combined flow nutrient film hydroponic system was developed with its length of the growing medium 96.52 cm, radius of 5.08cm and volume of 7826.1996cm^{3}. The growing medium frame has a length of 91cm, breadth of 60.96cm and height of 97.4765cm the frame of the hydroponic system has a length of 82cm, breadth of 75cm and height of 154cm. the combine flow nutrient film hydroponic technique has a pump working intermittently while the nutrient flow into the system continuously. A rock wool substrate (diameter 10cm) was used to anchor the plants and provide nutrient to the plant’s roots. The substrate was previously cleaned with tap water. The volume of nutrient solution prepared was 120 liters. The pH of the nutrient solution and the electrical conductivity was checked. The pH and EC were monitored and when it falls below the range the unmixed nutrient solution was added. A 0.5hp centrifugal pump of 2.54cm diameter was located at the bottom tank which is used to transfer the nutrient solution to the top tank for it to flow under gravity to the hydroponic system, which excess nutrient solution is been collected back to the nutrient solution for recycling.

2.8 Experimental Design

A complete randomized block NFHT was used with three (3) treatment (T1-2 plants m^{-2}, T2 – 4 plants m^{-2} and T3 – 6 plants m^{-2}) with two (2) replications as shown in Figure 2. (kankanamge and Kodithuwakku, 2017; Meneghelli *et al.,* 2017).

Figure 2. Pictorial view of the hydroponically grown lettuce during experimental study

2.9 NFHT Nursery

The nursery medium comprises of rice husk and coco peats called the substrate. The substrate mix ratio is 1: 1 i.e., 50% coco peat and 50% rice husk. Lettuce seedling was raised. The nursery lasted for seven (7) days. The nursery was wetted twice a day, in the morning and the other in the evening.

2.9.1 *Sampling before transplanting*

Before transplanting, ten (10) plants were randomly selected and the initial dry biomass of the plant aerial (DPA), the root dry biomass (RDB), total dry biomass (TDB) were determined as represented in Table 1 (Humberto *et al.,* 2016).

$$TDB = DPA + RDB \quad (12)$$

Table 1. The initial DPA, RDB and TDB of the seedling before transplanting to the system

Items	DPA	RDB	TDB
1	0.004	0.002	0.006

2	0.005	0.003	0.008
3	0.005	0.004	0.009
4	0.004	0.003	0.007
5	0.005	0.004	0.009
6	0.004	0.002	0.006
7	0.004	0.004	0.008
8	0.003	0.002	0.005
9	0.003	0.002	0.005
10	0.003	0.001	0.004
Mean	0.004	0.003	0.007
Standard deviation	0.001	0.001	0.002
Maximum value	0.005	0.004	0.009
Minimum value	0.003	0.001	0.004

2.9.2 Transplanted seedlings

After the seedlings were transplanted to the system, it was allowed to run for five days on water before the nutrients solution was added. The harvested plants consisted of a whole plant (aerial part and root part). After 3weeks the plants were harvested from each treatment, they were identified and labeled. These plants were placed in a container with clean water to remove the substrate residues and then washed under the tap prior to its transfer to the laboratory. For each replication estimation of the TDB, DPA, RDB, and concentration of N, P, K, Ca and Mg was determined (Humberto et al., 2016).

2.10 Statistical analyses

The effect of population density of the plant on the DPA, RDB, and TDB was analysed using one-way Analysis of variance (ANOVA). Duncan's multiple range tests was used to test between the plant density levels. Analysis was carried out using IBM SPSS Statistics 22.

3. Results and Discussion

3.1 Plant nutrient concentration absorption

The data obtained for the plant nutrient absorption (Table 2) from the NFHT was subjected to statistical analysis by considering the experiment as a complete randomized design with one variable being investigated, the plant population density. The analysis indicates the significant effect at 3 weeks of harvest. This implies that at 3 weeks of plant age in an NFHT system there was a significant effect of the population density (2, 4, and 6 plant per meter square) on the nutrient concentration absorption of lettuce. This report was similar with Humberto *et al.* (2016); for *Rosmarinus officinalis* using a population density of 8, 16, and 24 plants per square meter. The nutrient concentration being absorbed by the plant was estimated from the second month after planting. It was reported that there was a significant effect of the plant population density on the nutrient concentration being absorbed. The bar chart representation of the average nutrient accumulation as shown in Figure 3 shows that there is a slight difference in the concentration of N, P, K, Ca, and Mg for the three different plant population densities at 3 weeks of harvest this coincide with the claim of Rodriguez and Leihner (2006), where it was reported that the higher the plant population density the lower the nutrient absorbed by the individual plant.

Table 2: Mean comparison of the nutrient absorption by plant at different plant population density.

ELEMENT	Population density (plant/m)	DPBA (ppm)	RDB (ppm)	Average (ppm)
N	2	0.4650	0.1200	0.1700
	4	0.1700	0.0910	0.1790
	6	0.1650	0.0650	0.4650
P	2	14.8028	7.3294	11.0661
	4	14.2085	6.1462	10.1774
	6	6.7099	6.5440	6.6270
	2	2.1535	0.9916	1.5726
K	4	1.7662	1.1620	1.4641
	6	1.7275	1.6500	.6888
Ca	2	4.9600	3.6800	4.3200
	4	4.4800	4.6400	4.5600
	6	2.8800	5.4400	4.1600
Mg	2	11.6800	10.7200	11.2000

4	8.4800	7.3600	7.9200
6	5.7600	5.4400	5.6000

N=Nitrogen, P=phosphorus, K=potassium, Ca= calcium, Mg=Magnesium

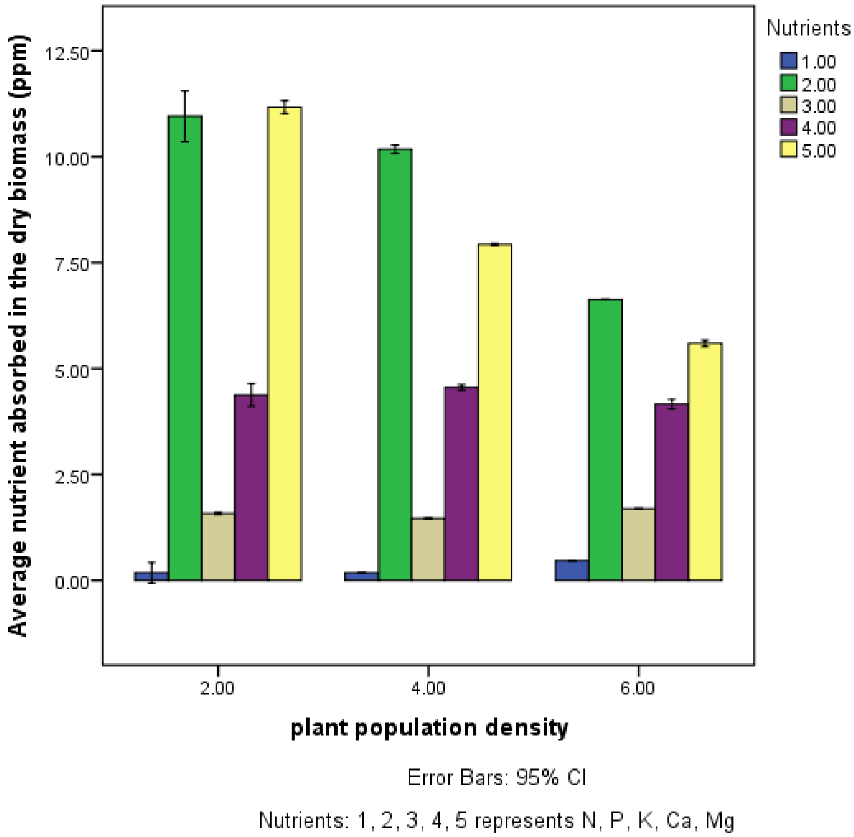

Figure 3. Effect of plant population density on the various average nutrient absorption of the dry biomass

3.2 Dry biomass of lettuce

The data obtained for the lettuce dry biomass from NFHT was subjected to statistical analysis by considering the experiment as a complete randomized design with one variable being investigated, the plant population density. The analysis for variance of the effect of plant population density on the dry biomass (RDB, DPA, and TDB) is as presented in Table 3. The analysis indicates the significant effect at 3 weeks of harvest. This implies that at 3 weeks of plant age in an NFHT system there was a significant effect of the population density (2, 4, and 6 plant per meter square) on the dry biomass of lettuce. Similar trend was observed by Humberto *et al.* (2016) and Mishra *et al.* (2009) also reported that plant spacing do have a significant effect on the dry biomass, in an experiment which was conducted in India using *Rosmarinus Officinalis and* a spacing of 30×20 cm, 40×30 cm, and 60×30 cm. Cometti *et al.* (2013) conducted an experimental study on hydroponically grown lettuce in Brazil, and from the research which lasted for 52 days and reported that cooling and concentration has significant effect in lettuce productivity, but the effect of plant population density was not evaluated.

Table 3. Mean comparison of the Dry plant aerial biomass, Root dry biomass, and Total dry biomass at different plant population density

Plant population density	DPA	RDB	TDB
2	0.1875±0.1021[c]	0.0325±0.0320[b]	0.2200±0.1312[c]
4	0.0900±0.1038[b]	0.1025±0.1330[c]	0.1925±0.1735[b]
6	0.1433±0.1153[b]	0.0258±0.0315[a]	0.1692±0.1369[a]

Different letters in a column indicate statistically significance ($p < 0.05$) by Duncan's test

Mean comparison for the dry biomass

As shown in Figure 4 and Table 3 the total dry biomass (TDB g/plant) which is a sum of the DPA and the RDB in treatment 1(population density of 2) was slightly higher to treatment 2 and 3 at 3 weeks of harvest. The effect of plant density on the DPA, RDB and TDB was statistically significant effect. Similar observation was made by Humberto *et al.* (2016) and Misrah *et al.* (2009), where an experiment was conducted in a hydroponic system using *Rosmarinus Officinalis* which has a longer plant duration that can stay up to 14 months. From their research it was observed that plant lines with the lowest population had the highest dry biomass.

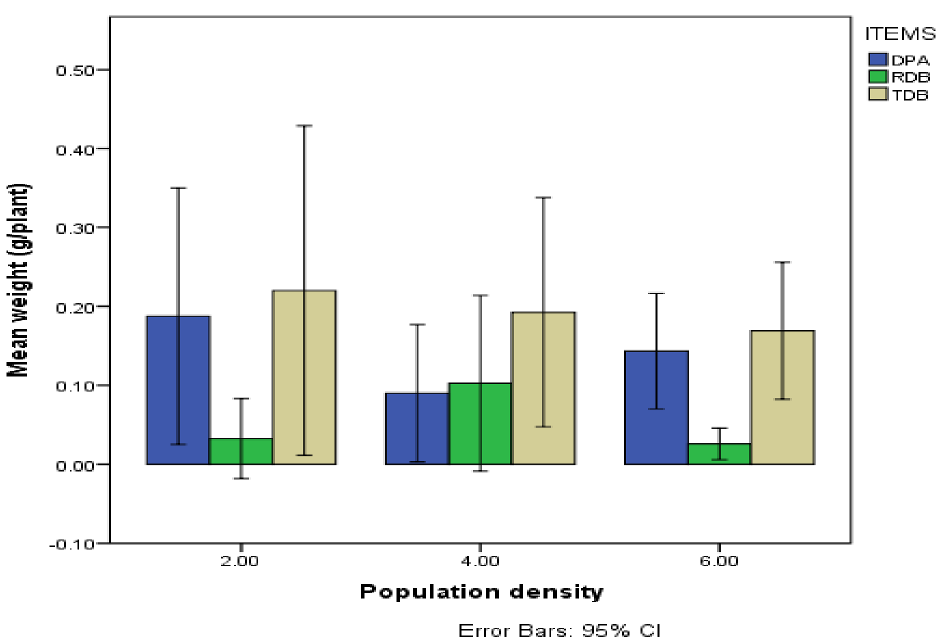

Figure 4. Effect of plant population density on the dry plant aerial biomass, Root dry biomass, and the total dry biomass

4. Conclusion

The NFHT was designed and evaluated using lettuce, with population density of 2, 4, 6 plant per square meter. The result of the effect of the plant population density on the nutrient concentration accumulation or absorption was slightly different between the three treatments used but this difference was significant at 3 weeks of planting. Also, the effect of the plant population density on the dry biomass showed that there was a slight difference in the dry biomass across the 3-population density used. The plant line with the lowest population density had the highest dry biomass produced. This study would help agronomist to choose the right plant spacing, and it will also create awareness on the plant nutrient concentration requirement.

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A SPATIAL TREND ANALYSIS OF RAINFALL PATTERN FOR PLANNING AND MANAGEMENT OF WATER RESOURCES

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Abstract

Continuous changes in climatic data pattern and its potential impacts on water resources are now becoming a great concern among water users globally. A study on the spatial trend of rainfall pattern for Ilorin West Local Government Area of Kwara State in Nigeria was conducted to detect and describe quantitatively each of the generating processes underlying a given sequence of observations, using the daily rainfall data for the study area from 2001 to 2015, obtained from the Nigerian Meteorological Agency (NIMET). In the study, the total cumulative amount of rainfall and number of rainy days were determined using descriptive statistics, and the significant of trends of rainfall on monthly and yearly basis were also examined, using Mann-Kendall Test. The results revealed that the annual rainfall could be as high and low as 2,572.9 mm and 872.4 mm respectively, with the average annual rainy days of about 90 days. There is a significant trend for rainfall in the months of February (7.3979), July (-2.0299) and October (1.8319), hence the null hypothesis that says that there is no significant trend occurred in these months is rejected. The monthly rainfall in January, April, August and December has positive insignificant trends while, negative insignificant trends exist in March, May, June and November. However, September showed no positive or negative trend for rainfall. Therefore, there is a need for spatial trend analysis using available rainfall data. Information from these reports may be helpful for planning, designing, as well as for the management of water resources to meet the needs of water users in the study area.

Keywords: Rainfall, spatial trend, climatic data, water users, water resources

Introduction

The studies of rainfall are an important tool for understanding the nature and behaviour of climate changes and very significant for proper planning, design, management of water resources and sustainable agricultural productivity. Spatial trend analysis is an estimation of the time and space distribution of rainfall within a catchment area. It is one of the technical ways of predicting the future pattern of rainfall events and it uses time series observations over a significant period to predict the future behaviour of those observations (Rathnayake, 2019).

Rainfall is one major determinant in climate variability because the amount of moisture determines quite a number of meteorological events and the overall ambient conditions of a location. Climates vary based on rainfall not only in terms of its amount but also by its form and seasonal distribution. These variables directly affect the forms of life that thrive in a location and the types of economic activities that can feasibly occur there (Mac Alpine-Belton, 2018). Rainfall can both positively and negatively affect the economic growth of an area. Positively, it has dramatic effect on agriculture because all plants need at least some water to survive and rain is the most effective means of getting water to plants. A regular rainfall pattern is very vital to healthy plants, too much or too little rainfall can be harmful and devastating to crops. Negatively, excessive rainfall could damage crops by causing water logging which could lead to rotting of roots, heavy down pour could fall fully grown crops, flower could fall due to the lashing of rain and it can cause soil erosion and leaching of nutrients thereby reducing crop yield drastically.

The agriculture prospect and viability of an area is significantly determined by the trend of rainfall it receives. Rainfall is an important variable that has a direct and indirect impact on the natural environment, human life, and influences irrigation and in turn agriculture. Every minor change in the intensity of rainfall or amount can cause a severe challenge on human and agricultural activities (Rathnayake, 2019). The agricultural production and productivity of crops depend on the timely, quantity and distribution of rainfall (Kumar, 2016).

Time series is a set of observations taken at specified times usually at regular interval and a set of data that depends on time is called a series. Therefore, rainfall represents the time series and its analysis is helpful to compare the actual performance. Trend is present when a time series exhibits steady upward growth or a downward decline, at least over successive time periods and it is helpful in forecasting the rainfall pattern of an area (Maragatham, 2012).

According to Ayugi *et al.* (2016), rainfall variations in both spatial and temporal scales are likely the most evident effects of the changes occurring in the earth's climate system. An understanding of the characteristics of rainfall is very vital in water resources planning and management due to changes in climate. Such information is important in agricultural planning, flood frequency analysis, flood hazard mapping, hydrological modeling and water resources assessments (Gallego *et al.,* 2011).

It is in the light of the above that this study seeks to examine the spatial and significance trends of rainfall in Ilorin West Local Government Area, Kwara State on monthly and yearly basis using Mann-Kendall test from year 2001 – 2015 in order to enhance food security in Nigeria.

2. Materials and Methods

2.1 Location of the Study Area

Ilorin West is one of the sixteen Local Government Areas of Kwara State in Nigeria. It is located at latitude of $08^0 50'$ N and longitude $04^0 54'$ E. It is situated on the altitude of approximately 320 m above sea level. Its climate is characterized with an average annual temperature of 26.5^0C and average annual rainfall of 1217 mm. Figure 1 is a map showing Ilorin West Local Government Area of Kwara State, Nigeria.

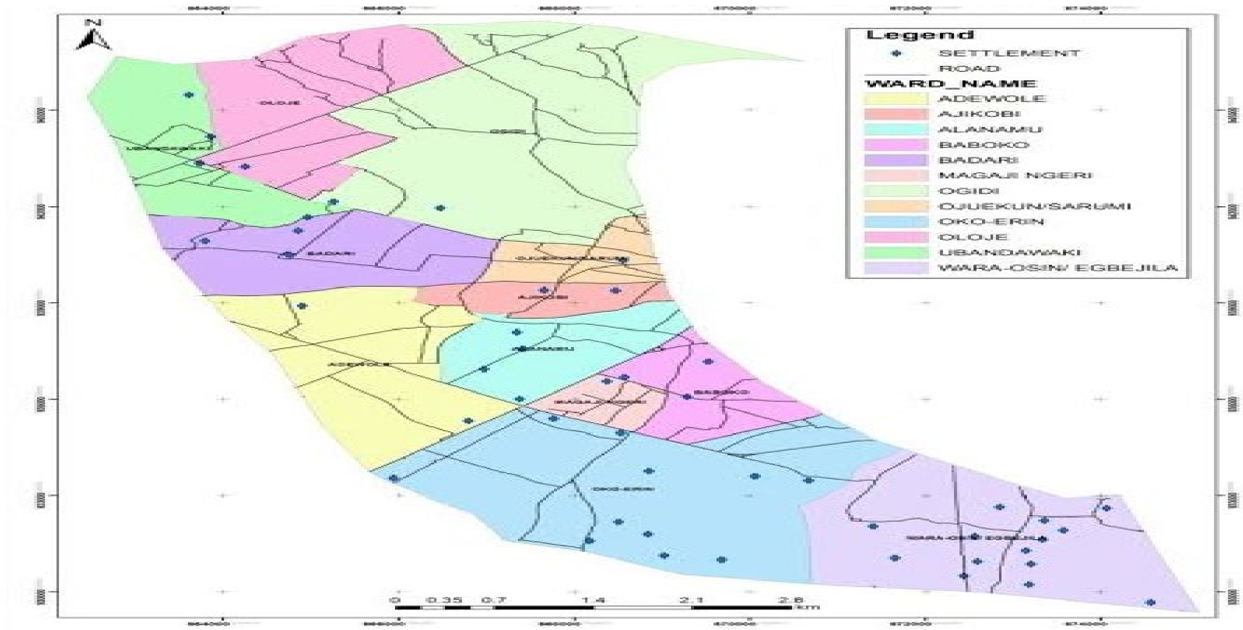

Figure 1: Map of Ilorin West Local Government Area of Kwara State, Nigeria.

Source: www.Googlemap.com

2.2 Data Collection and Processing

The data involved in this study is rainfall measured in millimeter (mm). Fifteen years of rainfall data (2001-2015) were collected from the Nigerian Meteorological Agency (NIMET), Abuja, Nigeria. The daily rainfall data collected were summed and averaged to obtain the mean daily and monthly values. Similarly, the mean monthly values across the period of record were averaged to obtain the mean annual values.

Data Analysis

2.3.1 *Research hypotheses*

The following hypotheses were generated for the purpose of the study:

(1) Null hypothesis I (H_{o1})

There is no temporal trend in the data values i.e., "H_{01}: no trend".

(2) Null hypothesis II (H_{o2})

There is no temporal trend in the data values i.e., "H_{02}: no trend".

2.3.2 *Descriptive statistics for total amount of rainfall and number of rainy days*

The descriptive statistics used in this study for the determination of the total amount of rainfall (mm) and total number of rainy days were mean, standard deviation, median, minimum, maximum, sum and range of rainfall data.

2.3.3 *Inferential statistic for rainfall trend analysis*

The inferential statistic used for analyzing the trend in rainfall pattern was the Mann-Kendall Statistics, using the following procedure:

The data were listed in the order collected over time: $X_j = X_1, X_2, ..., X_n$, where X_1 is the datum at time T_1.
The data were listed in the order collected over time: $X_i = X_1, X_2, ..., X_n$, where X_1 is the datum at time T_1.
A data matrix was conducted and the signs of all possible differences were computed.
The Mann-Kendall Statistic (S), which is the number of positive signs minus the number of negative signs in the data matrix table.

$$\text{Sign}\left(X_j - X_i\right) = 1 \qquad if\ X_j - X_i > 0$$
$$= 0 \qquad if\ X_j - X_i = 0$$
$$= -1 \qquad if\ X_j - X_i < 0$$

Mann-Kendall Statistic (S) was determined from Equation 1 below:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign\left(X_j - X_i\right) \qquad (1)$$

Where; Xi and X_j are the sequential data for the ith and jth terms
Source: (EPA/600/R-96/084, 2000)

The Variance of S was calculated using Equation 2

$$VAR(S) = \frac{n(n-1)(2n-5)}{18} \qquad (2)$$

Where; n = is the number of observations

For situation where ties occur then VAR(S) is extended to the form Equation 3.

$$VAR\ (S) = \frac{\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p\left(t_p - 1\right)(2t+5)\right]}{18} \qquad (3)$$

Where: q = the number of tied groups
t_p = the number of data values in the p^{th} group

The Mann-Kendall Statistic (Z) was calculated from Equations 4 through 6.

$$Z = \frac{S-1}{\sqrt{VAR(S)}}\ if\ S > 0 \qquad (4)$$

$$Z = 0 \qquad if\ S = 0 \qquad (5)$$

$$Z = \frac{S-1}{\sqrt{VAR(S)}}\ if\ S < 0 \qquad (6)$$

The following hypotheses were checked and tested:

(1) For testing the null hypothesis of no trend against H_1 (upward trend), reject H_0 if $S > 0$ and if $p > \alpha$ OR reject H_0 if $Z > Z_{1-\alpha}$-

(2) For testing the null hypothesis of no trend against H_2 (downward trend), reject H_0 if $S<0$ and if $p < \alpha$ OR reject H_0 if $Z < Z_{1-\alpha}$

3. Results and Discussion

3.1 Annual Amounts of Rainfall and Number of Rainy Days

The annual amounts of rainfall and annual number of rainy days in the study area from year 2001 to 2015 is presented in Table 1 and graphically represented in Figure 2. The annual rainfall ranged between 2572.9 mm to 892.4 mm, with the highest rainfall occurred in the year 2014 while the lowest rainfall occurred in the year 2008. Year 2008 had the highest number of rainy days (107 days) while year 2001 had the lowest number of rainy days (67 days).

Table 1: Annual Amounts of Rainfall and Number of Rainy Days

Year	Annual Rainfall (mm)	Total Number of Rainy Days (Days)
2001	892.4	67
2002	973.0	96
2003	2043.5	83
2004	1392.5	88
2005	1221.5	82
2006	1300.7	102
2007	1305.9	104
2008	1438.4	107
2009	1377.8	105
2010	1149.9	85
2011	1149.9	85
2012	1149.1	87
2013	1323.9	93
2014	2572.9	97

2015	1405.2	69

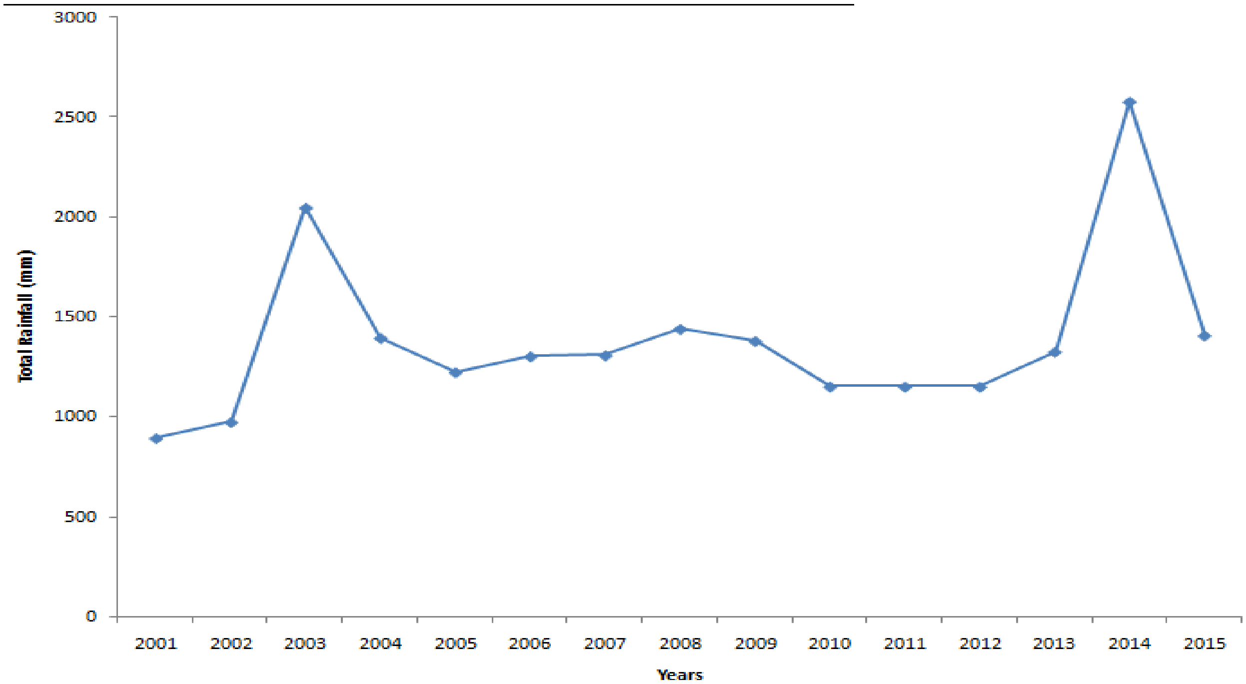

Figure 1: Annual total amounts of rainfall for the period of records

3.2 Descriptive Statistics of Annual Amount of Rainfall and Total Numbers of Rainy Days

The descriptive statistics of the annual amount of rainfall (mm) and total numbers of rainy days from year 2001 -2015 are presented in Table 2 and graphically represented in Figure 2. From the descriptive statistics, the mean annual rainfall for 15 years period is 1,379 mm while, the highest yearly rainfall amount is 2,572.9 mm. It rained for 1,350 days out of 5,475 days implying that the ratio of rain days to non-rainy days is about 2:8. The average of rainy days is about 90 days and number of rainy days is as low as 69 days and high as 107 days.

Parameter	Mean	SD	Median	Minimum	Maximum	Sum	Range
Total Annual Amount of Rainfall	1379.74	420.063	1305.900	892.400	2572.900	20696.10	1680.50
Days of Rainfall	90	12.23	88	67	107	1350	40

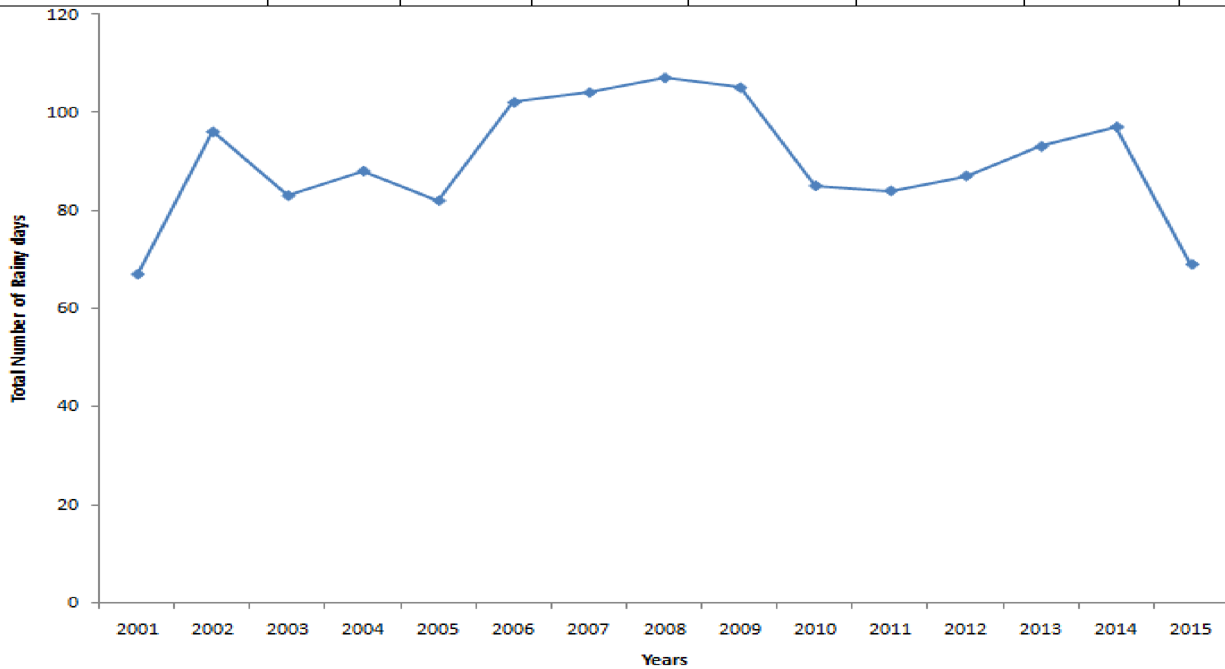

Figure 2: Annual Variation of Rain for the period of records

3.3 Cumulative Monthly Variation of Total Amount of Rainfall

The cumulative monthly variation of annual amount of rainfall for the period of records is shown in Figure 3. By characterizing the rainfall pattern over the 15 years starting from January when the rainfall is low and increases gradually till it peaks in June. Then, descends quickly in July and goes to August break and swift rise to a second peak in September. The August break is a period when rainfall lessens considerably amidst the peak of raining season and usually it occurs around the month of August every year in the study area. There is another quick descend after the second peak is reached in September that goes to low level in November. The dry season starts from November and remain through December, the last month of the year. It can be deduced from Figure 3 that dry season in the study area commenced from the month of November to March.

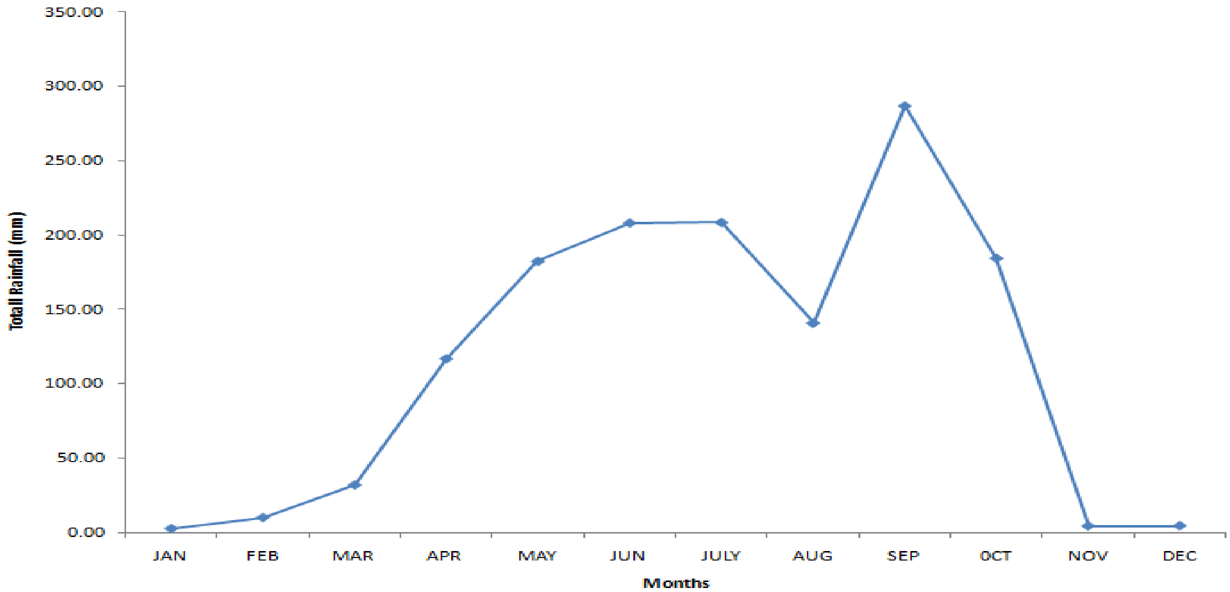

Figure 3: Cumulative Monthly Variation of Total Amount of Rainfall for the period of records

3.4 Cumulative Monthly Variations of Rainy Days

The cumulative monthly variation of rainy days for the period of records is shown in Figure 4. By characterizing the rainfall pattern starting from January, there were no rainy days because rainfall is low, rainy days increased gradually till it peaks in June. By July it descends quickly and goes to August break and swift rise to a second peak in September. There is another quick descend after the second peak is reached in September that goes to low level in November. The dry season starts from November and remain practically so through December, the last month of the year. It can be deduced from Figure 4 that dry season in the study area commenced from the month of November (where there few or no rainy days) to March.

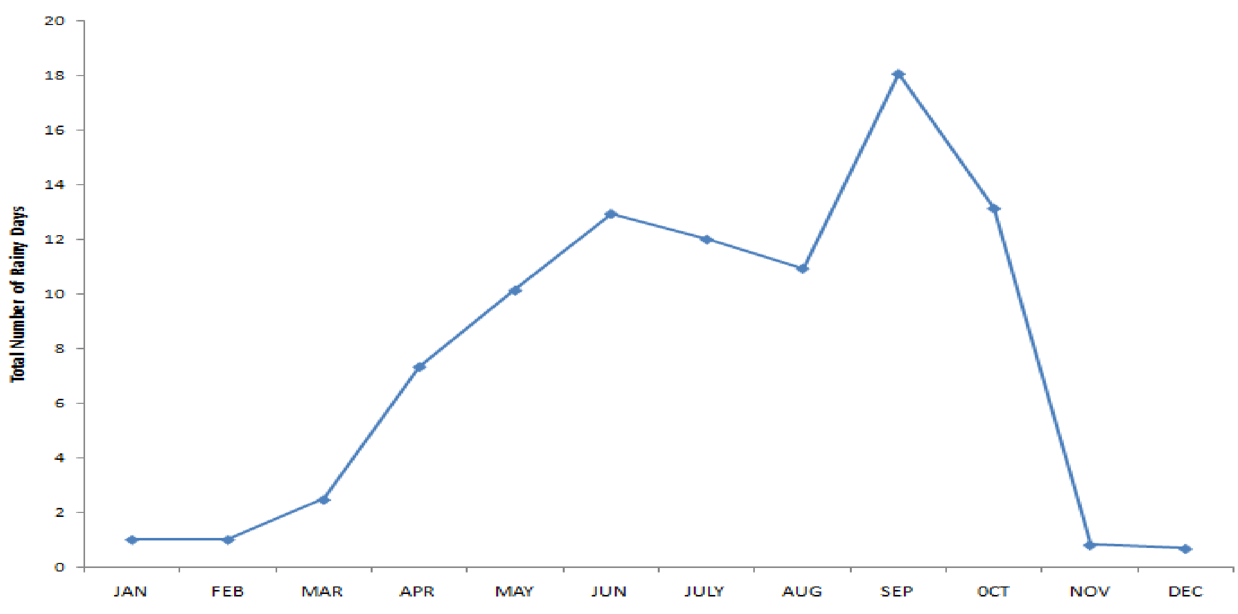

Figure 4: Cumulative Monthly Variation of Rain for the period of records

3.5 *Mann-Kendall Z-test for Rainfall Amounts (Mm) for the Monthly Periods*

The result of Mann-Kendall Z-test for amount of rainfall (mm) for monthly periods is presented in Table 3. The $Z_{1-\alpha}$ value from statistical table at α equal to 0.10, 0.025 and 0.005 level of significance or 90%, 97.5% and 99.5% confidence levels are; 1.64, 1.960 and 2.576 respectively. From Table 3, the absolute Mann-Kendall Z values for monthly rainfall of February (7.3979), July (-2.0299) and October (1.8319) are greater than the critical values at the confidence level considered, hence the null hypothesis that stated that there is no significant trend occurred is rejected in these months, implying that there is significant trend in the months of February, July and October.

However, months of February and October have positive (upward) trend while the month of July has negative (downward) trend. Monthly rainfall in January, April, August and December has positive insignificant trends while, negative insignificant trends for rainfall exists in March, May, June and November. However, September showed characteristically no positive or negative trend for rainfall.

Table 3: Mann-Kendall Z-Test for Amount of Rainfall (mm) for Monthly Periods

	Total Monthly Rainfall	
Months	**Correlation coefficient (R)**	**Mann-Kendall Z-test (Z)**
January	0.860	0.25080
February	0.835	7.39780
March	0.675	-1.1502
April	0.712	0.0495
May	-0.141	-1.3368
June	0.328	-0.5446
July	0.125	-2.0299
August	0.763	0.1485
September	0.146	0.0000
October	0.204	1.8319
November	0.858	-0.2183
December	0.782	0.9612

4. Conclusions

It is concluded from the results of this study that the annual rainfall amount is as high as 2572.9 mm and low as 872.40 mm. Also, there is a significant trend for rainfall in the months of February (7.3979), July (-2.0299) and October (1.8319), Therefore, the null hypothesis that stated that there is no significant trend occurred is rejected in these months whereas there is insignificant trend in other months except the month of September.

Therefore, Ilorin-West rainfall regime is stable and activities like farming and agricultural investments can effectively be carried out in accordance with the existing pattern of rainfall that is experienced here, since, eight out of twelve months considered in this study witnessed no significant trend coupled with the uniqueness of the month of September, a month of very high rainfall that showed no coherent trend what so ever.

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COMPARISON OF NITRATE AND PHOSPHATE ADSORPTION IN WATER BY $ZNCL_2$ ACTIVATED CARBON MATERIALS: A CASE STUDY OF CASSAVA PEEL AND RECYCLED BAMBOO BIOMASS

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Abstract

Eutrophication and algae boom in water bodies caused by nitrate enrichment from wastewater addition are serious environmental concerns. Nitrates and Phosphates are major contributors to this environmental problem which influence freshwater and terrestrial ecosystems productivity. The study confirms that Zinc Chloride chemical activation process improved the Nitrate and Phosphate adsorption levels of recycled bamboo carbon and cassava peel carbon although desorption phenomena was observed to have occurred in the carbon materials at some particular points. Comparison of the adsorption levels of phosphate and nitrate ions by the two biomasses show that there the recycled bamboo activated carbon at 10 and 20% Zinc Chloride activation levels exhibited a much stronger affinity for both Phosphate and Nitrate ions when compared to cassava peel activated carbon at 33 and 66% activation levels. This implies that recycled bamboo activated carbon offers a more effective opportunity in Phosphate and Nitrate pollution mitigation for polluted water.

Keywords: Adsorption, Decontamination, Eutrophication, Cassava Peels, Recycled Bamboo

1. Introduction

Bamboo (*Bambuseae spp.*) is plant which grows abundantly in the tropical and temperate regions within latitude 40^0S and 40^0N, from jungle to high mountainsides (Liese, 2004; Ogedengbe, 2010). Research has shown that the plant has in the past been put into diverse uses. The Chinese have made use of bamboo in the field of health care in control of blood circulation, protection of human body from harmful electromagnetic waves and treatment in cases of ingestion of poisonous substances. In the electronic world, bamboo is utilized in electromagnetic shielding components (Cheng *et al*., 2010) while it has also been adopted as an absorbent/adsorbent in the environmental field in form of activated charcoal (Mahanim *et al*. 2011). The plant is also a major choice of low-cost support for formworks in construction industry. Despite the fact that the country is blessed with different varieties of bamboo, its utilization in Nigeria is still relatively low when compared with some countries like China, India and other parts of Asia (Onilude, 2005).
Cassava (*Manihot escutenta,* Crantz), is native to South America as well as southern and western Mexico. It was one of the first crops to be domesticated, and there is archaeological evidence that it was grown in Peru 4,000 years ago and in Mexico 2,000 years ago (Harlan, 1970). Cassava is adapted to the zone within latitudes 30^0 north and south of the equator, at elevations of not more than 2,000 m above sea level, in temperatures ranging from 18^0 to 29^0 C, rainfall of 50 to 5,000 mm annually, and to poor soils with a pH ranging between 4.0 and 9.0. Since its introduction into West Africa in the sixteenth century, cassava has spread rapidly to various parts of Africa, where it is grown alone in sequence or in different inter-cropping systems with other staples crops. The crop has become a major staple food in many tropical countries, Nigeria inclusive. This has led to production of large volume of wastes (solid and wastewater), which has been observed to pose environmental nuisance when not properly managed. According to Obadina *et al.* (2006) cassava peels account for up to 10 % of the wet weight of cassava tubers. This shows that the volume of solid waste generation could become a source of concern in large production communities.

Nitrates as a pollutant have been known to cause severe environmental problems like eutrophication and algae boom (FAO and IWMI, 2017), it has also been identified as the cause of mortality resulting from disease infections, such as cyanosis and cancer of the alimentary canal (Wang *et al.*, 2005), blue baby syndrome (methemoglobinemia) in infants (Ako Ako *et al.*, (2014). Studies have shown that pollution resulting from agricultural activities can cause a significant deterioration of surface and groundwater quality (Sasakova, 2018; FAO and IWMI, 2017). In support of this point of view, (Demiral and Gunduzoglu, 2011) stated that various types of agricultural, domestic and industrial wastewater have been known to contain several nitrogenous compounds including ammonia, nitrates and nitrites.

Phosphates on their own part are negatively charged ions, considered as the growth determining nutrient for plants and microbial growth (Muñoz *et al.*, 1997; FAO and IWMI, 2017) and responsible for influencing freshwater and terrestrial ecosystems productivity (Zhang *et al.*, 1997) although phosphates are widely used in cleaning products, toothpaste, fire extinguishers, textile processing and food (Weiner *et al.,* 2001). It has also been found to contribute to eutrophication in water bodies when its presence is in excess.

Foo and Lee (2010) described activated carbon (AC) is one of the most popular adsorbents used in numerous industries for the removal and recovery of organic and inorganic compounds from gaseous and liquid streams. Various authors have investigated the use of different biomass as raw material for activated carbon production among such are agricultural by-products like Almond shell (Bansode *et al.,* 2003), Coconut shell (Olafadehan *et al.,* 2012), Maize cob (Igwe and Abia, 2007), Flamboyant pond back, Milk bush kernel shell and Rice husk (Alade *et al.*, 2012), Bamboo (Ijaola *et al.,* 2013), Coconut shell and Palm kernel shell (Ademiluyi and David-West, 2012), Longan seed (Mopoung and Nogklai, 2008), Cassava peels (Omotosho and Sangodoyin, 2013) etc.

The objective of the study is to compare the Nitrate and Phosphate adsorption in activated carbon derived from cassava peel and recycled bamboo carbon. The research is also aimed at investigating the applicability of the produced activated carbon materials in treatment of water related environmental problems such as eutrophication and algae booms.

2. Materials and Methods

2.1 Production of Carbon Biomass

The cassava peel carbon (CPC) used in this study was produced by collecting waste cassava (*Manihot esculenta Crantz)* peels from a cassava processing industry in Ibadan, Nigeria. The cassava peels were inspected, washed and sundried to a moisture content of between 8–10% wet basis. The dried cassava peels were then carbonized in a muffle furnace (Carbolite, England Model AAF 11/18) at a temperature of 420^0C for a period of 90 mins as described by Omotosho and Sangodoyin (2012). The resulting carbon material (Plate 1) was allowed to cool overnight under inert conditions.

The recycled bamboo carbon (RBC) utilized in this study was produced from bamboo material collected from a construction site located within the University of Ibadan campus. The material was inspected, reduced and washed to remove any form of impurities. The bamboo material was then further soaked for 24hrs to remove traces of impurities that may still adhere onto the surface during process of its use on the construction site. Material was then subjected to sun drying until a moisture content of 8-10% wet basis was attained. The dried biomass was then carbonized using a muffle furnace (Carbolite, England model AAF 11/18) at a temperature of 350^0C for 2hrs after which samples were cooled in an inert condition overnight (Plate 2).

Both biomasses (cassava peel and bamboo) were wrapped in Aluminum foil during carbonization process. This acted as an antioxidant and also reduced the rate at which the heat from the oven radiated to the samples in order to ensure equal reaction.

The carbonized samples (as shown in Plate 1 and 2) were then weighed and the yield percentages were calculated as follows:

$$\text{Carbon Yeild(\%)} = \left[\frac{W_1}{W_2}\right] x100 \quad (1)$$

Where

W_1 = Mass of obtained carbon material(g)

W_2 = Initial mass biomass(g)

The resulting carbon materials were then reduced to size of range 450-500µm by pounding in a mortar and sieving with the aid of a 500µm sieve, the material passing through was then passed through another sieve of 450µm, the carbon material left on the sieve was then collected. The reduced recycled bamboo carbon (RBC) and cassava peel carbon (CPC) were pre-washed with de-ionized water to remove any form of dirt that may have adhered to it during size reduction process and later dried an oven at 120^0C for 8hrs.

2.2 *Activation of Samples*

Cassava peel activated carbon (CPAC) was produced by weighing two, 300gm samples of the obtained CPC using a digital precision weighing balance (AND GF-2000) and then activated using $ZnCl_2$ at activation ratios of 1:3 and 2:3 (activating agent: carbon material) as recommended by Omotosho and Sangodoyin (2013), this was equivalent to 33 and 66% $ZnCl_2$ activation. While the recycled bamboo activated carbon (RBAC) was produced by weighing another two, 300g samples of the carbon material obtained from the waste bamboo carbonization using the same precision weighing balance mentioned above and activated in the ratio of 10 and 20% with $ZnCl_2$ following the method described by Ijaola *et al.,* (2013).

2.3 *Pore Space Development Analysis*

1.5gms each of the obtained CPC, CPAC, RBC and RBAC were subjected to High energy electrons from Scanning Electron Microscope (ZEISS EVO® MA 15) with variety of signals used to focus the surface of the carbon materials to obtain micrographs at Sheda Science and Technology complex (SHESTCO), Abuja, Nigeria. The pore space and surface area were then read with the aid of a java interactive software Programme called image J.

2.*4. Characterization of Activated Carbon*

The physico-chemical characteristics of the activated carbon were determined using various approved American Standard Test Methods (ASTM). The bulk density was determined using the ASTM D2854, contact pH was determined following the ASTM D6851-02, the total ash content of the carbon materials was determined with the aid of ASTM D2866-11 while moisture content of the carbon materials was determined in consonance with ASTM D2867-09 guidelines.

2.5. *Collection of Test Water Samples*

Polluted water sample (25 L) was collected from Abadina stream located within the University of Ibadan campus on latitude $7^0$26'57.27" and longitude $3^0$53'8.9". The sample was collected in opaque, airtight plastic containers and kept under ice to reduce deterioration and change in composition due to light and temperature during the process of transportation to treatment site.

2.6. *Biomass Adsorption Efficiency*

An experimental set up (Figure 1) consisting of a reservoir, which was connected to three specially constructed transparent Perspex adsorption columns of 0.003m thickness, 0.18m length, 0.18m breath and 0.65m height containing 200g each containing 200g of the biomass to be tested was employed in the treatment process. The contaminated water released from the reservoir into three specially constructed transparent Perspex adsorption columns containing the carbon materials simultaneously at a rate of 0.378 l/hr. Water samples were strained from the adsorption columns after a period of 2 and 4hrs from the three adsorption columns and analyzed for tested parameters.

The efficiency of the carbon biomasses was measured with the aid of the percentage decontamination. The percentage decontamination is defined as the percentage of the total contaminant in the water sample removed by the activated carbon through adsorption. It is represented mathematically by the equation below.

$$\text{Percentage Decontamination} = \left[\frac{C_1 - C_2}{C_1}\right] X100 \qquad (2)$$

Where;

C_1= Concentration of wastewater before treatment (mgl^{-1})

C_2= Concentration of wastewater after treatment (mgl^{-1})

2.7. Nitrate and Phosphate Content Analysis

The polluted water/treatment effluent sample was subjected to centrifuge at a speed of 4200 rpm to achieve separation of the solid component. The clear supernatant obtained was decanted and used for the test procedure.

Nitrate content of the water samples was measured using the Colorimetric, Brucine method which is based on the reaction of nitrate ion with brucine sulfate in a $13NH_2SO_4$ solution at 100^0C and pH of 6.5. The solution was then subjected to spectrophotometry using a Spectrophotometer (Spectrumlab 23A) which was set to operate at wavelength of 410nm with blanks used for calibration and quality check.

The Phosphate content was tested by adding one sachet of HACH PhosVer®3 reagent powder to 10ml of the obtained supernatant and also vigorously mixed and allowed to rest for 7mins then subjected to spectrophotometry at appropriate wavelength with blanks used for calibration and quality check. Concentration in mg/l of Nitrate and Phosphate was obtained at the beginning and end of the adsorption process. The amount of nitrate and phosphate adsorbed in mg/g at time t was computed using the equation 3

$$\text{Amount of Nitrate/Phosphate Adsorbed} = \frac{(C_0 - C_1)V}{W} \qquad (3)$$

Where:

C_0 and C_t = nitrate concentrations at initial stage and after contact time t (mgl-1)

W = weight of carbon material (CPAC) in grams

V = the volume of filtrate drawn (l).

3. Results and Discussion

Results obtained from inter-material physico-chemical analysis of the carbon materials show that the CPC and CPAC have a relatively higher bulk density than the RBC and RBAC as shown in the table 1. This shows that the particles of the CPC and CPAC have a higher susceptibility to compaction in containment conditions leading to a higher packed volume. However, the ash content of the materials followed a reverse trend as the RBC and RBAC showed a higher value than the CPC and CPAC.

A further analysis of intra-material physico-chemical characteristics shows that for the cassava peel biomass the CPC exhibited a slightly lower pH when compared to the CPAC at both activation levels. The bulk density of the biomass also showed a progressive increase as the level of activation increased. However, the trend for ash content of the carbon materials did not follow a direct pattern, the CPC had the highest value followed by the CPAC at 66% activation level while the CPAC at 33% activation level had the lowest value.

3.1 Effect of $ZnCl_2$ Impregnation Ratio on Carbon Characterization

The effect of Zinc Chloride impregnation on the carbon materials in terms of pH, bulk density ash content and moisture content are displayed in table I. Results show that for CPC, the bulk density slightly increased when the activation ratio was increased. The RBC also showed a corresponding increase in bulk density while the ash content reduced as activation ratio increased.

An examination of the morphological characteristics of carbon biomasses as revealed in table 2 shows that the values of average pore area, average pore width and average pore lengths increased with level of activation. This implies that the $ZnCl_2$ activation was able to open up the pores on the carbon materials as expected in a chemical activation process.

However, a comparison of values of average pore width for the two different biomasses at the different activation levels reveals that the bamboo biomass had much higher values than those of the cassava biomass, this trend is reversed in the average pore area measurements of the carbon materials. The table also shows that the percentage carbon yield of both biomasses was very close, this shows that the base materials used for the activation process had a relatively close transformation effect.

3.2 Scanning Electron Microscope (SEM) Imagery and Characteristics

Images obtained from SEM micrograph analysis as shown in plate 3 reveals that the RBC (0% Zn_2Cl activation) exhibited a net like structure with a thread like edge and a well open pore space. The surface configuration predicts a material which would have relatively good adsorptive characteristics. However, in RBAC at 10% $ZnCl_2$ activation ratio the pore eye enlarged in length indicating an increase in pore area as a result of the activation, a closer look reveals that the netlike structure becomes uneven and unable to hold tie (Plate 4). This shows that there would be an improvement in adsorptive characteristics over RBC. At 20% (Plate 5)Zn_2Cl activation ratio the RBAC still exhibited further increase in surface area resulting in a phenolic ring structure and increased reaction sites. Improvement is further observed and which is directly proportional to the adsorption intensity of the carbon material.

A close observation of image from the micrograph of the CPC's surface as shown in plate 6 reveals that pore space development on the carbon material was not very pronounced. Surface configuration is directly related to the adsorptive characteristics. Smooth adsorbent surfaces have been confirmed to offer lower adsorption characteristics when compared with adsorbents with rough configuration.

At 33% Zn_2Cl activation, CPAC showed relatively larger pore opening characteristics when compared to the CPC as shown in the spectrometry image (Plate 7). Thus it can be predicted that the adsorbent would be more effective than pure cassava peel carbon in adsorbing materials.

Micrograph analysis of the CPAC at 66% $ZnCl_2$ activation reveals that the material surface exhibited a hexagonal honeycomb structure (Plate 8); this theoretically indicates good adsorptive surface characteristics. The CPAC material surface shows a very obvious effect of chemical activation on the base carbon material.

3.3 Nitrate and Phosphate Decontamination by CPC and CPAC

Effluent collected from the treatment process after 2hrs contact time showed a progressive increase in level of phosphate ion decontamination with increase in level of $ZnCl_2$ activation. A maximum value of 56.42% for the CPAC at 66% Zinc Chloride activation level was observed, however after four hours, although the increasing trend was maintained the maximum value of 54.40% for the CPAC at 66% Zinc Chloride activation level was recorded showing that there must have been some level of desorption of phosphate ions shortly before the expiration of the 4hrs contact time (figure 2). The nitrate adsorption pattern also exhibited the same progressive pattern with increase in $ZnCl_2$ activation levels. The CPC had the lowest value of 43.02 and 53.60% nitrate decontamination levels while the CPAC at 66% Zn_2Cl activation level exhibited the highest values of 50.28 and 59.20% nitrate decontamination levels after 2 and 4 hours respectively (figure 3). This shows that the chemical activation had a positive effect on both nitrate and phosphate adsorption levels in both CPC and CPAC although there was a case of desorption in the phosphate ion decontamination as discussed above.

3.4 Nitrate and Phosphate Decontamination by RBC and RBAC

A critical analysis of the phosphate ion decontamination trend in the WBC and RBAC shows that the RBC also exhibited some level of desorption after four hours contact time this might be due to the rapid filling up of the site-specific adsorption points on the material. However, the RBAC showed a much better trend, the decontamination increased with time and $ZnCl_2$ activation ratio. The RBAC at 20% activation ratio had the highest values of decontamination of 80.00 and 82.64% respectively after 2 and 4hrs respectively (figure 4). This result also points to a positive effect of the Zn_2Cl activation on adsorption of phosphate ions in the water.

Adsorption of nitrates by the RBAC was more intense when compared to the CPAC. Results from the study shows that the values obtained for decontamination of nitrates was far above 70% in both levels of $ZnCl_2$ after the 2 and 4 hrs contact period as shown in figure 5.

4. Conclusion

Result from the laboratory this scale study shows that Nitrate and Phosphate adsorption by carbon derived from cassava peels and recycled bamboo improved with activation using $ZnCl_2$ although desorption phenomena was observed at some points.

Comparison of Nitrate and Phosphate adsorption by the two biomasses show that there was not much significant difference in adsorption levels of CPC and RBC for phosphate and nitrate ions, however after activation the RBAC at both activation levels exhibited a much stronger affinity for both Nitrate and Phosphate ions when compared to CPAC. This implies that RBAC offers a much robust opportunity in treatment of Phosphate and Nitrate pollution in water.

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Illustrations

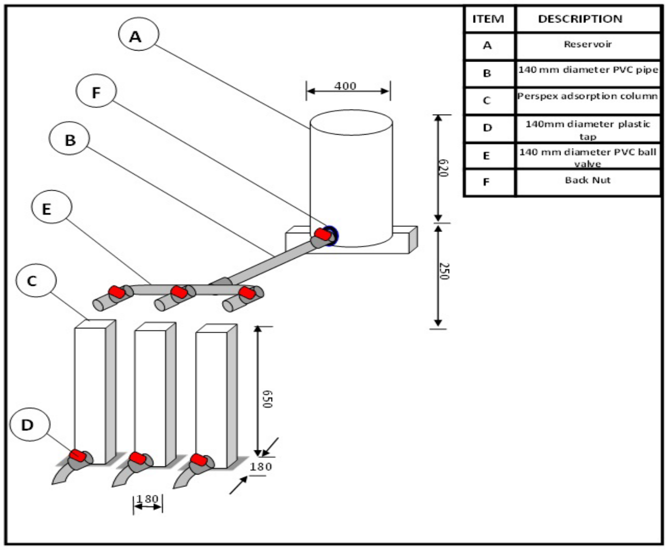


Figure 1: Diagram of decontamination treatment setup

Table 1: Comparison of some selected physico-chemical parameters of carbon materials

Biomass	Activation (%)	pH	Bulk Density	Ash Content	Moisture Content
	0	5.3	0.407	2.65	2.31
CPC	33	5.3	0.410	2.38	2.21
	66	5.4	0.413	2.44	2.33
RBC	0	6.8	0.167	2.83	2.42
	10	6.9	0.177	2.67	2.41
	20	7.2	0.191	2.40	2.43

*Results were obtained from subjecting 1.5g of Cassava Peel Carbon and Waste Bamboo Carbon to SEM at Sheda Science and Technology complex, Abuja, Nigeria

Table 2: Comparison of some selected morphological characteristics of carbon materials

	Activation (%)	Average Pore Area (µm)**	Average Pore Width (µm)**	Average Pore Length (µm)**	Carbon Yield (%)*
CPC	0	166.60	10.39	13.78	34.63

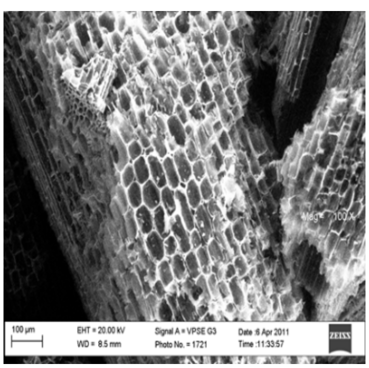
	33	674.00	61.73	25.20	
	66	863.30	18.91	27.70	
RBC	0	50.45	172.30	15.00	
	10	69.11	200.20	17.00	34.10
	20	104.83	354.26	18.76	

*Results obtained by gravimetric analysis in the laboratory
**Results were obtained from subjecting SEM images to Image J interactive application software

Plate 1: Cassava peel carbon material

Plate 2: Recycled bamboo carbon material

Plate 4 a, b and c: Micrograph of activated carbon from Nigerian bamboo according to different impregnation ratio of Zncl$_2$



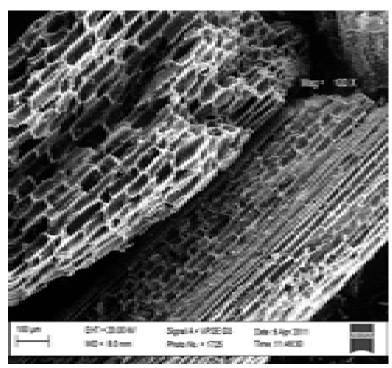


Plate 3: Micrograph of recycled bamboo carbon (RBC)at 0% Activation

Plate 4: Micrograph of recycled bamboo carbon (RBAC) at 10% Activation

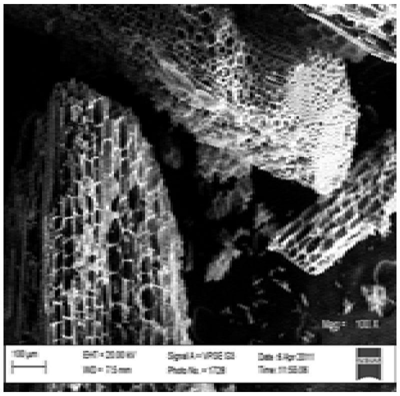


Plate 5: Micrograph of recycled bamboo carbon (RBAC)at 20% Activation

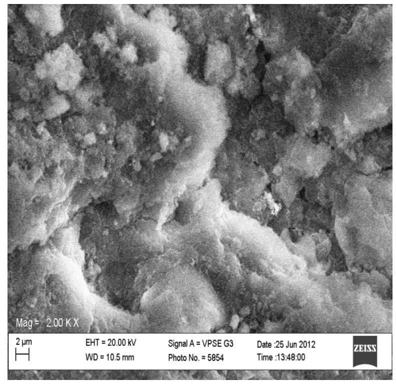


Plate 6: Micrograph of Cassava Peel carbon (CPC)at 0% Activation

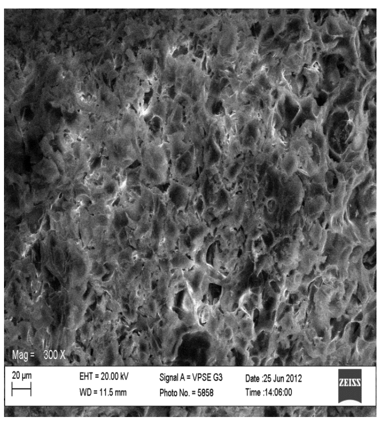


Plate 7: Micrograph of Cassava Peel carbon (CPAC) at 33% Activation

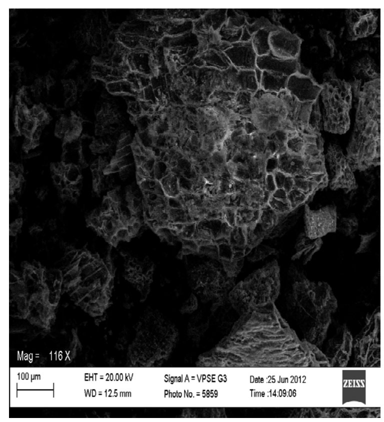


Plate 8: Micrograph of Cassava Peel carbon (CPC)at 66% Activation

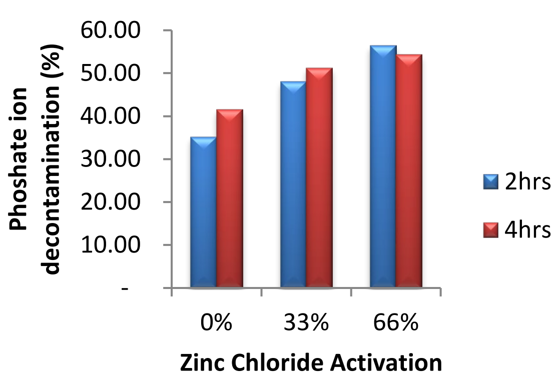


Figure 2: Phosphate ion decontamination by CPC and CPAC after 2 and 4hrs respectively

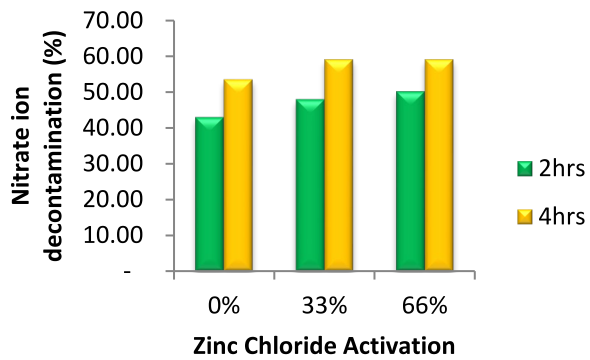


Figure 3: Nitrate ion decontamination by CPC and CPAC after 2 and 4hrs respectively.

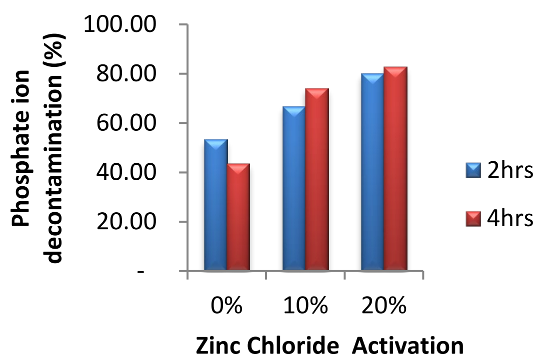


Figure 4: Phosphate ion decontamination by RBC and RBAC after 2 and 4hrs respectively

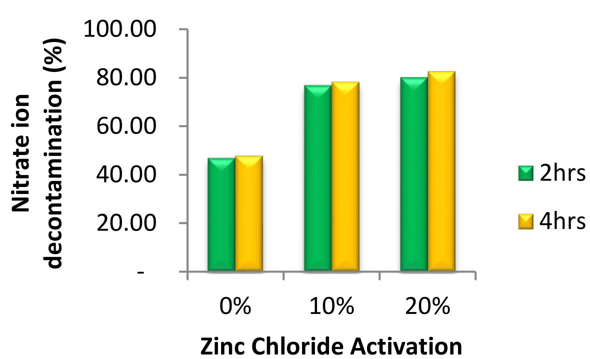


Figure 5: Nitrate ion decontamination by RBC and RBAC after 2 and 4hrs respectively.

HEAVY METALS LEVEL IN IRRIGATION WATER AT TUKUNTAWA GIDAN RADIO IRRIGATION FARM, KANO STATE

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Abstract

The study was designed to determine the concentration of the heavy metals Pb, Cd, Ni and Cr (which are among the most toxic heavy metals) in the irrigation water use for irrigating ready to eat vegetables at the Gidan Radio irrigation farm within the Kano metropolis of Kano state Nigeria, The study area is the Rafin Kuka Tukuntawa Gidan Radio Irrigation Farm which is a drainage basin conveying Municipal wastewater from Kano Municipal, part of Sharada Phase I, Zoo Road and Shagari Quarters which finally discharges it content into the Tanburawa River. Water samples were collected at five different points along the drainage flow path, labeled as TK1, TK2, TK3, TK4 and TK5 (TK = Tukuntawa). The samples were analyzed for heavy metals (Cd, Mn, Pb, Cr, Co, Cu, Zn), and Statistical Analysis SPSS version 20.0 statistical software was utilized in the computation of the data for statistical significance and standard deviation between the obtained value and the FAO (1992) criteria for irrigation waters. The results gave average concentration, Standard Deviation and statistical significant at $P \leq 0.05$ of Cd(0.0385mg/l, 0.0197, 0.077), Mn (0.1738mg/l, 0.1112, 0.626), Pb(0.0344mg/l, 0.0119, 0.000), Cr(0.1886mg/l, 0.0524, 0.010), Co(0.1122mg/l, 0.0356, 0.017), Cu(0.8314mg/l, 0.2822, 0.001), Zn(0.6965mg/l, 0.3162, 0.003) respectively. From the findings of the research, it can be concluded that the concentrations of the heavy metals in the Municipal wastewater use for irrigation is within the acceptable limit for some of the analyzed heavy metals with the exception of Chromium (Cr) which slightly exceed the guideline values, Cobalt which also exceed the guideline and copper which shows a high concentration of contamination in the irrigation wastewater. It can be argued that there are potential health risks for the urban population who consume vegetables grown with this Municipal wastewater and other food crops which have high levels of copper above the maximum recommended values by relevant authorities. Although the level of concentration for some metals does not exceed the permissible limit, it is strongly recommended that people should not take large quantities of those vegetables so as to avoid large accumulation of the heavy metals in human body. Regular monitoring of heavy metals in water and plant tissues is essential in order to prevent excessive build-up of these metals in the human food chain.

Keywords: Water quality, Heavy metals concentration, Irrigation.

1. Introduction

Pollution can be categorized into two types: point and diffuse, point source pollution is regarded as pollution released via discharges from discrete outlets such as pipes and effluent outfalls. These sources are generally manmade and mediated by man-made devices. The increase rate of discharge of industrial wastes in river basin is posing serious danger to the water resources and the health of people in the area (Bichi and Anyata, 1999).

In Nigeria, improper disposal of untreated industrial wastewater has resulted in colored, murky, odorous and unwholesome surface waters, fish kills and a loss of recreational amenities. The uncontrolled releases of waste effluents to large water bodies have affected both water quality and aquatic life (Udosen, 2006; Dan'azumi and Bichi, 2010). A significant proportion of the population still relies on these polluted surface and ground waters for drinking, irrigation, fishing and other domestic uses. According to one World Bank report (1990), advisors warn that water contamination has the second highest potential for future negative impacts on GDP and in Nigeria alone, higher incidences of water-related diseases cost the country an estimated US $1 billion annually through increased health costs and lost productivity, and put 40 million people at risk. In greater Kano, waste water treatment facilities are virtually non-existent, such that poor people, including those who engage in urban farming practices to make a living, cannot afford defensive sanitary practices. Local surface water is of vital importance, and the shallow ground water supplies found in Fadama depressions where much of the peri-urban agriculture takes place, are highly polluted with urban and industrial contaminants (Binns *et al,* 2003).

Urban farming is a common practice in developing countries, including Nigeria. Many residents of these urban areas make living from farming activities; also some people who are not full-time farmers are involved in farming to support their income. As a result of the prevailing land tenure system, land spaces for agricultural purposes are usually scarce. Urban farmers usually make use of any available land spaces that are free or the so called 'no man's land'. Such land usually includes dumpsites, rail and road sides, and others close to market places, polluted water bodies, mechanic workshops, and industrial areas, among others, which are potential sources of heavy metal pollution. (John and Samuel, 2012). The main issues associated to such practice is the build-up of heavy metals in soil, plants, food chains, and ultimately in human beings (Khalid et al., 2018).

Municipal solid waste application in agricultural land, wastewater discharge from industries and houses along with abundant pesticide use are the other major sources of the toxic heavy metals. Heavy metals contaminants can be found on the surface and in the tissues of fresh vegetables (Arif et al. 2011). Certain trace elements are essential in plant nutrition, but plants growing in a polluted environment can accumulate trace elements at high contaminations causing a serious risk to human health when they are consumed (Voutsa et al. 1996). Tricopoulos in 1997 revealed carcinogenic effects of several heavy metals such as Cadmium (Cd), Iron (Fe), Lead (Pb), Mercury (Hg), Zinc (Zn) and Nickel (Ni). There have been a number of studies which reported the deposition of heavy metals in soil, Crops and vegetables grown in the vicinity of industrial areas (Yang et al. 2004, Mingorance *et al.* 2007 and Khan *et al.* 2008).

The aim of this study was to determine the concentration of the heavy metals Pb, Cd, Ni and Cr in the irrigation water use for irrigating ready to eat vegetables at the Gidan Radio irrigation farm within the Kano metropolis of Kano state Nigeria, and compare with the permissible limit of FAO/WHO.

2. Materials and Methods

2.1 *The project area*

Kano is a city in northern Nigeria (11^0 59.981N, 8^0 31.491E) which is the largest city in northern Nigeria with the population density of 9,401.288 (Census, 2006). The study area is the Rafin Kuka Tukuntawa Gidan Radio Irrigation Farm (Figure 1), ($11^0 57^1$ 33.12^{11}N, $8^0 3^1 33.62^{11}$E) which is a drainage basin conveying Municipal wastewater from Kano Municipal, part of Sharada Phase I, Zoo Road and Shagari Quarters which finally discharges it content into the Tanburawa River.

2.2 *Water Sampling*

Water samples were collected at five different points along the drainage flow path, labeled as TK1, TK2, TK3, TK4 and TK5 (TK = Tukuntawa). Sample collection was done using the standard procedure described by the Department of waters affairs and forestry Pretoria (DWAF, 1992) in order to achieve an optimal level of success in sample collection. One litres polyethylene bottle after being thoroughly washed with detergent, rinsed with water and then distilled were used for collection of the sample irrigation water from the drainage. Ice packs were used to keep the samples cool and refrigerated in order to stabilize the metal before analyzing.

2.3 Analysis of Heavy Metals

The open-beaker digestion (OBD) method was employed for the chemical analysis of water samples (Dike *et al*., 2004). The 50ml of the water samples was measured into a beaker and 10ml HNO_3 was added. Beaker and the content were placed on a hot plate and digested until the brown fumes of HNO_3 escaped. Heating continued until the content reduced to 10ml; the content was then washed into a 50ml volumetric flask and made up to the mark. The digest obtained was subjected to determination of the metals.

2.4 Determination of Heavy Metals

The analysis/measurements of heavy metal concentration were carried out with an Atomic Absorption Spectrophotometer (AAS). All concentrations were determined using the absorbance made with air-acetylene flame. Eight working solutions were prepared from the stock solutions for each of the metals by successive serial dilution and each of the standard solutions was then aspirated into the flame of AAS and the absorbance recorded in each case. A plot of the concentration against the corresponding absorbance gives the calibration curve of each metal. The samples, after aspirated into the flame and the absorbance obtained were then extrapolated from the calibration plot to obtain the corresponding concentration.

2.5 Statistical Analysis SPSS

Version 20.0 statistical software was utilized in the computation of data for statistical significance and standard deviation between the obtained value and the WHO guidelines for irrigation water quality and the (FAO, 1992) criteria for irrigation waters.

Figure 1: Map of the Project Area (Google, 2019)

Source: *Google-earth-pro.en.softonic.com*

3. Results and Discussion

The results of the analysis for the heavy metals parameters for Cd, Mn, Pb, Cr, Co, Cu, and Zn of the water samples are shown in Table 1. These results were compared with the WHO guidelines for irrigation water quality. In addition, the average value of Heavy metals, their significance difference, and standard deviation for the statistical analysis were also found in Table 1.

Table 1. Concentration levels of heavy metals in irrigation water

S/No	Parameters (mg/l)	WHO Guideline for irrigation water (mg/l)	TK I	TK II	TK III	TK IV	TK V	Average	Significance difference	Std. Deviation
1	Cadmium	0.01	0.044	0.044	0.044	0.022	0.000	0.0308	0.077	0.0197
2	Manganese	0.2	0.097	0.193	0.193	0.338	0.048	0.1738	0.626	0.1112
3	Lead	5.0	0.030	0.051	0.020	0.041	0.030	0.0344	0.000	0.0119
4	Chromium	0.1	0.253	0.138	0.230	0.184	0.138	0.1886	0.010	0.0524
5	Cobalt	0.05	0.131	0.091	0.065	0.117	0.157	0.1122	0.017	0.0356
6	Copper	0.2	0.861	0.562	0.749	0.974	1.011	0.8314	0.001	0.2822
7	Zinc	2.0	1.311	1.461	1.049	0.824	0.712	0.6965	0.003	0.3162

3.1 *Cadmium*

The Average concentration of Cadmium found in the Municipal wastewater used for irrigation 0.0385mg/l shows no significance difference when compared with the FAO guidelines for irrigation water quality of 0.01mg/l (Table 1).

3.2 *Manganese*

The Average concentration of Manganese found in the Municipal wastewater used for irrigation shows no significantly difference when compared with the FAO guidelines for irrigation water quality of 0.2mg/l (Table 1).

3.3 *Lead*

The Average concentration of Lead found in the Municipal wastewater used for irrigation 0.0344mg/l shows a higher significance difference which indicates lower value when compared with the FAO guidelines for irrigation water quality of 5.0mg/l (Table 1).

3.4 *Chromium*

The Average concentration of Chromium found in the Municipal wastewater used for irrigation 0.1886mg/l show significance difference which indicate higher value when compared with the FAO guidelines for irrigation water quality of 0.1mg/l (Table 1).

3.5 *Cobalt*

The Average concentration of Cobalt found in the Municipal wastewater used for irrigation 0.1122mg/l show significance difference which indicate higher value when compared with the FAO guidelines for irrigation water quality of 0.05mg/l (Table 1)

3.6 *Copper*

The Average concentration of Copper found in the Municipal wastewater used for irrigation 0.8314mg/l show high significance difference which indicate higher value when compared with the FAO guidelines for irrigation water quality of 0.2mg/l (Table 1).

3.7 *Zinc*

The Average concentration of Zinc found in the Municipal wastewater used for irrigation 0.6965mg/l shows a higher significance difference which indicates lower value when compared with the FAO guidelines for irrigation water quality of 2.0mg/l (Table 1).

4. Conclusion

From the findings of the research, it can be concluded that the concentrations of the heavy metals in the Municipal wastewater use for irrigation is within the acceptable limit for some of the analyzed heavy metals with the exception of Chromium (Cr) which slightly exceed the guideline values, Cobalt which also exceed the guideline and copper which shows a high concentration of contamination in the irrigation wastewater. It can be argued that there are potential health risks for the urban population who consume vegetables grown with this Municipal wastewater and other food crops which have high levels of copper above the maximum recommended values by relevant authorities. Nonetheless, all these metals have toxic potential, but the detrimental impact becomes apparent only after decades of exposure. Although the level of concentration for some metals does not exceed the permissible limit, it is strongly recommended that people should not take large quantities of those vegetables so as to avoid large accumulation of the heavy metals in human body. Regular monitoring of heavy metals in water and plant tissues is essential in order to prevent excessive build-up of these metals in the human food chain. Appropriate measures should be put in place by the companies to always treat their waste effluents before discharging them into the immediate environment, since this will control the levels of heavy metals in the water and soil.

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IMPACT OF SOIL AND WATER CONSERVATION PRACTICES ON PHYSICOHEMICAL PROPERTIES OF SOIL IN A RICE GROWN ENVINMENT

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Abstract

This study assessed the impact of physical and chemical properties of soil in a rice grown environment in Minna environs Niger State, Nigeria under different soil and water conservation practices. Soil samples were collected at different depths of 0–10cm, 10–20cm and 20–30cm, respectively using a soil auger to determine their physical and chemical properties such as moisture content, particle size, bulk density, particle density, porosity and organic matter. Textural classification was carried out to determine the percentage dominance of the various soil types present in each of the study site locations. The moisture content of the site 1, 2, 3, 4, and 5 were between 14.3-13.7%, 13.2-10.2%, 15.4 - 13.2%, 15.6 -13.6% and 16.1-10.9%, respectively. The clay content of sites 3, 4 and 5 are higher than that of sites 1 and 2 while the silt contents of sites 1, 2 and 3 are higher than that of sites 4 and 5. The mean value of soil organic carbon from each of the study locations were 2.37%, 2.03%, 2.43%, 2.07% and 2.17% for sites 1, 2, 3, 4, and 5 respectively. It is therefore concluded that, site 1 is susceptible to erosion because of poor infiltration rate, and well ploughed or cultivated land by a tractor (harrowed). The particle sizes analysis indicated that the soil type in site 1 and site 2 are mainly sandy loam, while site 3 and site 5 are mainly loamy and predominantly clay loam in site 4.

Keywords: Degradation, erosion, fertility, irrigation, management

1. Introduction

Soil and water are essential inputs to agricultural production (Teshager *et al*., 2016). Agricultural practice is crucial for development and livelihoods of the majority of the population of Nigeria (George *et al*. 2018). Agricultural land use in Nigeria often result in the degradation of natural soil fertility and reduced productivity. Soil degradation under some farming activities sometimes brings about soil erosion, sedimentation and leaching (Sharma *et al*. 2018). Berhe *et al*., (2018) stated that with the current rate of soil loss through various agent of erosion, there will be a rapid displacement of the top soil resource into the sea, ocean, rivers and stream. In Nigeria, low crop production has been linked partly to the poor soil condition caused by previous severe erosion (Musa *et al*. 2017). Soil erosion occurs when soil particles are carried off by water or wind and deposited somewhere else. Erosion begins when rain or irrigation water detaches soil particles. When there is too much water on the soil surface, it fills surface depression and begins to flow with enough speed; this surface runoff carries away the loosed soil (Okorafor *et al*., 2017). Soil erosion depends on the erosivity of the rainfall and the erodibility of the soil (Pham et al. 2018).

The extent of washing away of the soil particles depends on the soil characteristics and type involved, which leads to the concept of erodibility (Musa *et al*. 2017). Soil erodibility is an estimate of the ability of soil to resist erosion based on the physical and chemical characteristics of each soil (Deviren *et al*., 2018; Dou *et al*. 2020). Generally, soils with faster infiltration rates, high organic matter, and improved structure are more resistance to erosion (Malvar *et al*. 2017). Water is one of the major factors in rice production with increasing scarcity of water; the costs of its use and resource development (Alhassan *et al*. 2017). Therefore, farmers and researchers alike are looking for ways to reduce water use in rice production, increase its use efficiency and increase yield of paddy rice. Traditional rice cultivation uses floodwater management, which requires various inputs that are costly and time consuming (Alhassan *et al*. 2017). Water management is not just about how water is delivered but also when, how often, and how much water is used to obtained maximum yield (Vories *et al*. 2017).

The greatest challenge for agriculture in Nigeria is to produce more rice with less water if food security is to be maintained. Thus, irrigation water use efficiency should play a greater role in meeting future rice demands (Alhassan *et al*. 2017). The only solution for worldwide water shortage and utilization problem is to make efficient use of agricultural water for improve crop productivity (Kang *et al*. 2017). Irrigation interval method is the most common practice among rice farmers in rural communities of Nigeria, determination of suitable irrigation frequency that will improve the water use efficiency and save cost becomes very important. Little information is available on improving water use efficiency of rice in the savanna ecological zone of Nigeria.

This study is therefore aimed at evaluating the effect of soil and water conservation practices on physical and chemical properties of soil in a rice-grown environment in North Central Nigeria.

2. Materials and Methods

2.1 Study Area

The study was conducted on the permanent site farm of the Federal University of Technology, Minna, Gidan Kwanu which is known to have a total land mass of eighteen thousand nine hundred hectares (18,900 ha.). Located along kilometer 10 Minna – Bida Road, South – East of Minna in Bosso Local Government Area of Niger State. It has a horse – shoe shaped stretch of land, lying approximately on longitude of 06^0 28^{ll} E and latitude of 09^0 35^{ll} N. The site is bounded Northwards by the Western rail line from Lagos to the northern part of the country and the eastern side by the Minna – Bida Road and to the North – West by the Dagga hill and river Dagga (Musa *et al*., 2013; Musa *et al*. 2020).

2.2 *Soil Sample Collection*

Soil samples were collected at depths of 0–10 cm, 10–20 cm and 20–30 cm, respectively using a soil auger for each of the study area. The distance intervals between the sampling points was 10 m within the study area. This spacing is based on the boarder basins commonly prepared for rice farming. 450 g of soil sample was collected from each sampling point in the field at depths of between 0 and 45 cm to determine their physical properties. These properties were determined according to the works of Musa *et al.* (2013, 2020). The samples were collected based on condition of the land. Site 1 is the cultivated tilled area by a tractor (harrowed) while site 2 is the manually tilled area with small sized mounds made using the hoe. Site 3 is section where the remains of rice stocks and straws are tilled with a tractor and site 4 is a waterlogged area with remains of rice stocks and straws, which was manually tilled using the hoe. Site 5 is a Plane land, which was manually tiled using the hoe.

The hydrometer method was used to determine the particle size analysis. 50g of soil sample from a 2 mm sieve was poured in a conical flask. 50 ml of sodium hexa-metaphosphate was added to the soil sample in the flask after which 100 ml of distilled water was added. The solutions were mechanically shaken and stirred to allow the particles to disperse well but not done in such a manner as to reduce the sizes of soil particles and was allowed to stand for 24 hours. This is in accordance with the works of Musa *et al.,* (2017) and Bieganowski *et al*., (2018). According to Musa *et al*. (2019), a correction factor in relation to the temperature was added to the hydrometer readings giving new value of Hydrometer Correction Factor (H). Equations 1-3 were used to determine the percentage components of the various soil components.

$$\% \, Sand = \frac{100-(H \, X \, 100)}{Weight \, of \, soil} \quad (1)$$

$$\% \, Clay = \frac{(H \, X \, 100)}{Weight \, of \, soil \, sample} \quad (2)$$

$$\% \, Silt = \frac{100}{(\% \, sand+\% \, clay)} \quad (3)$$

$$\% \text{ of silt} + \% \text{ of clay} = \frac{\text{Corrected 40s hydrometer reading}}{\text{Dry weight of the soil}} \quad (4)$$

$$\% \text{ of silt} + \% \text{ of clay} = \frac{\{H_1 + 0.36\,(T_1 - 20) - 2.0\} \times 100}{50} \quad (5)$$

$$\% \text{ of clay} = \frac{\text{Corrected 2 hours hydrometer reading}}{\text{Dry weight of the soil}} \quad (6)$$

$$\% \text{ of clay} = \frac{\{H_2 + 0.36\,(T_2 - 20) - 2.0\} \times 100}{50} \quad (7)$$

% of silt = {% of silt + % of clay} - % of clay which is Eq (5) - Eq (7) (8)

% of sand = 100 - {% of silt + % of clay}

Where H_1 = Hydrometer reading at 40 s, T_1 = Temperature of the content at 40 s, H_2 = Hydrometer reading at 2 hours and T_2 = Temperature at 2 hours. Note that sand particle will settle within 40 s, silt particle will settle within 2 hours but at 2 hours, clay particle will still be floating or in suspension which the hydrometer will reading. Correction factor for temperature above 20 is 0.36 (T_1 - 20) while correction factor for the salt added is -2.0. Please check your Equations and compare them

2.3 *Moisture Content*

Determination of moisture content of the various soil samples were carried out using gravimetric method. A 78g portion of the samples was collected and oven dried at a temperature of 105 ℃ for 24 hours. This is in accordance with the work of Musa et al., (2017) and Bieganowski *et al*. (2018). The initial weight of the container W_1 was determined and 78g of soil sample was added to the crucible and was re-weighed as W_2. After 24 hours of oven drying of the soil samples in the crucible at 105 ^{0}C, the dried soil and crucible was re-weighed as W_3. Equation 4 was used to determine the moisture content of the various soil samples.

$$M_c = \frac{W_2 - W_3}{W_3 - W_1} \qquad 4$$

Where M_c is the moisture content, W_1 is the weight of container, W_2 is the weight of container and sample and W_3 is the weight after oven dry.

2.4 *Bulk density*

The mass of each empty crucible to be used was determined as M_1 after which soil samples were placed in the various crucible of known weight and were re-weighed (M_2). The crucible with the soil samples were kept in the oven for 24 hours at 105 ℃. After the oven drying process, the crucible with the dried soil samples were reweighed as M_3. The bulk density was calculated as mass of oven-dried soil per volume of core (g/cm^3) and gravimetric moisture content as mass of water in the soil sample per mass of the oven-dried soil. Equation 5 was used to determine the bulk density of the various soil samples.

$$Bulk\ Density\ (BD) = \frac{Mass\ of\ Oven\ Dry\ Soil}{Volume\ of\ core\ sampler} \qquad 5$$

Total soil porosity was determined from the relationship between bulk density and particle density.

Practical determination of soil porosity (P) using Equation (9)

$$P = \left(1 - \frac{BD}{PD}\right) \times 100 \qquad (9)$$

Where: BD = bulk density; and PD = Particle density A

$$G_s = \frac{M_2 - M_1}{(M_4 - M_2) - (M_3 - M_2)}$$

PD = specific gravity (G_s) of x density of water (ρ_w)

M_1 = mass empty density bottle, M_2 = mass of bottle + dry soil that is half-filled the bottle, M_3 = mass of bottle + half-filled soil + water to fill the bottle to the top and M_4 = mass of bottle + water only to fill the bottle to the top all gram.

3. Results and Discussion

Results of the various laboratory analyses for the soil samples collected from each of the study locations are presented in Tables 1, 2, 3 and 4 respectively. The soil textural classification (Table 1) for the various soil samples based on the various cultivation practice was carried out using soil textural triangle. The percentage of sand content recorded generally was observed to be relatively high for all the five-study locations which ranged between 43% and 53% when compared with the other components of soil such as silt content ranging between 11% and 24% while clay content ranged between 32% and 38%. The results obtained from Bougocous hydrometer method showed that sites 1 and 2 has higher percentages of sand compared to sites 3, 4 and 5. Similarly, the clay content of sites 3, 4 and 5 are higher than that of sites 1 and 2 while the silt contents of sites 1, 2 and 3 are higher than that of sites 4 and 5. This result shows that sites 1, 2, 3 and 5 are most suitable for rice production than that of site 4. This is in accordance with the work of Musa *et al*., (2017) who stated that soil aggregation is essential for the resistance of land surface to erodibility, and it influence the capacity of soils to remain productive. However, water erosion from detachment; mainly by rainfall, and from transport, mainly by runoff are also agents who are contributing to the process of land degradation.

Table 1: Soil particles size and textural classification result of the study areas

		Particles size			
Locations	**Samples**	**% sand**	**% silt**	**% clay**	**Textural classifications**
Site 1	1	46	19	34	Sandy Loam Soil
Site 2	2	47	23	30	Sandy Loam Soil
Site 3	3	43	24	33	Loam Soil
Site 4	4	53	15	32	Clay Loam Soil
Site 5	5	51	11	38	Loamy Soil

Table 2 present the results of the moisture content of each of the study locations. The results show that the mean moisture content of sites 1, 2, 3, 4, and 5 were determined to 14%, 12%, 14.30%, 14.50% and 12.80% respectively. This were similar to the work carried out at a different location of the same study area by Musa and Egharevba (2009) whose moisture content range between 10% and 13%. This indicates the dryness of the soil within each of the study locations compared with the result of Akilapa (2010) which

Balasubramanian and Bell (2017) confirmed that infiltration rate would be higher when the soil is dry. It has been established by many researchers that low moisture reduces the cohesiveness among the particles thus making them freely dispersible by water and other erosion agents, thereby making it vulnerable to erosion. This is in accordance with the works of Popoola (2010), Tabbal *et al*., (2010) and Ethan *et al*. (2012).

Table 2: Moisture content of each of the study locations

Locations	Samples	Soil depth (cm)	W_1 (g)	W_2 (g)	W_3 (g)	Mc (%)	AMc (%)
Site 1	1	0-10	25.168	104.239	90.148	14.3	14.00
		10-20	25.529	104.605	86.162	14.0	
		20-30	24.941	102.175	82.452	13.7	
Site 2	2	0-10	24.073	101.515	87.143	13.2	12.00
		10-20	24.861	103.654	89.132	12.6	
		20-30	23.942	100.451	79.142	10.2	
Site 3	3	0-10	25.986	103.065	93.168	15.4	14.30
		10-20	24.676	102.175	92.196	14.3	
		20-30	24.918	101.113	90.184	13.2	
Site 4	4	0-10	25.023	102.142	96.168	15.6	14.50
		10-20	25.147	105.163	93.145	14.3	
		20-30	24.186	103.163	92.131	13.6	
Site 5	5	0-10	26.012	105.196	96.333	16.1	12.80
		10-20	25.023	103.148	94.145	11.4	
		20-30	25.140	102.132	90.132	10.9	

Where W_1 is weight of the crucible container, W_2 is the weight of the crucible container and fresh soil sample, W_3 is the weight of crucible container and oven dried soil samples, Mc is the moisture content of the soil and AMc is the average soil moisture content.

The lowest value of bulk density as presented in Table 3 was found in site 3. It ranges from 1.28 g/cm to 1.39g/cm. While, site 4 has the lowest value of particle density which ranges from 1.56gc/m to 1.76g/cm. The soil bulk and particle density were affected by soil and water conservation practices. The lower mean bulk and particle value under integrated measures might be the subsequent effect of reduced soil loss and crop residue through erosion; and addition of organic matter from plants. Similarly works were reported by Rakkar and Blanco-Canqui (2018) and Seitz *et al*., (2019) who indicated lower mean soil bulk and particle value in conserved plots of rice farm than non-treated cultivated lands. Data regarding particle size distribution revealed dominantly sandy loam and loam textural class, which implies that soil and water conservation practices do not alter the soil texture. The result agrees with the finding of Datta et al., (2017) who reported non-significant difference in texture due to soil and water conservation practices.

Soil and water conservation practices influenced soil organic carbon (OC) of the farmlands within the study area as observed in Table 3. The mean value of soil organic carbon from each of the study locations were 2.37%, 2.03%, 2.43%, 2.07% and 2.17% for sites 1, 2, 3, 4, and 5 respectively. It was generally observed that the soil and water conservation practices and its integration have positive impacts on soil organic carbon of cultivated lands. This result therefore indicates that soil and water conservation practices have a positive role in improving soil organic carbon. This is in accordance with the works of Hann et al., (2006) and Akintola (2010).

Table 3: Soil Aggregate Results of the study locations

Locations	Samples	Horizon Depth (cm)	Particle Size			Bd	Pd	P	OC	OM
			% Sand	% Silt	% Clay	(g/cm^3)	(g/cm^3)	(%)	(%)	(%)
		0-10	48	28	24	1.45	2.94	18.20	2.30	4.00
Site 1	1	10-20	47	14	39	1.28	1.58	13.60	2.50	2.60
		20-30	43	16	41	1.43	1.62	14.90	2.50	3.10
		0-10	59	21	20	1.40	2.94	20.30	1.80	4.80
Site 2	2	10-20	41	23	36	1.51	1.99	29.70	2.80	4.00
		20-30	42	24	34	1.46	3.10	24.10	1.50	3.40
		0-10	42	23	35	1.39	1.99	53.50	2.60	2.60
Site 3	3	10-20	43	24	33	1.28	2.80	44.50	2.00	4.60
		20-30	45	25	30	1.39	2.94	23.60	2.70	4.30
		0-10	51	18	31	1.80	1.56	57.10	1.90	5.10
Site 4	4	10-20	56	14	30	1.63	1.63	42.30	2.30	3.60
		20-30	52	12	36	1.57	1.76	34.10	2.00	4.20
		0-10	48	11	40	1.45	1.82	7.05	1.80	2.90
Site 5	5	10-20	55	9	36	1.52	1.86	50.20	1.90	3.20
		20-30	49	13	38	1.44	1.91	40.30	2.80	4.00

Where Bd is the bulk density, Pd is the particle density, P is Porosity, OC is the Organic carbon, OM is the Organic Matter

Table 4: Summary of Results

Locations	Samples	AMC	ABD (g/cm^3)	APD (g/cm^3)	AP (%)	AOC (%)	AOM (%)	APS % Sand	% Silt	% Clay	Textural class/soil type
Site 1	1	14.00	1.39	2.05	15.57	2.37	3.23	46	19	34	Sandy Loam
Site 2	2	12.00	1.46	2.68	24.70	2.03	4.07	47	23	30	Sandy Loam
Site 3	3	14.50	1.35	2.58	40.53	2.43	3.83	43	24	33	Loam
Site 4	4	12.80	1.67	1.65	44.50	2.07	4.30	53	15	32	Clay Loam
Site 5	5	14.30	1.47	1.86	32.52	2.17	3.37	51	11	38	Loam

Where ABD is the Average Bulk Density, APD is the Average Particle Density, AP is the Average Porosity, AOC is the Average Organic Carbon, AOM is the Average Organic Matter, and APS is the Average Particle Sizes

Soil Organic matter (SOM) in each of the study locations were different as observed in Table 4. The soil organic matter for sites 1, 2, 3, 4 and 5 were 3.23%, 4.07%, 3.83%, 4.30% and 3.37% respectively. These results showed that, if SOM is increased in the soil, the infiltration rate tend to also increase. These results are similar to the work of Romkans et al. (2007). The average OM for sites 1, 3 and 5 were lesser than those of sites 2 and 4 which significantly implies that soil particles are drier. Thus, shape, size and stability of soil aggregates may affect the infiltration rate of rainwater. For instance, coarse-grained sandy soils have large spaces between each grain which allow water to infiltrate quickly. These results are similar to the works reported by Zhang *et al*. (2012) the infiltration rates under different dryland conditions in Indonesia.

The ability of soil to store water depends on the void spaces within it. Thus, water movement within sandy soils are faster when compared to the tightly clay soils. This is in accordance with works of Musa *et al*. (2017) and Musa and Egharevba (2009). The results of the soil analysis show that the soil storage capacity depends on the soil porosity. The study locations sites 1 and 2 are mostly sandy soils and has high level of porosity, making it difficult to store water. This is in accordance with the work of Akilapa (2010) who confirmed that soils run through fingers when fetch and easily dry up when subjected under high temperature mostly contain minerals.

4. Conclusion

The effect of soil and water conservation practices on physical and chemical properties of soil in a rice grown environment in Minna, north central Nigeria was carried out. From the various results obtained, the particles size analysis showed that the soils type in Sites 1 and 2 are sandy loam, Sites 3 and 5 are loam while Site 4 is clay loam respectively. Some factors affecting infiltration rate of water includes the texture, management practice and bulk density. Sites 1 and 2 with light textured soils were observed to have a higher infiltration rate than the heavier textured soils of Sites 3, 4 and 5, which is due to the large conducting pores in sandy soil. Cultivated tilled lands normally have lower values of infiltration rates than those fallowed soils. However, soil erosion is a cause of soil fertility loss, reduce crop yield and thereby exacerbates the risk of flooding. As the result of the study reveal, indigenous soil and water conservation technologies are considered as effective methods conservation. Moreover, the sample with the least moisture content was obtained in Site 2 having average moisture content of 12%. It is therefore concluded that the soil within the Site 2 needs special management practice to ensure good infiltration rate of water for soil and water conservation because of its poor infiltration rates which may lead to occurrence of surface runoff: during which fine soil particles are carried away as a result of water erosion, poor watershed management, rapid population growth and inappropriate use of farming practices that had contributed for a lion share of the losses caused and pose a serious threat to the production of rice and other agricultural crops.

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MAPPING OF TYPHA GRASS INFESTATION IN HADEJIA VALLEY IRRIGATION SCHEME, JIGAWA STATE, NIGERIA

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Abstract

Remote sensing and Geographic Information System (GIS) were used to identify and classify Typha grass within Hadejia Valley Irrigation Scheme (HVIS). Data were collected using a Global Positioning System (GPS), an Unmanned Aerial Vehicle known as a drone, 1m^2 metal quadrant, sickle, bag, weighing scale, and administrative Maps of Jigawa State and Nigeria. Ground truthing was conducted in June 2018 for data collection and repeated in August and November 2018 for data validation. Data were processed and analyzed using MapSource, ArcGIS 10.3, ERDAS and Imagine 9.2 software and Landsat 8 imagery with path 188, row 051 at a spatial resolution of 28.5m. The results indicated that Typha grass-covered 4,769.5ha within HVIS, with 6,567ha around the irrigation scheme. Typha biomass in this area was estimated as 110,890.88 tons (stems 48.8% and leaves 51.2%) at 23.25 tons per hectare. The grass was more predominant in burrow pits and some Night Storage Reservoirs (NSRs) around the sectors. Infested burrow pits were in Gatafa, Aguza, Marina, Ayama, Furawa, Mado and Akubushi sectors while NSRs with Typha grass were in Adaha, Aukayi, Zumoni, Marina and Auyo sectors. The management of HVIS should ensure that the communities within HVIS maintain the NSRs within their sectors and also stop enlarging burrow pits within the sectors through their individual and collective activities.

Keywords: remote sensing, Typha infestation, Hadejia Valley Irrigation Scheme

1. Introduction

Remote sensing satellite data have been applied to identify and study various wetland features such as tidal flats, lagoons, marshy vegetation, saltmarshes etc. This data has also helped to understand, identify, and monitor spatial patterns, significance and extent of wetlands to the local community (Bhuvaneswari *et al.* 2011; Rani *et al*. 2011). Remote sensing and Geographic Information systems have also been applied to classify and map the plant communities of wetlands in Prairie Pothole Region of Central North Dakota (Mita *et al.,* 2007). Medium resolution remote sensing and GIS have been used for habitat and species mapping, land change detection and monitoring of conservation areas (De Roeck *et al.,* 2008). Monitoring of wetlands status is increasingly seen as an important issue worldwide because of their increasingly recognized role in ecosystem service provision, the importance in maintaining human health and wellbeing, natural ecosystem bio-integrity, and carbon sequestration. Typical of the current status of this wetland focus is the work of Dabrowska-Zielinska *et al.,* (2009) who applied multi-spectral remote sensing techniques to obtain data on changes in soil moisture and evapotranspiration for the management of wetlands in Poland. In wetland marshes of the Parana River Delta in Argentina, similar procedures used radar remote sensing for water level evaluation, and to study and understand the basic interactions between the soil under different flood situations and the vegetation composition (Grings et al., 2009). Prigent (2001) as well used satellite observation to find submerged wetlands; and Harris *et al.* (2005) have applied large-scale remote sensing methods to monitor near-surface peatland hydrological conditions, as well as to detect near-surface moisture stress in *Sphagnum* moss dominated habitats. In Finland, GIS and remote sensing tools have been used, combined with ground evaluations, to measure the effects of rehabilitation on the aquatic vegetation of a shallow eutrophic lake (Valta-Hulkkonen *et al.,* 2004). Landsat (TM) images have been used to create a classification of the vegetation community types and plant community structure in the lower Roanoke River floodplain of northeastern North Carolina, USA (Townsend and Walsh, 2001), and for classifying coastal wetland vegetation classes in Yancheng National Nature Reserve (YNNR), China (Zhang et al., 2011). These techniques have also been used for detection of the land use and land cover change in Kainji Lake Basin, Nigeria (Ikusemoran, 2009). Moreover, Salako *et al* (2016) used remote sensing and GIS to monitor vegetation areas in the Hadejia community. All these have proven that remote sensing can be used to identify the vegetation areas in any wetland community. It is, therefore, based on this that remote sensing is used to map the area of Typha grass infestation within HVIS to identify the extent to which Typha grass infestation has covered the irrigation site.

2. Methodology

2.1 Study Area

According to Bdliya and Muhammad (2003), HVIS has located within the Hadejia-Nguru Wetlands (Hadejia-Nguru Wetlands) system between latitude 12.3829°- 12.9036° N and longitude 10.1851°- 10.6748° E and bounded by routes linking Hadejia, Katagum, Nguru and Gashua towns. The climate is generally characterized by distinct dry and wet seasons. The dry season which normally lasts for about 7 months usually starts from October to April, punctuated by the cold harmattan condition between December and February. The temperature in the Wetlands varies with time of the year reaching the peak (maximum) of about 41ºC in April and May and about 29ºC (minimum) during the harmattan in January. The rainfall pattern in Hadejia-Nguru Wetlands has not been stable over the years, but in most cases, rainfall starts from June till September and sometimes October in a rainy year with a long break of up to a month in between the first rain and subsequent ones. The months of July and August are the only reliable periods of rainfall. The total annual rainfall ranges from 500 mm to 700 mm.

The Hadejia Valley Project is located within Auyo, Kaugama, Miga, Kafin Hausa and Hadejia Local Government Areas of Jigawa State between the Hadejia and Kafin Hausa rivers. Water released from the upstream Challawa and Tiga dams into the river system is impounded in a barrage/storage pond with a capacity of 11.0 million cubic meters from where it is diverted through water control structures into the feeder canal to serve the irrigation area of the project. The project is a gravity irrigation scheme covering 12,500 hectares out of which 5,300 hectares were developed. The remaining area and the rehabilitation of the completed area are also expected to be carried out under the TRIMING Project. The Hadejia Barrage is an operational reservoir more than 200 km downstream of Challawa Gorge Dam. It serves as the headworks for the Hadejia Valley Irrigation Project supplied by water from the Hadejia River, which runs majorly on the releases from the Challawa Gorge dam. The headworks consist of a 1 km long barrage constructed as an earth-fill diversion dam with a maximum height of 9.25m across the Hadejia River and bounded by two (2), 12 km long dykes on the north and the south side that create a reservoir with a capacity of 11.4 million m^3. The dykes, constructed in 1981, have suffered severe erosion and can hardly be identified from the adjacent ground levels anymore. However, the Hadejia Barrage has also been infested by Typha grass.

2.2 Data Collection

The data used for mapping in this research were obtained from reconnaissance surveys, observations, satellite images, drones, the quadrant method and interviews. Maps and diagrams of the Hadejia Valley Irrigation Scheme (HVIS) area were prepared from shapefile data.

Materials used for data collection include Global Positioning System (GPS), Unmanned Aerial Vehicle called a drone, a 1m by 1m quadrant made of wood, cutlass, sickle and android phone and an administrative Map of Jigawa State and Nigeria.

A ground-truthing survey was also conducted in April, August and October 2018 as related below:

i. Garmin GPS to capture the geographic coordinates (Lat./Long.) of some points on the field to identify *Typha* grass and shrubs/forests, wetlands and others adjoining land use/ land cover.

ii. Unmanned Aerial Vehicle (UAV), was used to take aerial photographs of every sector surveyed, especially where the Typha plant can be seen physically and the extent of the plant in water bodies was revealed from the aerial pictures taken. The drone was assembled in every sector and then flew to heights ranging between 35 and 75 km high. The choice of this height was to ensure a wider coverage in the aerial sector and fly the drone to safety from water bodies and wind velocity. The pictures were taken every 10 seconds. The drone was left at a stationary position to take shots to the left, right, front and back views of that position before it moved further again. The process was repeated about 3 – 4 times in every sector surveyed.

2.3 Quadrant method

This method was used to determine the Typha biomass in each of the surveyed sectors. A Typha infested area of 1 m by 1 m was marked out in a sector. The Typha components (stem, leaves and root) within the marked-out area were weighed and recorded. The counted Typha within the 1 m X 1 m quadrants taken was then used to estimate the quantity of Typha in the mapped-out sector. This estimation by extrapolation gives the quantity of Typha in a sector. The same procedure was repeated for all other sectors surveyed.

2.4 Data Analysis

The data were processed and analyzed in the GIS laboratory of National Agricultural Extension & Research Liaison Services (NAERLS), Ahmadu Bello University, Zaria. The software used for the data analysis was MapSource, Google Earth Pro and ArcGIS 10.3 version. ERDAS Imagine 9.2 was used to create a transition probability matrix. ERDAS Imagine 9.2, according to Rongqun *et al.,* (2010), can be used for transition probabilities which express the likelihood that a pixel of a given class will change to any other class (or stay the same) in the next period.

2.5 Methodology used for Image Classification

Landsat 8 imagery with path 188 row 051 at a spatial resolution of 28.5 m was used. United State Geological Survey (USGS) Landsat images of July and November 2018 were acquired, with a cloud cover and scene cover of less than 1%. The Landsat 8 comprises 11 bands but only 4 bands were used for layer stacking and image classification. These are the bands 1, 2, 3 and 4 which indicate the RGB and NIR. The Landsat image was imported into ERDAS Imagine 9.2 software with bands 1, 2, 3 and 4 layers stacked. After layer stacking, supervised classification was performed in ERDAS Imagine. Thereafter, the result/output was exported and saved in the working folder. The administrative map/shapefile of Jigawa was then added into ArcGIS Environment same as the result/output of image classification. The administrative map was used to clip the research area. The classified image shows the shape of the area covering Jigawa. One of the Environmental Systems Research Institute (ESRI)'s software, ArcMap 10.3.1 was used to calculate the vector image of the research area. This gives a perfect result for image classification.

Bands 3, 2, and 1 were included in the band composite because of their ability to identify water bodies and man-made features, with vegetation showing in green natural colour. Band 4 (near-infrared) and band 3 were required for running the Normalised Difference Vegetation Index (NDVI) and used as ancillary data for image supervised classification. NDVI is a Remote Sensing/ GIS technique used over the years by scientists to quantitatively and qualitatively evaluate the vegetation cover of an area.

Seven categories of classification were made as shown in Figures 1 to 6 which include settlement, Typha grass, mutara weed, sand deposit, wetland, rice and water body. The settlement area is shown on the classification as pink, Typha grass as red, the water body as blue, rice as green, and the wetland as grey.

NDVI as proposed by Rouse et al. (1974) is mathematically defined as:

$$NDVI = \frac{NIR - R}{NIR + R} \quad (1)$$

Where NIR and R are the reflectances in the near-infrared and red regions respectively. It is the algebraic combination of red and near-infrared bands to represent the amount of green vegetation in the image (Biehl, 2010).

Image classification continued till getting to the stage where there was the need to:

Zoom to the Landsat image

Create a polygon on a feature area on the Landsat image

Add it to the signature window

Repeat this process four times

Merge it on the signature window

Name the features e.g. Typha area, waterbody

Repeat the same process for other features.

Thereafter, save the signature file, then:

Click on classifier

Supervised classification

From the input file, Navigate to the working folder and select the layer stacked image as input

Select the signature file as input for the signature section.

Navigate to the working folder and save the output as a classified image for the output section.

3. Results and Discussion

Figure 7 shows the HVIS by sector. The result indicated that the total area covered by Typha grass within the irrigation sectors and its environs were 11,336.5 ha. This result was quite different, though not too much, from the work of Salako *et al* (2016) who estimated the area covered by Typha grass in Hadejia-Nguru wetlands in 2015 as 18,152.52 ha. Although, the area occupied by *Typha* grass, other tall grasses and tree clusters were all considered for the Typha infestation area in their study. More so, *Mutara* grass which is similar to Typha grass is considered separately in this research to have a clear distinction between the two. The amount of stem weight and leaves weight estimated was 499,939.65tons and 940,929.5tons respectively. The result of the analysis further indicated that some reservoirs are being maintained by the fish farmers (fishermen) in the communities making them free of Typha grass (Gatafa, Akubushi and Yamidi).

The areas where the Typha grass is densely populated are burrow pits that are located in most sectors of and Marke community. The identified sectors where burrow pits were discovered were Gatafa, Agusa, Marina, Ayama, Furawa, Ayama, Mado and Akubushi. Akubushi had the highest number of burrow pits that have been filled with Typha grass and this might have contributed to having the highest area (95 ha) covered by Typha grass. Other vegetation discovered in the research area includes *Mutara* grass-covered 2,013 ha while rice and other crops covered 5,834 ha. Current management practices employed by farmers to checkmate Typha grass invasion include burning of Typha grass and manual harvesting of the grass from time to time within the schemes. This is mostly done when Typha grass completely obstructs water convergence through the canal.

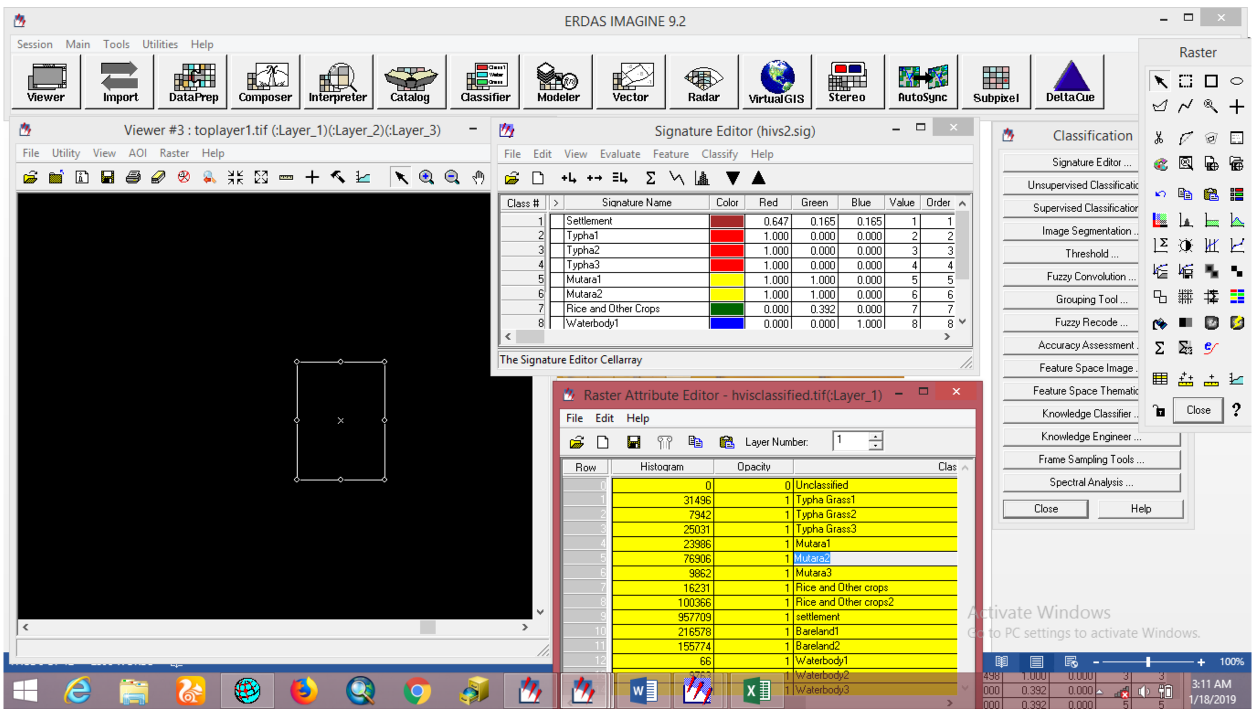

Figure 1 Interface of the ERDAS IMAGINE 9.2 used for Image Classification

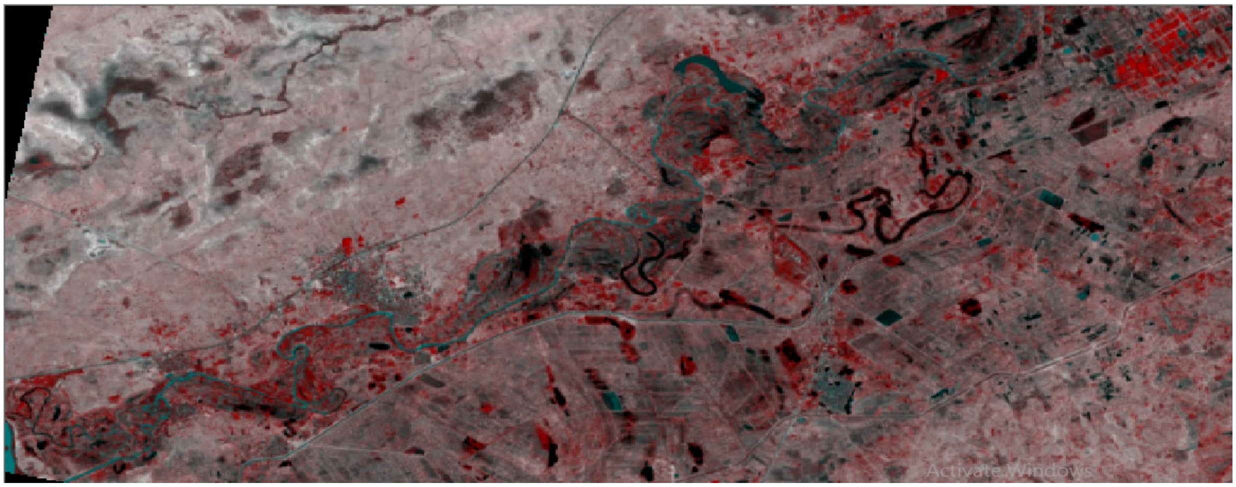

Figure 2. Research area after layer stacking in ERDAS Imagine

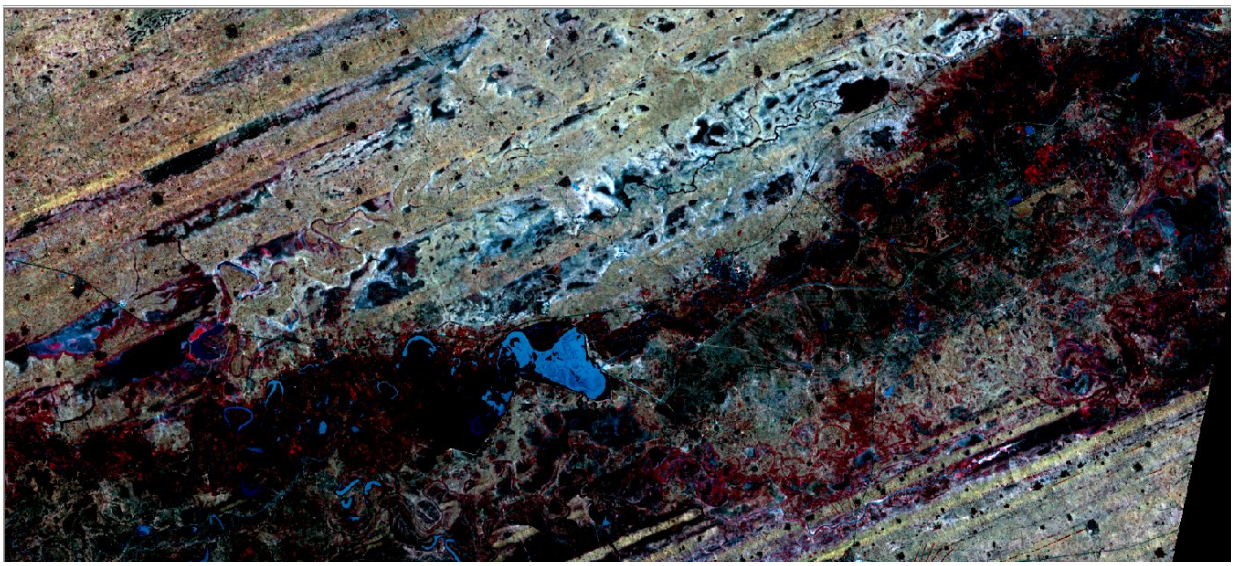

Figure 3. Supervised image classification after processing

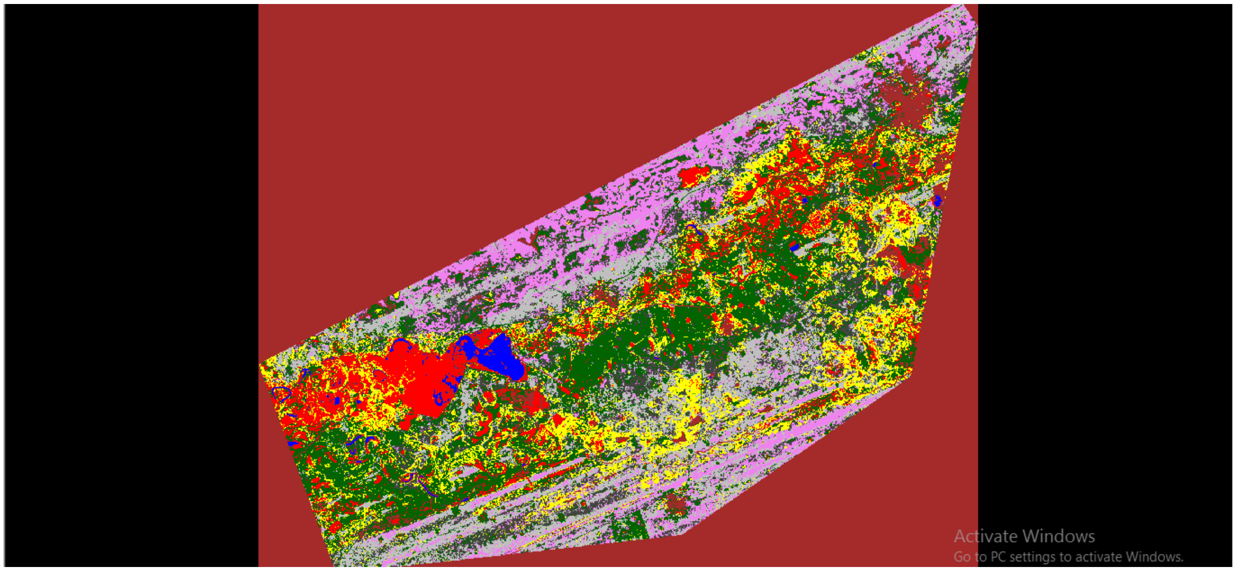

Figure 4. Result of Image Classification

Table 1: Irrigation Sectors with the area covered by Typha grass

Sector/ Location	**Latitude**	**Longitude**	**Sector size (ha)**	**Area covered by Typha (ha)**	**stem weight (tons)**	leaves weight (tons)
Mado	12°20’58.48”N	9°55’46.76”E	200	67	2954.7	5561
Marina	12°20’4.24”N	9°54’40.44”E	540	46	2028.6	3818
Gamsarka	12°18’52.74”N	9°51’28.36”E	147	65	2866.5	5395
Gatafa	12°23’50.11”N	9°58’55.33”E	500	76	3351.6	6308
Adaha	12°19’54.90”N	9°52’43.78”E	291	42	1852.2	3486
Akubushim	12°22’19.60”N	9°57’30.41”E	978	95	4189.5	7885
Auyakayi	12°22’1.69”N	9°58’4.44”E	338	38	1675.8	3154
Aguza	12°21’17.20”N	9°56’23.31”E	315	62.9	2773.89	5220.7
Zumoni	12°19’12.88”N	9°52’6.42”E	352	42	1852.2	3486

Ayama	12°18’45.31”N	9°52’13.92”E	150	43	1896.3	3569
Auyo	12°20’30.15”N	9°55’45.06”E	307	65.2	2875.32	5411.6
Furawa	12°20’26.33” N	9°57’12.15” E	634	72.4	3192.84	6009.2
Yamidi	12°24’41.29”N	10° ‘54.61”E	140	22.8	1005.48	1892.4
Shawara	12°24’55.70”N	10° ‘50.46”E	278	35	1543.5	2905
Arbunau-Hausawa	12°21’17.70”N	9°57’19.37”E	140	26.9	1186.29	2232.7
Meshaywa	12°23’41.93”N	9°59’25.90”E	187	47	2072.7	3901
Ganuwar-Kuka	12°25’27.46”N	10° ‘47.49”E	210	45	1984.5	3735
Tsakar	12°24’3.05”N	10° ‘18.39”E	200	39	1719.9	3237
Muran	12°23’22.78”N	9°58’18.93”E	115	49	2160.9	4067
Feeder Canal	12°18’53.14”N	9°49’35.86"E		15.3	674.73	1269.9
Storage pond (Barrage)	12°19'32.08"N	9°48'16.40"E		2,788	122950.8	231404
Main drain	12°18'14.38"N	9°50'49.99"E		987	43526.7	81921
HVIS surroundings				6,567	289604.7	545061
Total				**11,336.5**	**499,939.65**	**940,929.5**

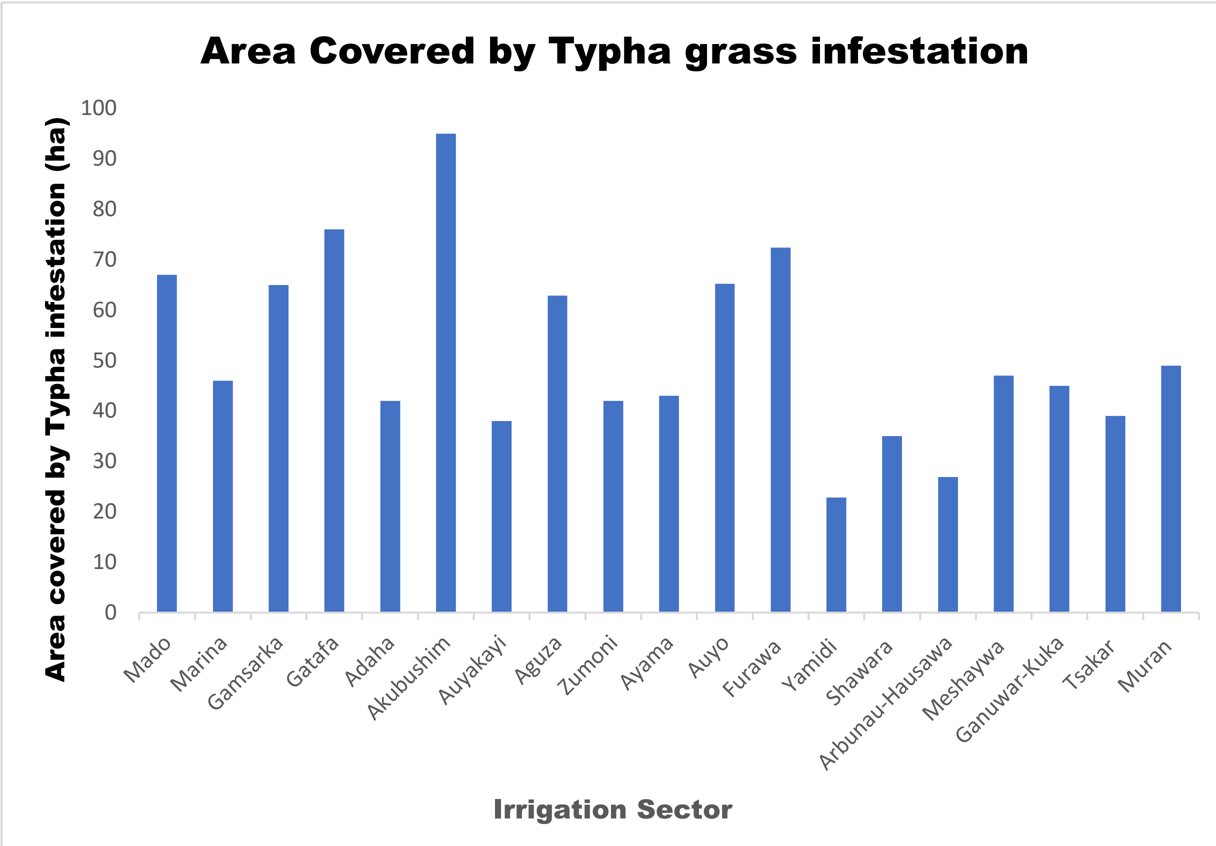

Figure 5: Area covered by Typha grass infestation within the sector

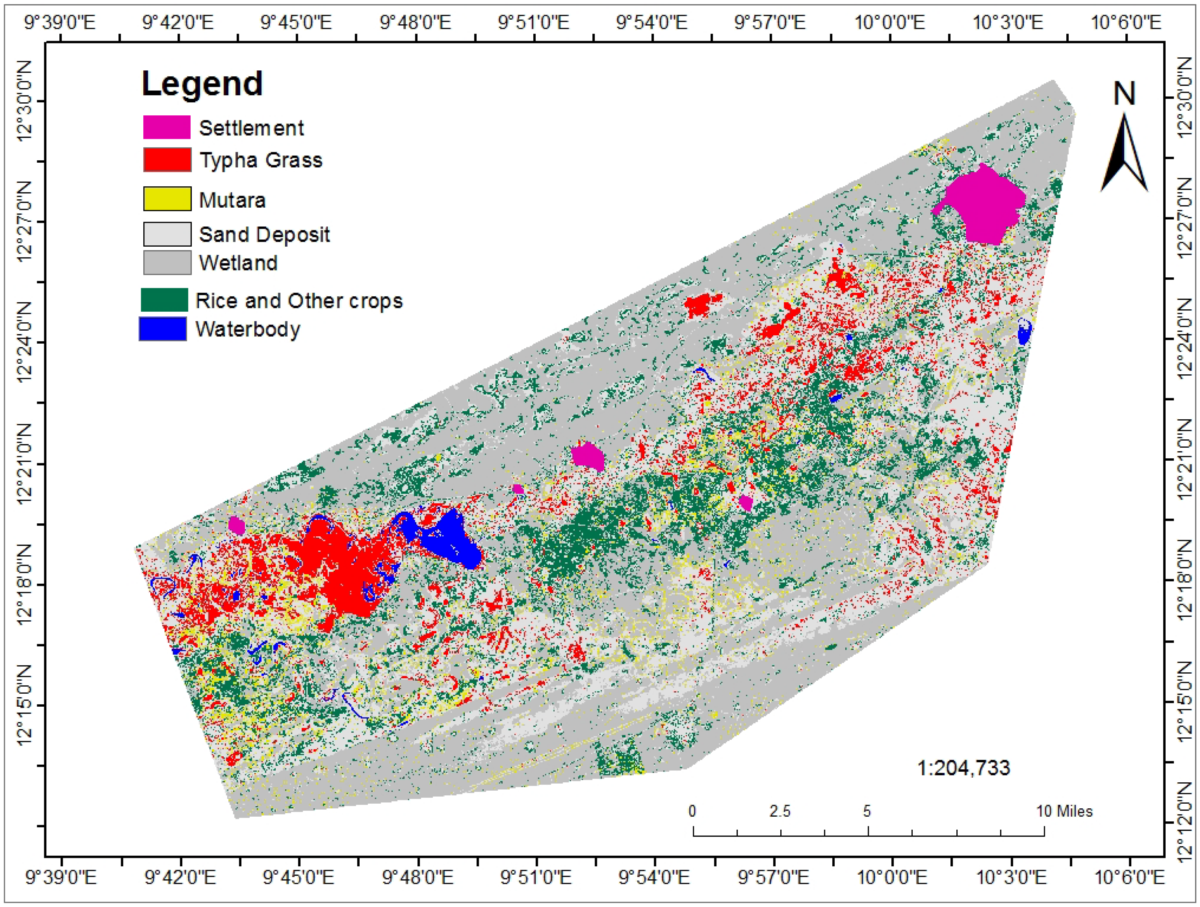

Figure 6. Layout of the HVIS with its classification

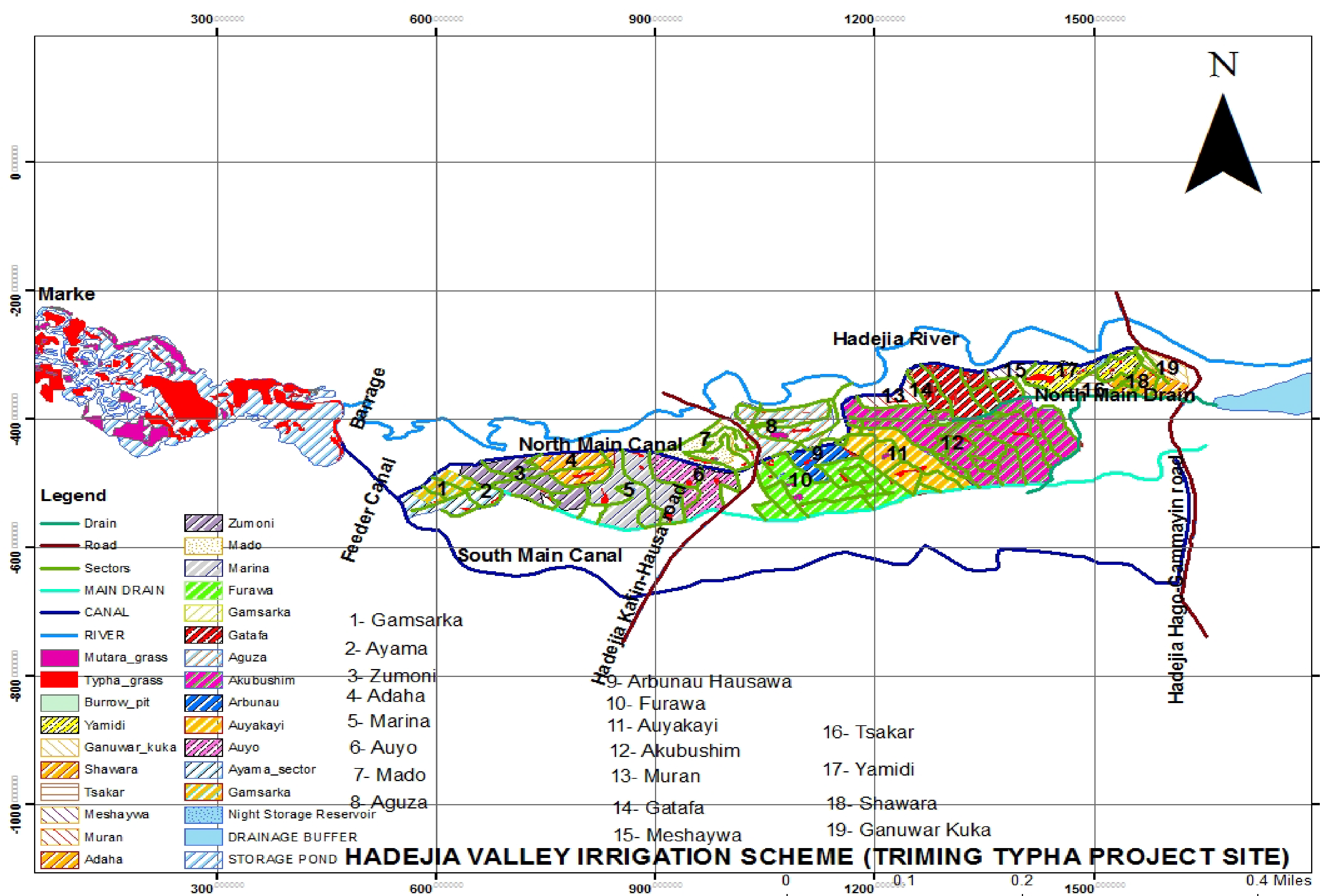
N
Marke
Hadejia River
North Main Drain
North Main Canal
South Main Canal
Barrage
Feeder Canal
Hadejia Katin-Hausa road
Hadejia Hago-Gammayin road
Legend
Drain
Road
Sectors
MAIN DRAIN
CANAL
RIVER
Mutara_grass
Typha_grass
Burrow_pit
Yamidi
Ganuwar_kuka
Shawara
Tsakar
Meshaywa
Muran
Adaha
Zumoni
Mado
Marina
Furawa
Gamsarka
Gatafa
Aguza
Akubushim
Arbunau
Auyakayi
Auyo
Ayama_sector
Gamsarka
Night Storage Reservoir
DRAINAGE BUFFER
STORAGE POND
1- Gamsarka
2- Ayama
3- Zumoni
4- Adaha
5- Marina
6- Auyo
7- Mado
8- Aguza
9- Arbunau Hausawa
10- Furawa
11- Auyakayi
12- Akubushim
13- Muran
14- Gatafa
15- Meshaywa
16- Tsakar
17- Yamidi
18- Shawara
19- Ganuwar Kuka
HADEJIA VALLEY IRRIGATION SCHEME (TRIMING TYPHA PROJECT SITE)
0 0.1 0.2 0.4 Miles

Figure 7: Hadejia Valley Irrigation Scheme indicating Sectors within the research area

Plate 1. A burrow pit dominated by Typha grass

4. Conclusions and Recommendations

4.1 Conclusions

Typha grass has occupied up to 11,336.5 ha area within the study area. Stem and leaves biomass of Typha grass were estimated as 499,939.65 tons and 940,929.5 tons respectively. This can meet up with the requirement of Typha grass needs for both biogas and animal feed production which is the aim of this project. Other grass besides Typha grass that occupied the area was Mutara grass which is similar to Typha grass. Identified reservoirs occupied by Typha grass were Adaha, Ayukaye, Zumoni, Marina and Auyo sectors.

4.2 Recommendations

Communities within HVIS should continue their efforts in maintaining some of the reservoirs that were free of Typha grass infestation.

Efforts should be made by the management of HVIS to ensure that the communities within HVIS stop creating burrow pits in the sectors that allow the growth and development of Typha grass.

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EFFECT OF MUNICIPAL SOLID WASTE LANDFILL LEACHATE ON ENGINEERING PROPERTIES OF TEST SOIL

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Abstract

The paper presents the result of laboratory analysis of the effects of municipal solid waste landfill leachate on the engineering properties of test soil. The soil used for the present study was from Uyo village road. It was sandy loam soil and acidic. The soil was collected at a depth of 0 to 0.9 m away from the waste dumpsite, whereas municipal solid waste landfill leachate was collected from a well dug 10 m away from dumped municipal solid waste and analyzed to identify the pollutants and its effect on engineering properties of the test soil. The test soil applied with municipal solid waste landfill leachate was recovered from 0.25 m and 0.50 m radial distances at a depth of 0.15, 0.30, 0.45 and 0.60 m from the point of application of leachate after 50 days were the application of the leachate end and 80 days from the start of the experiment for laboratory analysis. Engineering properties such as particle size distribution, specific gravity, optimum moisture content, maximum dry density, unconfined compressive strength, liquid limit, plastic limit and shrinkage limit were considered. The concentrations of various chemicals at 0.25 m and 0.50 radial distances and 0.15, 0.30, 0.45 and 0.6 m depth from the point of application of leachate were different. This study found the effect of municipal solid waste landfill leachate on the engineering properties of soil. The type of soil, the composition of leachate, infiltration rate, aquifers, and ground water table will have a major role in the area of influence or influence zone of the pollutants in a landfill.

Keywords: Engineering properties of test soil, landfill leachate, municipal solid waste.

1. Introduction

Municipal solid waste comprises household and commercial wastes. There is a mistaken belief that municipal solid waste is reasonably safe and would not harmfully affect the environment. The most common waste disposal method which is eco-friendlier is landfill. Landfills are often subjected to the generation of leachate. Landfill leachate is generated from liquids existing in the waste as it comes into a landfill or from rainwater that passes through the waste within the facility. Leachate consists of water and water-soluble compounds in the refuse that accumulates, as water moves through the landfill. The contaminants present in the municipal solid waste landfill leachate can be classified as hazardous chemicals, conventional contaminants and non-conventional contaminants. Material cannot be classified as hazardous waste, until a chemical leached from it in concentrations at least 100-times the drinking water standard (40 CFR, 2005). Conventional contaminants include parameters such as total dissolved solids, hardness, alkalinity and presence of chemicals such as chloride, sulfate, iron, manganese and hydrogen sulfide. In addition, this group includes a variety of non-differentiated organics measured as chemical oxygen demand, biochemical oxygen demand, and total organic carbon. Non-conventional contaminants are largely organic chemicals that have not been defined, and whose potential hazards to public health and groundwater quality are not known. It is estimated that on average 95 % of the organic materials in municipal landfill leachate are of unknown composition. Those chemicals have not been identified and their potential impacts on the environment are unknown (Lee and Anne, 1994). The risks of leachate generation can be mitigated by properly designed and engineered landfill sites, such as sites that are constructed on geologically impermeable materials or sites that use impermeable liners made of geomembranes or engineered clay. Landfill liners should properly function so that it prevents leachate from seeping through the bottom and contaminating the groundwater. But in most cases, liners will not function properly and will lead to the spread of leachate to the soil beneath. This may tend to pollute the soil. This research aims at identifying some selected pollutants and their effect on the engineering properties of the test soil.

2. Materials and Methods

2.1 Soil

The soil used in this study was from Uyo village road. It is sandy loam soil and acidic. The soil was collected at a depth of 0 to 0.9 m. Analysis of the upper layers is relevant in understanding soil interactions with other environmental compartments and the pathways of pollutants between them (Miroslav & Vladimir, 1998).

2.2 Municipal Solid Waste leachate

The leachate used in this experiment was collected from the Uyo village road waste dumping site in October 2018. Since the dumpsite was not equipped with a leachate collecting system, the leachate was collected from a well dug 10 m away from the dumped municipal solid. The sample was then transported to the laboratory and kept in the refrigerator at 4 ^{o}C before analysis and use in the study.

2.3 Test Set-up

A rectangular intermediate bulk container (IBC) test tank with length, breadth and height dimensions of 1.12, 0.95 and 0.9 m respectively was used for the experiment. An overhead tank is provided to supply leachate to the soil through a PVC tap system where the rate of flow can be controlled. From the overhead tank, the leachate was supplied through a PVC perforated pipe, from which it percolates to the soil.

2.4 Experimental Procedure

The experiment was conducted in the developed laboratory set-up to study the leaching process. Test soil was air-dried for 28 days and filled in the IBC test tank. The compacted and uncompacted bulk densities of the soils were 13.8 and 12.3 kN/m^3 respectively. At the centre of the tank, above the filled soil, a circular pit of 60 mm diameter and 50 mm depth was prepared. This pit resembles a solid waste dumping place. A circular PVC pipe of 60 mm diameter and 400 mm length was placed at this pit. Perforations were made on the portion of the PVC 50 mm where it is having contact with the soil. Leachate was transferred to the soil through this perforated container. Perforations facilitate the uniform passage of the leachate to the surrounding soil. The entire leachate (4.76 litres, approximately 5 litres) was transferred to the soil from the overhead leachate tank to the perforated PVC pipe at a constant rate to achieve 50% saturation in 50 days (Fig. 1). At the beginning of any tests, uncontaminated water was first allowed through the tank to ensure steady-state conditions before the municipal solid waste leachate was introduced. This allows for the establishment of a proper outflow condition at the port so that a constant velocity is maintained. A discharge velocity of about 1.157 x 10^{-6} l/sec was used in all the experiments. The leachate treated soils were collected from positions corresponding to 0.25 m and 0.50 m radial distances from the point of application of leachate. The samples were collected after 50 days, i.e., the day at which the application of leachate ended, 80 days from the commencement of the experiment (Fig. 1). To collect samples at different depths, a PVC pipe of 14 mm diameter and 0.7 m long was introduced at the centre radial distances to enable the collection of the sample at the required depth. Eight samples were separated corresponding to different depths of 0.15, 0.30, 0.45 and 0.60 m at 0.25 and 0.50 m radial distances as shown in Fig. 1 and analysed for engineering properties.

Fig. 1 Laboratory Test Set-up

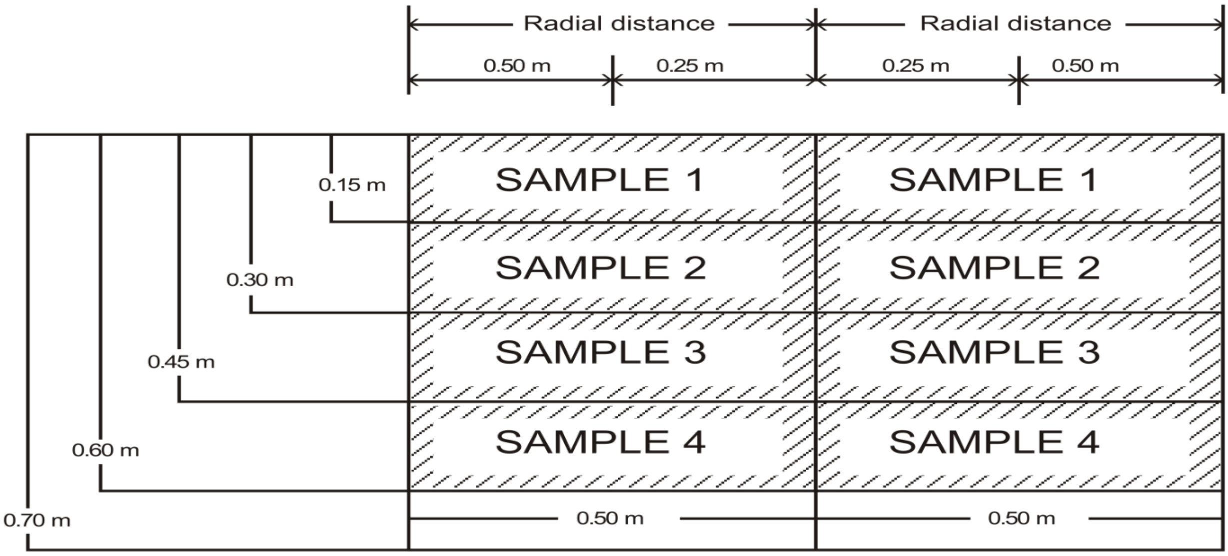

Fig. 2 Samples at Different Depths

2.5 Geotechnical Analysis of Samples

Selected geotechnical engineering properties of the soils were determined in the laboratory in line with the current Bureau of Indian Specifications (IS: SP: 36 (Part 1) 1987). Parameters such as particle size distribution, specific gravity, optimum moisture content, maximum dry density, unconfined compressive strength, liquid limit, plastic limit and shrinkage limit.

3. Results and Discussion

3.1 Selected Physico-chemical and Heavy Metal Properties of Municipal Solid Waste Landfill Leachate

The data about the Physico-chemical and heavy metal properties of municipal solid waste landfill leachate are presented in Table 1.

Table 1. Mean Selected Physico-chemical and Heavy Metal Properties of Municipal Solid Waste Landfill Leachate

Parameters	Leachate

pH	8.51
E.C (μs/cm)	4463
Lead (mg/l)	0.31
Cadmium (mg/l)	0.06
Nickel (mg/l)	0.35
Copper (mg/l)	8.67

3.2 Effect of Municipal Solid Waste Landfill Leachate on Engineering Properties of Test Soil

Tables 2 and 3 show the results of engineering properties of the test soil treated with municipal solid waste landfill leachate for 50 days in an intermediate bulk container (IBC) test tank, recovered from 0.25 and 0.50 m radial distances from the point of application of leachate after 50 days were the application of leachate end and 80 days from the commencement of the experiment. Variation in the engineering properties of the test soil may be due to the influence of the chemical composition of municipal solid waste landfill leachate used for the experiment. In the municipal solid waste landfill leachate is a contaminated liquid emanating from the dumped wastes. In order to generalize the effect of the municipal solid waste on the engineering properties of the test soil, variation of the engineering properties was plotted graphically with respect to depth.

Table 2 Engineering Properties of Test Soil after 50 Days

	0.25 m Radial Distance				**0.50m Radial Distance**				**Control**
Depth (m)	0.15	0.30	0.45	0.60	0.15	0.30	0.45	0.60	
Clay (%)	10.8	12.8	12.8	12.8	10.5	10.8	10.8	12.8	10.0
Silt (%)	3.4	1.4	1.4	1.4	5.4	3.4	3.4	1.4	5.4
Specific gravity	2.4	2.6	2.8	2.8	2.5	2.7	2.7	2.9	3.2
Optimum moisture content	16	19	20	27	12	16	18	18	10
Maximum dry density	1.50	1.44	1.47	1.48	1.45	1.45	1.48	1.48	1.63
Unconfined compressive strength	110	111	114	118	108	115	118	119	101
Liquid limit	35	36	38	39	34	35	39	30	32
Plastic limit	15	15	14	14	14	15	16	15	13
shrinkage	20	22	21	20	19	20	20	22	17

Table 3 Engineering Properties of Test Soil after 80 Days

	0.25 m Radial Distance				**0.50m Radial Distance**				**Control**
Depth (m)	0.15	0.30	0.45	0.60	0.15	0.30	0.45	0.60	

Clay (%)	6	5	7	6	5	6	7	7	10.0
Silt (%)	13.8	13	9	13	12	11.5	9.2	10	5.4
Specific gravity	2.10	2.30	2.40	2.70	2.40	2.60	2.70	2.90	3.2
Optimum moisture content	10	14	16	20	15	16	16	19	10
Maximum dry density	1.62	1.51	1.54	1.50	1.57	1.54	1.56	1.59	1.63
Unconfined compressive strength	128	135	140	160	129	130	145	150	101
Liquid limit	30	35	34	33	32	37	39	31	32
Plastic limit	12	17	16	15	14	17	18	15	13
shrinkage	19	24	18	20	17	20	21	23	17

3.1.1 Particle Size Distribution

The results of the particle size distribution of test soil treated with municipal solid waste landfill leachate, recovered from 0.25 and 0.50 m radial distances and 0.15, 0.30, 0.45 and 0.60 m depth away from the point of application of leachate after 50 and 80 days with the control soil are present in Fig. 3. The figure shows that the treated test soil has more percentage of clay than untreated control soil at 50 days. As the maturity period increases (that is, after 80 days), the percentage of clay decreases.

For silt particles, the test soil has a lower percentage of silt at 50 days except at 0.15 m depth and at a 0.5m radial distance that recorded 5.4 % same as the untreated control soil. As the maturity period increases, which is 80 days, the percentage finer increases corresponding to silt particles.

The results of this study show that the clay particles increased due to the influence of chemical composition in the municipal solid waste landfill leachate. Variation in the particle size of the soil can be described by chemical weathering. Chemical weathering is the transformation of primary minerals into secondary materials. Secondary materials function as the basic building blocks of the small particles in the soil. As a result, new materials may be synthesized.

According to Mitchell (2005), clay grain content in heavily polluted soil samples is higher than that of light-polluted soil. When a soil mass is influenced by pollutants, the colloids in the soil, such as organic and inorganic composite colloids and soluble salts, get dissolved and it results in the weakening of the strong link between soil grains. Thus most of the soil grains will disperse easily and clay grain content will get increased in heavily polluted soil (Jia et al. 2009).

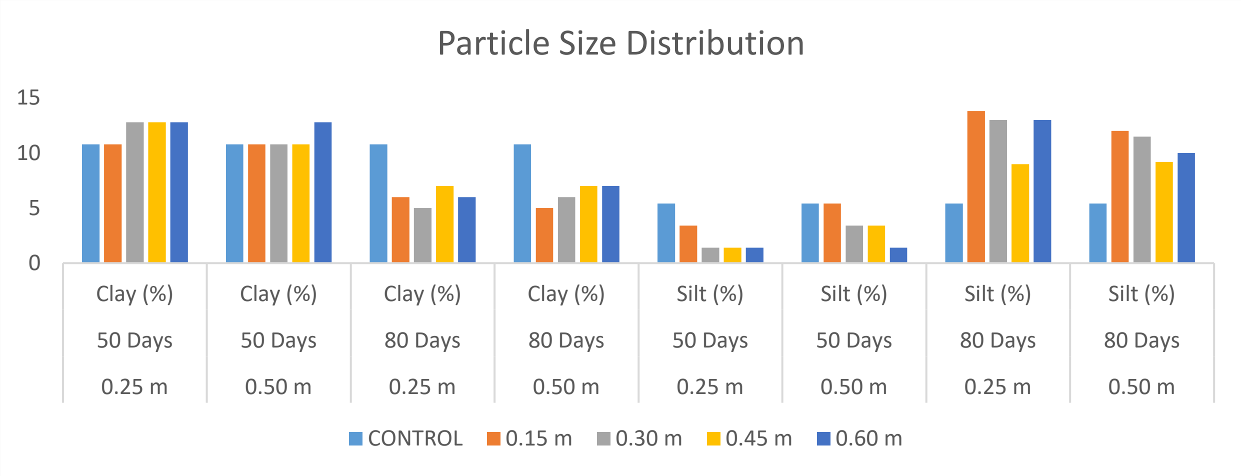

Fig. 3 Variation of Particle Size Distribution of Test Soil after 50 and 80 Days with Depth

3.1.2 Specific Gravity

The result of the specific gravity of test soil treated with municipal solid waste landfill leachate along with control soil is presented in fig. 4. The results show that the difference between the values of the specific gravity of the test soil at corresponding depths after 50 days was slightly higher compared to those after 80 days at corresponding depths. The values of the specific gravity of the treated test soils were generally lower than those obtained for the uncontaminated soil.

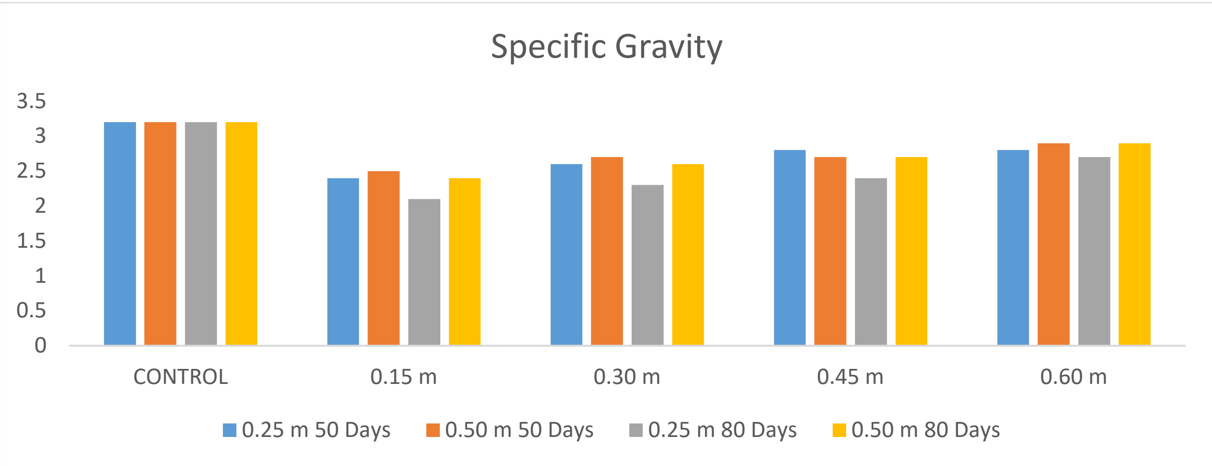

Fig. 4 Variation of Specific Gravity of Test Soil after 50 and 80 Days with Depth

3.1.3 Compaction Characteristics

Results of the compaction characteristics of treated test soil are presented in Figures 5 and 6. The results show variation in Maximum Dry Density (MDD) of treated test soil recovered from 0.25 and 0.5m radial distances at different depths (that is, 0.15, 0.3, 0.45 and 0.6 m). They were lower than that of untreated control soil. Optimum Moisture Content (OMC) was observed to increase with the increase in depth over that of untreated control soil. This result conforms with the results of the particle size distribution, which indicates greater percentages of fine fractions in the treated test soil. Since fine particles within soil have more affinity for water, and from the classical theory of soil mechanics, the higher the OMC, the lower the MDD.

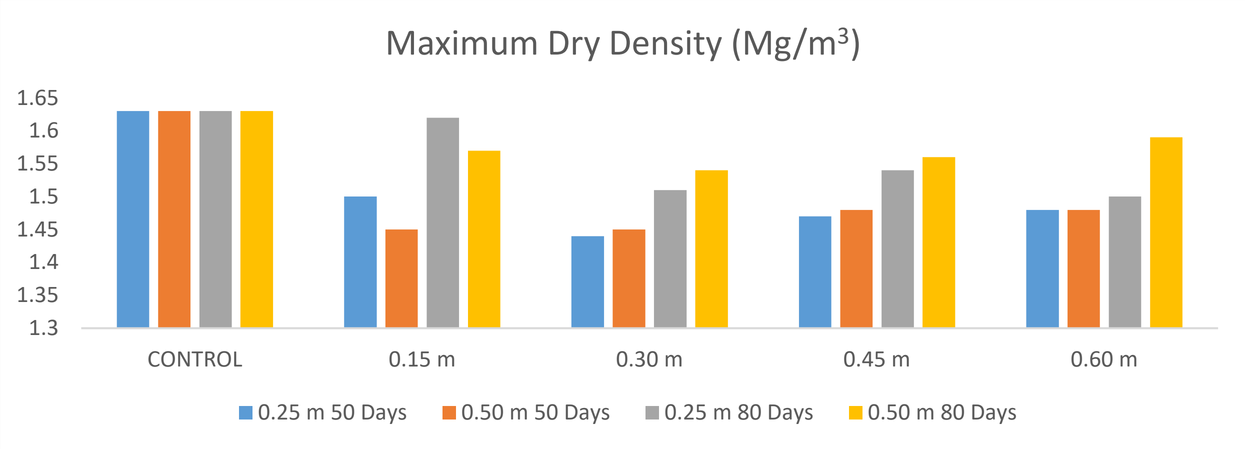

Fig. 5 Variation of Maximum Dry Density of Test Soil after 50 and 80 Days with Depth

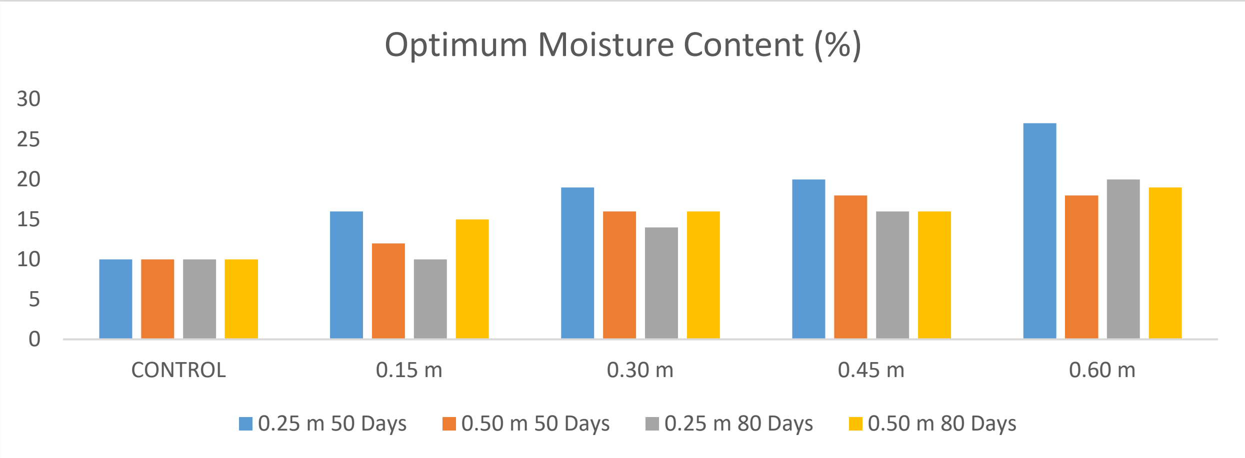

Fig. 6 Variation of Optimum Moisture Content of Test Soil after 50 and 80 Days with Depth

3.1.4 Unconfined Compressive Strength

Unconfined compressive strength of treated test soil was observed to be increased due to an increase in depth of treated test soil. It shows a slightly increasing trend towards maturity period, that is, after 80 days. An increase in unconfined compressive strength of treated test soil with an increase in depth may be attributed to the change in the thickness of the diffuse double layer.

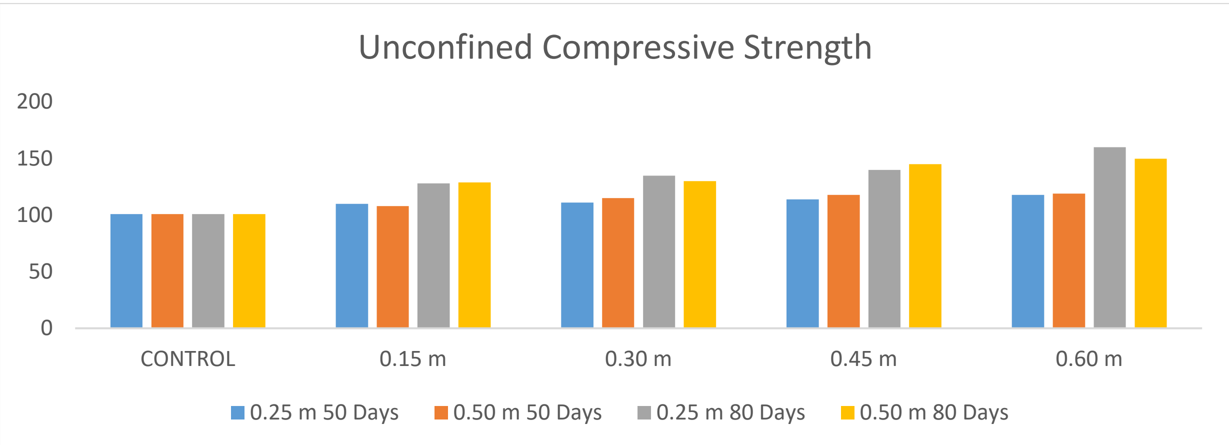

Fig. 7 Variation of Unconfined Compressive Strength of Test Soil after 50 and 80 Days with Depth

3.1.5 Atterberg Limits

Figures 8, 9 and 10 show the variation in Atterberg limits of test soil as the municipal solid waste landfill leachate and contact period changes. Municipal solid waste landfill causes an increase in liquid limit on treated test soil with an increase in depth after 50 days. As the maturity period increases, the liquid limit decreases. Thus it is proved that municipal solid waste landfill leachate as well as maturity period has a major influence on the liquid limit of treated test soil, showing a slight increase with low concentration and ageing and gradually reduces below that of untreated control soil.

The plastic limit of test soil is observed to vary with an increase in depth and radial distances after 50 and 80 days.

Fig. 10 shows that the application of municipal solid waste landfill to the treated test soil causes variation in shrinkage limit. No significant change is shown as ageing increases.

Variation in Atterberg limits may be attributed to the change like pore water fluid. The acidic nature of municipal solid waste landfill leachate in the pores media tends to disintegrate the soil particles and cause an increase in a specific area of soil.

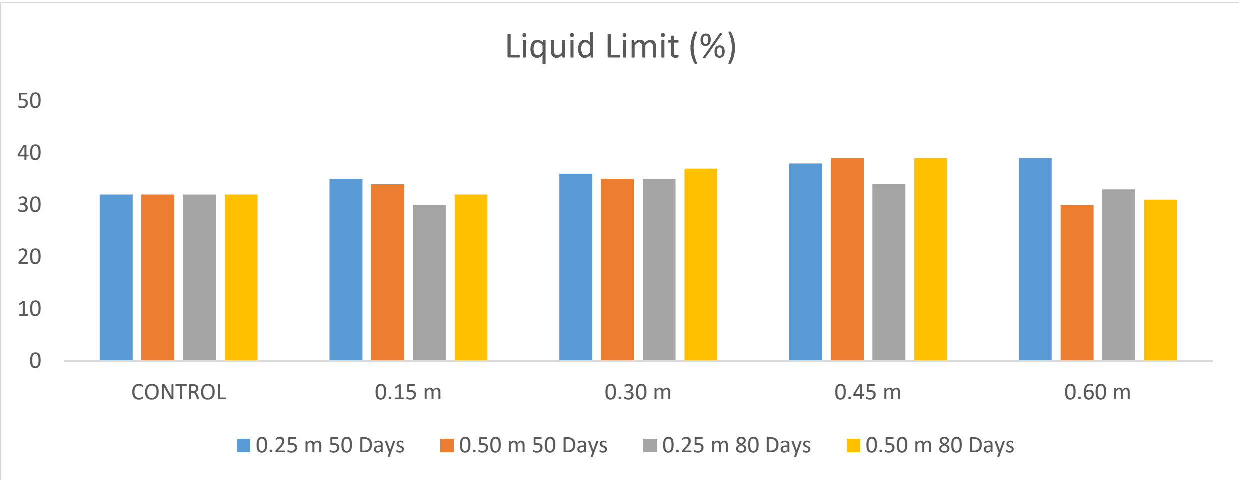

Fig. 8 Variation of Liquid Limit of Test Soil after 50 and 80 Days with Depth

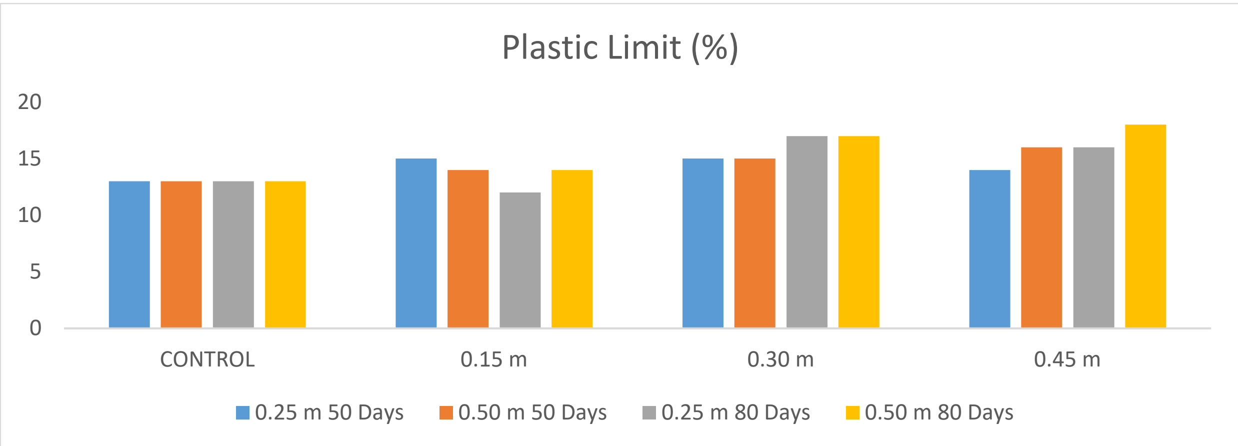

Fig. 9 Variation of Plastic Limit of Test Soil after 50 and 80 Days with Depth

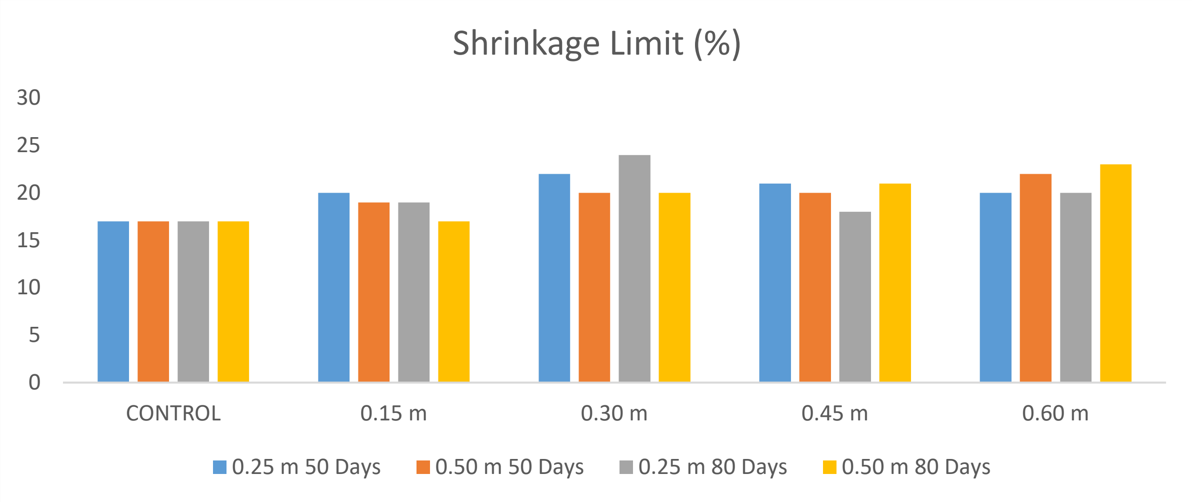

Fig. 10 Variations of Shrinkage Limit of Test Soil after 50 and 80 Days with Depth

4. Conclusion

The research aimed to identify some selected pollutants and their effect on the engineering properties of test soil. Based on the results of the study, the following conclusions can be drawn:

The municipal solid waste landfill leachate is following a point source or leaky pattern of flow through a uniformly dense, single soil layer. From the literature, it has been reported that soil type, number of layers, variation in density, presence of cracks and fissures, the direction of groundwater flow etc., will have a major role in the flow direction and pattern of leachate through the soil. Since the site conditions of each landfill are different, the flow pattern of leachate through the landfill cannot be generalized.

The composition of municipal solid waste landfill leachate varies from landfill to landfill. The adsorption property of soil, mobility and solubility of chemicals etc., will influence the retention of the chemicals in soil.

It is also proved that the composition of municipal solid waste landfill leachate has a major influence on the engineering properties of soil. The chemical composition of the leachate may cause disintegration of soil grains and this may cause a reduction in specific gravity and changes in Atterberg limits, as well as flocculation of soil grains.

Percolation of leachate was the only source of water in the test soil during the test period. After stopping the leachate application, a considerable change in chemical concentration was not observed. This proves that the chance for the mobility of chemicals through the soil without pore water flow is less.

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SOIL MOISTURE DYNAMICS IN NIGERIAN AGRICULTURAL SOILS: A REVIEW

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Abstract

Soil moisture is important for crop cultivation and its adequacy to meet crop-water requirements is determined by the degree of soil management practiced and the quantity of water applied to the soil. An understanding of soil moisture dynamics can provide land managers with critical information to increase productivity and better implement conservation practices. The objective of the studies was to review soil moisture dynamics in Nigerian agricultural soil thereby accessing factors that influence soil moisture dynamics such as vegetative cover, topographic position, soil properties, and precipitation among others. It was also discovered in the course of the studies that Land cover has been recognized as a key factor controlling patterns of soil moisture by influencing infiltration rates, runoff, and evapotranspiration. It is imperative to note that water content across different water potentials in the soil is determined by three moisture states; saturation, field capacity and permanent wilting point. The paper also briefly reviews some aspects of the soil water balance, highlighting the possible connections and feedbacks among the various processes as well as pointing out the manifold repercussions of soil moisture dynamics on vegetation response and biogeochemical cycles.

Keywords: *crop-water; infiltration rate; rooting zone; soil compaction; soil management; soil moisture dynamics, soil water potential*

Introduction

Maintenance and improvement of soil quality are critical for sustaining agricultural productivity (Fourie *et al*., 2007). Soil is a valuable resource, which must be managed in a way that can maintain its resilience in the face of climate change. It is an elementary fact that economic activity is dependent on the goods and services supplied by the natural environment" (Ekins, 2011). To ensure continued economic prosperity and production, agriculture must contend with the fact that our natural environment is changing. An understanding of soil moisture dynamics can provide land managers with critical information to increase productivity and better implement conservation practices. Land cover has been recognized as an important factor in controlling patterns of soil moisture by influencing infiltration rates, runoff, and evapotranspiration (Cubera *et al.,* 2004). The variability of biomass under different land covers and its influence on rainfall interception is of particular importance (Brooks *et al.*, 2003; Chang, 2006). Above and below-ground organic matter increases infiltration rate and soil moisture-holding capacity, reducing surface runoff and decreasing water yield in vegetated areas (Chang, 2006).

Soil moisture dynamics are the outcome of complex and highly interconnected processes. Some of the factors influencing these processes are vegetative cover, topographic, soil properties, and precipitation among others. Soil moisture varies among ecosystems, with time, depth and crop growing season (Isham *et al.* 2005; Zhang and Schilling, 2006; Tamea *et al.* 2009). Vegetative cover, in particular, plays an important role in the regional and local hydrologic balance (Cubera *et al.* 2004). Furthermore, different changes in vegetative cover due to land use can have varying effects on the magnitude and direction of water movement. Characteristics inherent to each species, such as rooting distribution and depth, photosynthetic pathway, aerial biomass, phenology, etc., all dictate their influence on the hydrological balance (Cubera *et al.,* 2004). The capacity of soil to regulate the terrestrial freshwater supply is a fundamental ecosystem service. Water percolating through soil is filtered, stored for plant utilization, and redistributed across flow paths to groundwater and surface water bodies. As such, the sustainability of water resources (considering both quantity and quality) is directly influenced by soil (O'Geen *et al*., 2010). Water dynamics in soil are governed by many factors that change vertically with depth, laterally across landforms and temporally in response to climate (Swarowsky, *et al.*, 2011)

Soil Moisture Dynamics

Despite being the major driver of plant productivity, soil moisture is subjected to the influence of factors that underline its dynamics within an ecosystem. Soil moisture dynamics are thus the outcome of complex and interconnected processes. Some of the factors influencing these processes are vegetative cover, soil characteristics, topographic position and precipitation (Zhang and Schilling, 2006; Liu and Zhang, 2007; Wang *et al.*, 2008; Kumagai *et al.*, 2009; Qi and Helmers, 2010). Understanding how these factors influence the hydrological balance of the ecosystem and the degree to which each impacts this balance is imperative for the health of the ecosystems. More importantly, understanding the degree of influence of these factors under a given configuration of mixed annual-perennial vegetation, may allow researchers and scientists to make better decisions for conservation and productivity purposes.

Land Cover

Land cover has been recognized as a key factor controlling patterns of soil moisture by influencing infiltration rates, runoff, and evapotranspiration (Cubera *et al.*, 2004). Different land covers have varying degrees of above and below-ground biomass production (Chang, 2006). Above-ground biomass determines the amount of precipitation water that is intercepted and thus the amount that reaches the ground (Brooks *et al*., 2003; Chang, 2006). Vegetation also deposits organic matter on the soil surface and below ground through root growth, which enhances infiltration rate and soil moisture-holding capacity, making surface runoff smaller, runoff timing longer, and water yield lower in vegetated areas than those in non-covered ones (Chang, 2006). In the Midwest of the United States, two vegetative covers have historical significance; native prairie vegetation and crops (e.g. corn and soybean). These two land covers have contrasting effects on the hydrological balance due to their inherent differences in water use and uptake patterns and plant phenology.

Topographic Position

Water moves in a watershed obeying the laws of gravity, capillarity and suction primarily (Brooks *et al.*, 2003; Hillel, 2004). immediately after infiltration, as water penetrates the soil profile and the length of the wetted part of the profile increases, the suction gradient decreases, since the difference in pressure head divides itself over an ever-increasing distance. As this trend continues, the suction gradient of the upper part of the soil profile becomes negligible, leaving the gravitational head gradient as the only force to move the water downward (Hillel, 2004). This gravitational gradient tends to move water from the upper parts of the watershed (i.e. recharge areas) toward lower parts (i.e. discharge areas). In these recharge areas, due to the effects of the gravitational gradient, there is often a rather deep unsaturated zone between the water table and the land surface. Conversely, the water table is found either close to or at the land surface in discharge areas (Fetter, 2001).

Precipitation

Precipitation has a direct effect on soil moisture. Once net precipitation reaches the ground, it moves into the soil, forms puddles on the soil surface or flows over the soil surface, depending on preceding soil moisture content. The precipitation that enters the soil and is not retained by it, moves either downwards to groundwater or laterally to a stream channel (Brooks *et al*., 2003). As water moves into the soil profile, it influences directly soil moisture content before leaving the system through evaporation, plant water uptake or simply moving towards the lower parts of the watersheds due to the influence of gravity (Brooks *et al*., 2003) The rate at which net precipitation enters the soil surface depends on several soil properties as well as on soil surface conditions such as plant material or litre near the soil surface (Brooks *et al.*, 2003). However, the intensity of precipitation and the antecedent soil moisture are two important factors that control the effect of a precipitation event on the soil.

Infiltration Rates

Infiltration is the movement of water into the immediate soil surface. It is an important component in watershed modelling for the prediction of surface runoff. For a given soil, the land use pattern plays a vital role in determining the infiltration characteristic and is of particular interest to soil scientists, hydrologists, agronomists, geographers and agricultural engineers (Suresh, 2008). The two essential parameters used in characterizing infiltration of water into soil profile are the rate and the cumulative amount (Suresh, 2008). Measurement and numerical solutions have shown that the infiltration rate in a uniform, initially dry soil when rainfall does not limit infiltration, decreases with time and approaches an asymptotic minimum rate (Saiko and Zonn, 2003). Available data in the literature showed that there are variations in the infiltration rates of tropical soils. According to Antigha and Essien (2007), these variations are due to high rainfall, land use type, and the influence of vegetation. Observably, the dynamics of soil characteristics concerning this changing infiltration rate may act in different proportions as either assets or constraints to the quality of land resources. The knowledge of infiltration characteristics is important in flood modelling, artificial recharge of the aquifer, mass transport through the subsurface, performance evaluation of landfill covers etc (Chow, 1988).

Infiltration is the process by which water on the soil surface penetrates the soil. It also refers to the vertical movement of water downwards from the soil surface to replenish the soil water/moisture deficiency, with excess percolating down to build up the water table by gravitational flow (Diamond, 2004; Marshal, 2002; Shanley, 2004). It also carries with it some amounts of nutrients to replenish the soil (Rattan, *et al.,* 2005), (Chhonkar, *et al.,* 2005). It is related to overland flow, determining the fraction of irrigation or rainwater that enters the soil to become groundwater and thus, affecting the amount of runoff responsible for subsequent soil erosion (Lie *et al.*, 1988). Infiltration rate is the volume flux of water flowing into the soil profile per unit area of the soil surface (Hillel, 1980). It is the rate at which infiltration occurs. It is usually measured by the depth in mm/hr, mm/min, cm/min, or cm/hr. Therefore, an infiltration rate of 25mm/hr means that a water layer of 25mm on the soil surface will take one hour to infiltrate. Cumulative infiltration and soil infiltration rate are related by equation (1) below;

$$I = {di}/{dt} \quad (1)$$

where I = Infiltration rate, t = Time; i = Cumulative Infiltration

Quantifying the soil infiltrability is of great importance to understanding and describing the hydrologic analysis and modelling, irrigation design and many natural and man-made processes (Lili, *et al* (2008). It is also used in the determination of saturated hydraulic conductivity of soil layers, groundwater recharge and a wide spectrum of water resource management and conservation problems (Deidda, 2002).

In an infiltration event, the high initial soil infiltrability, which is determined by the matrix potential gradient at the soil surface decreases rapidly with time. The rate of decrease slows down exponentially as the infiltration rate gradually reaches a steady-state (finally infiltration rate). The steady infiltration rate is equal to the saturated hydraulic conductivity of the soil (Harden & Scruggs, 2003). The process of soil infiltration is based on the theories/forces of gravity, capillarity, and adsorption, and is generally controlled by Darcy's law which states that the discharge rate q is proportional to the gradient in hydraulic head and hydraulic conductivity, as represented in equation (2) below;

$$q = {Q}/{A} = -K\frac{dh}{dl} \quad (2)$$

where K is the hydraulic conductivity, ${dh}/{dl}$ is the hydraulic gradient, and ${Q}/{A}$ is the specific discharge

Infiltration of rainfall into pervious surfaces is controlled by three mechanisms, the maximum possible rate of entry of the water through the soil/plant surface, the rate of movement of the water through the vadose (unsaturated) zone, and the rate of drainage from the vadose zone into the saturated zone. During periods of excess rainfall, long-term infiltration is the least of these three rates, and the runoff rate after depression storage is filled is the excess of the rainfall intensity greater than the infiltration rate (Wilcox et al. (2007). The infiltration rate typically decreases during periods of rainfall excess. Storage capacity is recovered when the drainage from the vadose zone is faster than the infiltration rate. The surface entry rate of water may be affected by the presence of a thin layer of silts and clay particles at the surface of the soil and vegetation. These particles may cause a surface seal that would decrease a normally high infiltration rate (Wilding, 2007). The movement of water through the soil depends on the characteristics of the underlying soil. Once the surface soil layer is saturated, water cannot enter the soil faster than it is being transmitted away, so this transmission rate affects the infiltration rate during the longer event (Wilding, 2007). The depletion of available storage capacity in the soil affects the transmission and drainage rates. The storage capacity of soils depends on the soil thickness, porosity, and soil-water content. Many factors, such as soil texture, root development, soil insect and animal boreholes, structure, and presence of organic matter, affect the effective porosity of the soil.

The infiltration of water into the surface soil is responsible for the largest abstraction (loss) of rainwater in natural areas. The infiltration capacity of most soils allows low-intensity rainfall to infiltrate unless the soil voids became saturated or the underlain soil was much more compact than the top layer (Morel-Seytoux 1978). High-intensity rainfalls generate substantial runoff because the infiltration capacity at the upper soil surface is surpassed, even though the underlain soil might still be very dry.

Factors affecting infiltration

The infiltration process appears to be very simple. However, it is influenced by various factors. Some of the factors influencing the soil infiltration include

Soil organic matter content
Soil compaction
Permeability of the soil
Soil capillarity
Porosity
Vegetation
Initial moisture content,
Surface sealing and crushing
Rainfall rates
Soil texture and structure

Zones of Infiltration

The distribution of water during the process of infiltration under the ponded conditions is categorized into five zones as illustrated in Figure 1 below:

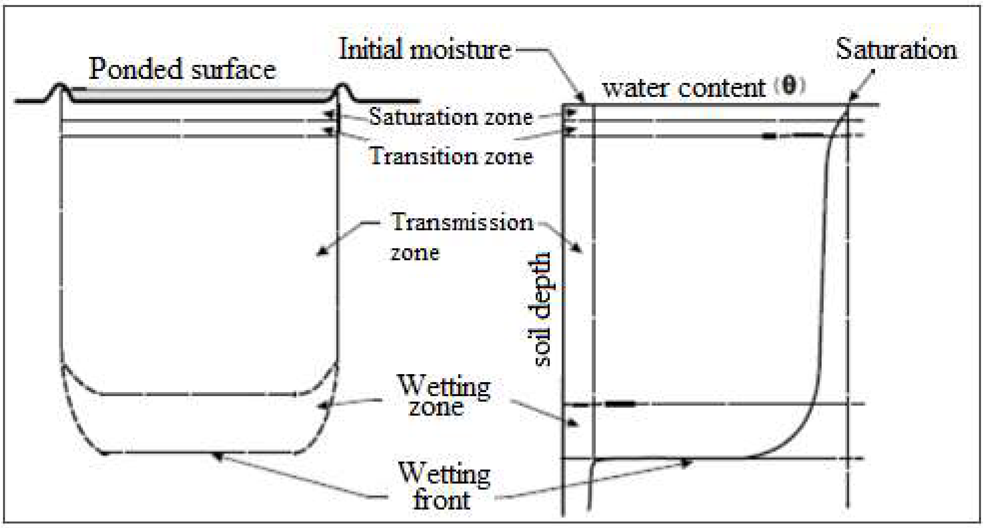

Fig. 1: Zones of Infiltration (Source: Hillel, 1982)

Saturated zone: The pore space in the saturated zone is filled with water, or is saturated and is just below the surface. Depending on the length of time elapsed from the initial application of the water; it extends generally only to a depth of about 0-15 cm

Transition zone: This zone is characterized by a rapid decrease in water content with depth, and will extend approximately between 15 -30 cm

Transmission zone: The transmission zone is characterized by a small change in water content with depth. In general, the transmission zone is a lengthening unsaturated zone with uniform higher water content. The hydraulic gradient in this zone is primarily driven by gravitational forces.

Wetting zone: The water content in this zone sharply declines with depth from the water content of the transmission zone to near the initial soil water content.

Wetting front: This zone is characterized by a steep hydraulic gradient and forms a severe boundary between the wet and dry soil. The hydraulic gradient is primarily driven by matrix potentials. Beyond the wetting front, there is no noticeable water penetration. (USDA Natural Resources Conservation Service;1998)

6.3 Methods of Infiltration Measurement

Numerous methods have been developed for measuring infiltration rates of soils in the field. These methods may be classified into three groups; Instrumental Methods, Hydrograph Methods and Other Methods.

6.3.1 Instrumental method

In the instrumental method, cylindrical infiltrometer also called flooding infiltrometer are used for the determination of infiltration by the constant head method or by the variable head method. For this method single ring or double ring infiltrometer may be used. In a flooding infiltrometer, the infiltration rate is calculated from the drop in water level per unit time or the amount of water required to maintain the specified depth or head of water per unit time and the maximum rate of entry of water into the soil is measured (USDA;1998).

A single ring infiltrometer in its simplest form consists of only one cylinder with which infiltration is measured by pouring the water into the cylinder and measuring the quantity of water added for the particular time interval by maintaining the constant head. As the name suggests single ring infiltrometer consists of a single ring having a diameter of 30 cm and a depth of about 25 cm. In this infiltrometer lateral movement of water is not restricted therefore it shows large variations in infiltration rates. The operator records how much water goes into the soil for a given period and the rate at which water goes into the soil is related to the soil's hydraulic conductivity (American Society Testing Materials (ASTM), 2003).

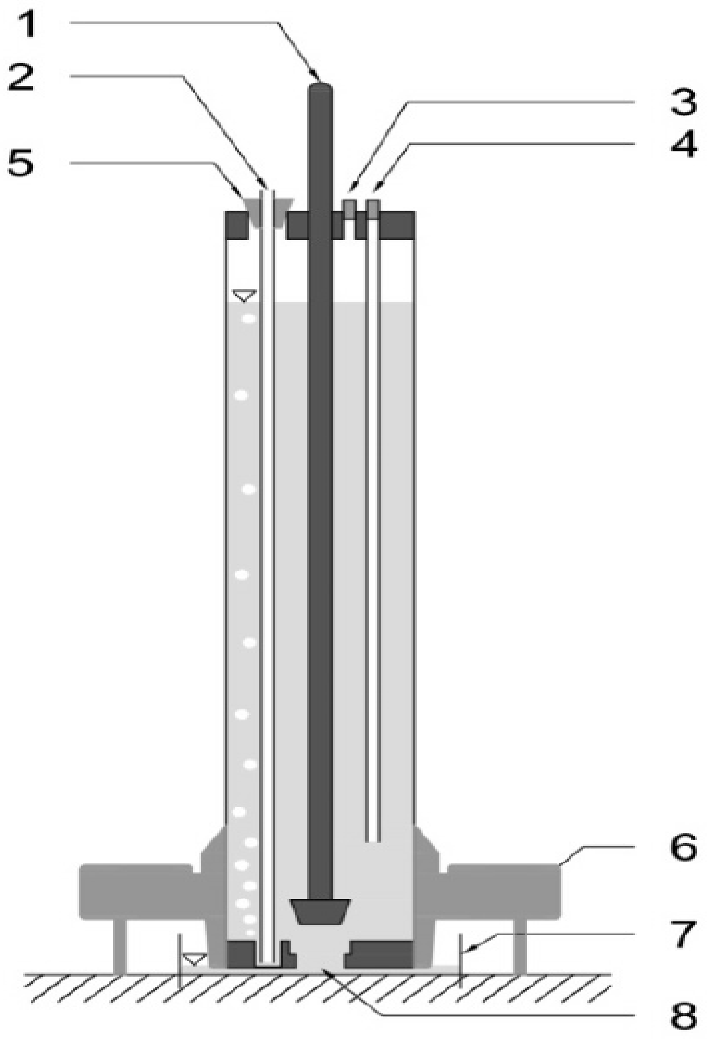

Figure 2: Schematic diagram of a single-ring infiltrator. Source: (Prima, 2015)

where, (1) piston; (2) air entry tube; (3) connector for vacuum side of the pressure sensor; (4) connector for pressure side of the pressure sensor; (5) rubber; (6) tripod; (7) water containment ring and (8) outlet

In double-ring infiltrator requires two rings: an inner and outer ring. The purpose is to create a one-dimensional flow of water from the inner ring, as the analysis of data is simplified. If water is flowing in one dimension at steady-state conditions, and a unit gradient is present in the underlying soil, the infiltration rate is approximately equal to the saturated hydraulic conductivity. It is done by driving the inner ring into the ground, and a second bring bigger ring around is to help control the flow of water through the first ring. Water is supplied either with a constant or falling head condition, and the operator records how much water infiltrates from the inner ring into the soil over a given period (ASTM, 2013).

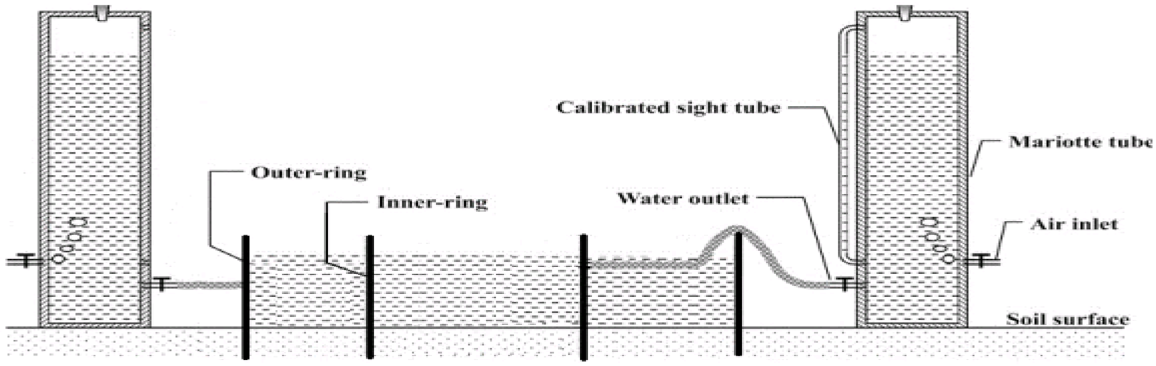

Figure 3: Schematic diagram of a single-ring infiltrator. Source: (Milad, 2015)

6.3.1.1 Limitations of infiltrometer

The ring infiltrometer are having certain limitations such as infiltration rate decreases with an increase in depth and diameter of infiltration rings. The rate of infiltrometer increases as the head of water increases in constant head and cannot be used on a sloping soil surface. Also, ring infiltrometers cannot reliably characterize infiltration of furrow irrigation, sprinkler irrigation, or rainfall and with single ring infiltrometers, water spreads laterally as well as vertically and the analysis is more difficult (Gregory *et al*., 2005).

6.3.2 Hydrograph method

Infiltration rate curves can be obtained for field plots and watersheds through the analysis of runoff hydrograph. In the hydrograph methods, the infiltration rate is determined from the record of the rainfall and runoff from the catchments area, neglecting evaporation. Also, total volumes of infiltration and various other losses from a given recorded rainfall can be obtained from a discharge hydrograph. From the total discharge hydrograph, the base flow is separated by using any method of baseflow separation. When base flow is separated the discharge hydrograph results in direct runoff hydrograph (DRH) and this will account for the direct surface runoff. Direct surface runoff also called excess rainfall in terms of inches uniformly distributed over a watershed can readily be calculated by picking values of direct runoff hydrograph discharge ordinates at equal time intervals from the hydrograph and using the following relationship in equation (3) below;

$$P_e = \frac{(0.03719)(\varepsilon_{q_i})}{An_d} \qquad (3)$$

where, P_e is the precipitation excess (in), q_i are the DRH ordinates at equal time intervals cfs), A is the drainage area (mi^2), n_d is the number of intervals in a 24- hr period.

Storage of Water in the Soil

Stored water in the soil is a dynamic property that changes spatially in response to climate, topography and soil properties, and temporally as a result of differences between utilization and redistribution via subsurface flow (Western *et al.* 1999). Changes in soil moisture storage can be generalized with a mass balance equation (4) as a result of the difference between the amount of water added and that which is lost (Hillel 1982).

Knowledge of the behaviour of soil water storage (SWS) and its distribution provides important information on various general circulation models, evapotranspiration and runoff, precipitation and atmospheric variability (Koster *et al*., 2004.). Several factors contribute to the variability in the distribution of SWS in space and time, and the scaling heterogeneity of factors makes the SWS variations highly scale-dependent (Quinn, 2004; Zhao *et al*., 2013; Biswas, 2014.). For instance, how soil type, tree cover, and micro-landform influence SWS have been studied, and the results show that soil properties exert a stronger influence than vegetation on SWS dynamics and fluxes, at both the plot and catchment scale (Ferreira *et al*., 2007; Geris *et al*., 2015). Other studies indicated that topography, parent material, climate and vegetation influenced the distribution of SWS within a field (Biswas, 2014; Grayson and Western, 1998). However, at large scales, such studies have proven to be very challenging due to many factors, such as human activities, geologic variability, and costly sampling (Schneider *et al*., 2008; Entin, *et al*., 2000). Most studies on SWS at large scales did not systematically consider the changes in SWS (i.e., soil water storage replenishment) influenced by vegetation and the environment, especially during the growing season.

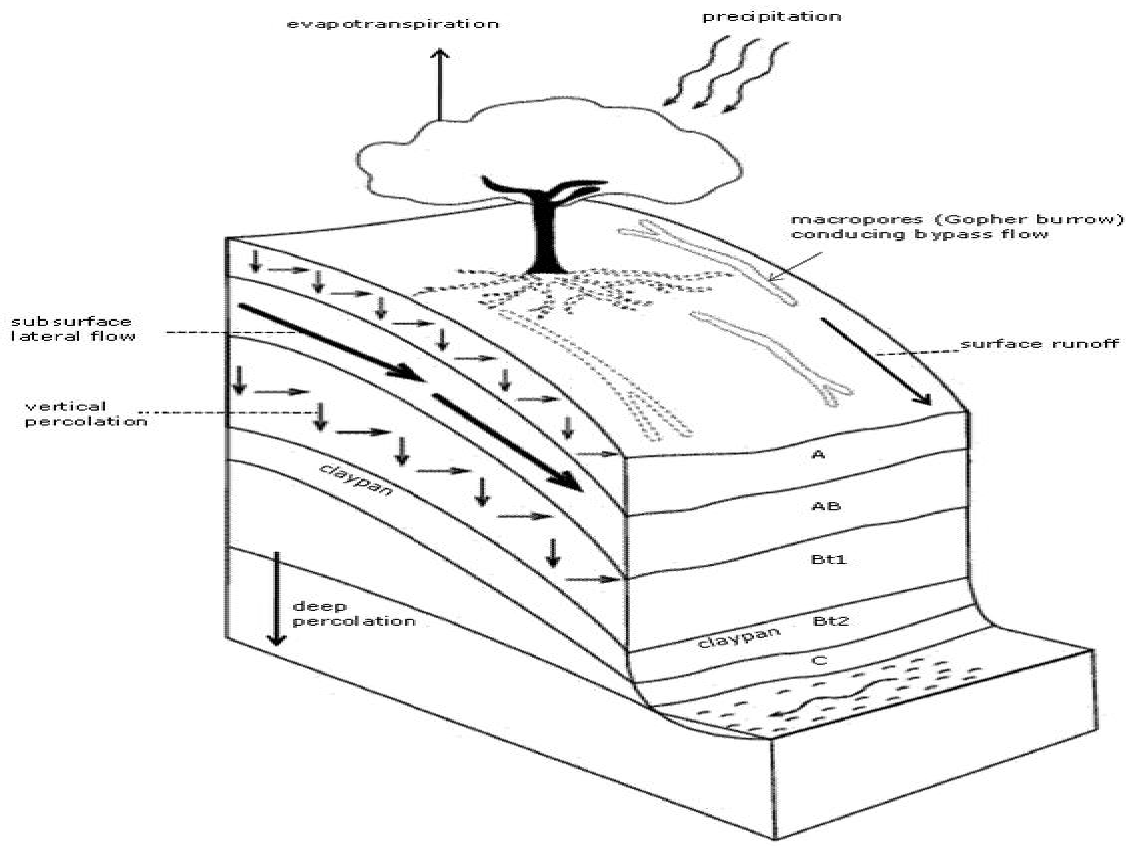

Figure 4: Conceptual diagram of a soil profile illustrating the multiple flow paths through which water moves through soil (Modified from O'Geen et al., 2010)

Change in soil moisture storage = inputs – outputs (4)

Water content increases (positive change in storage) when inputs including precipitation or irrigation exceed outputs. Water content decreases (negative change in storage) when outputs such as deep percolation, surface runoff, subsurface lateral flow, and evapotranspiration (ET) exceed inputs as stated in equation 1.

Water storage and redistribution are a function of soil pore space and pore-size distribution, which are governed by texture and structure (O'Geen *et al*., 2010). Generally speaking, clay-rich soils have the largest pore space, hence the greatest total water holding capacity. However, total water holding capacity does not describe how much water is available to plants, or how freely water drains into the soil. These processes are governed by potential energy.

Energy Potential of the Soil

Water is stored and redistributed within the soil in response to differences in potential energy. A potential energy gradient dictates soil moisture redistribution and losses, where water moves from areas of high- to low-potential energy (Hillel 1982). When at or near saturation, soils typically display water potentials near 0 MPa. Negative water potentials arise as the soil dries resulting in suction or tension on the water allowing the soil to retain water like a sponge.

Three soil moisture states, saturation, field capacity and permanent wilting point are used to describe water content across different water potentials in soil and are related to the energy required to move water (or extract water from the soil). When the soil is at or near saturation the direction of the potential energy gradient is downward through the soil profile or laterally downslope. This mechanism of flow by the force of gravity occurs mainly in macropores. As the soil dries, field capacity is reached after free drainage of macropores had occurred. Field capacity represents the soil water content retained against the force of gravity by matric forces (in micropores and mesopores) at a tension of -0.033 MPa. As water content decreases, soil matric potential decreases, becoming more negative, and as a result, water is held more strongly to mineral surfaces due to cohesive forces between water molecules and adhesive forces associated with water and mineral particles (capillary forces). Water held between saturation and field capacity is transitory, subject to free drainage over short periods, hence it is generally considered unavailable to plants. This free water is termed drainable porosity. In contrast, much of the water held at field capacity is available for plant uptake and use through evapotranspiration

9. *Energy State of Soil Water*

Soil water, like other bodies in nature, can contain energy in different quantities and forms. Classical physics recognizes two principal forms of energy, kinetic and potential. Since the movement of water in the soil is quite slow, its kinetic energy, which is proportional to the velocity squared, is generally considered to be negligible. On the other hand, the potential energy, which is due to position or internal condition, is of primary importance in determining the state and movement of water in the soil. Therefore, the potential energy of soil water varies over a very wide range, and differences in the potential energy of water between one point and another give rise to the tendency of water to flow within the soil. The spontaneous and universal tendency of all matter in nature is to move from where the potential energy is higher to where it is lower and to equilibrate with its surroundings. In the soil, water moves constantly in the direction of decreasing potential energy until equilibrium, definable as a condition of uniform potential energy throughout, is reached. Knowledge of the relative potential energy state of soil water at each point within the soil can allow us to evaluate the forces acting on soil water in all directions and to determine how far the water in a soil system is from equilibrium. The concept of soil water potential is of great fundamental importance. This concept replaces the arbitrary categorizations which prevailed in the early stages of the development of soil physics and which purported to recognize and classify different forms of soil water: e.g. gravitational water, capillary water, and hygroscope water.

A new definition by the soil physics terminology committee of the International Soil Science Society provided more clarity to what used to be a rather complicated theoretical set of criteria. The total potential of soil water was defined as follows: "the amount of work that must be done per unit quantity (mass, volume or weight) of pure free water to transport reversibly and isothermally an infinitesimal quantity of water from a pool of pure water at a specified elevation at atmospheric pressure (standard reference state) to the soil water at the point under consideration in the soil- plant-atmosphere-system". If work is required the potential is positive, but if the water in the reference state can accomplish work in moving into the soil the potential is negative. Soil water is subjected to several field forces which cause its potential to differ from that of pure free water. Such forces result from the attraction of the solid matrix for water, as well as from the presence of dissolved salts and the action of the local pressure in the soil gas phase and the action of the gravitational field

Quantitative Expression of Soil Water Potential

The dimensions of the soil water potential are those of energy per unit quantity of water and the units depend on the way the quantity is specified. Common alternatives used are:

a. energy per unit mass of water (J/kg) which is not widely in use

b. energy per unit volume of water (pressure) (J/m^3 or N/m^2): This is the most common method of expressing potential and can be written with units of either Pascal or bar or atmosphere.

c. energy per unit weight of water (head) (J/N = Nm/N = m): This method of expressing potential is also common and has units of length. For conversion from one unit to another knows that:

1 bar corresponds to 100 J/kg
bar = 10^5Pa
1 bar corresponds to a 10 m water head

Gravitational Potential

Everybody on the earth's surface is attracted towards the centre of the earth by a gravitational force equal to the weight of the body, that weight being the product of the body's mass by the gravitational acceleration. To raise a body against this attraction, work must be expended and this work is stored by the raised body in the form of gravitational potential energy. The amount of this energy depends on the body's position in the gravitational force field (Western and Grayson, 2000).

The gravitational potential of soil water at each point is determined by the elevation of the point relative to some arbitrary reference level. If the point in question is above the reference, ψg is positive. If the point in question is below the reference, ψg is negative. Thus, the gravitational potential is independent of soil properties. It depends only on the vertical distance between the reference and the point in question (Beven and Germann, 2013)

At a height z below a reference level (e.g. the soil surface) the gravitational potential of a mass M of water, occupying a volume V is given in equation (4) below:

$$V = -Mgz = -\rho\, wVgz \qquad (4)$$

where: ρw = density of water g = acceleration of gravity

Osmotic Potential

The osmotic potential is attributable to the presence of solutes in the soil water, and the water molecules move through a semi-permeable membrane from the pure free water into a solution (osmosis) which indicates that the presence of solutes reduces the potential energy of the water on the solution side (Beering, 2015). At equilibrium, sufficient water has passed through the membrane to bring about a significant difference in the heights of liquid. The difference (z) in the levels represents the osmotic potential. Since the osmotic potential of pure free water is zero the osmotic potential of a solution at the same temperature as free water is negative (water flow occurs from a point of high potential to one with lower potential). This potential is of importance in water movement into and through plant roots, in which there are layers of cells which exhibit different permeabilities to solvent and solute (Beering, 2015).

Matric Potential

Matric potential results from forces associated with the colloidal matric and includes forces associated with adsorption and capillarity. These forces attract and bind water in the soil and lower its potential energy below that of bulk water. The capillarity results from the surface tension of water and its contact angle with the solid particles. In an unsaturated (three-phase) soil system, curved menisci from which obey the equation of capillarity. Soil matric potential (SMP) is a realistic criterion for measuring soil water availability to plants as it constitutes the force with which water is held by soil matrix (soil particles and pore space) and is measured by a tensiometer. (Harminder, 2014

Influence of Texture and Structure

Differences in soil properties (texture and structure) affect the water content at saturation, field capacity, and permanent wilting point (Lindbo, 2012). Texture and structure determine pore size distribution in soil, and the amount of plant-available water (PAW) (Lindbo, 2012). The magnitude of PAW changes with soil texture. Coarse textured soils (sands and loamy sands) have low PAW because the pore size distribution consists mainly of large pores with limited ability to retain water. Although fine-textured soils have the highest total water storage capacity due to large porosity values, a significant fraction of water is held too strongly (strong matric forces/low, negative water potentials) for plant uptake. Fine-textured soils (clays, sandy clays and silty clays) have moderate PAW because their pore size distribution consists mainly of micropores. Loamy textured soils (loams, sandy loams, silt loams, silts, clay loams, sandy clay loams and silty clay loams) have the highest PAW because these textural classes give rise to a wide range in pore size distribution that results in an ideal combination of meso- and micro-porosity. Soil structure can increase PAW by increasing porosity. Soil depth and rock fragment content also affect water holding capacity because bedrock and rock fragments are assumed to be unable to hold plant available water and/or accommodate plant roots (Nature Education, 2012).

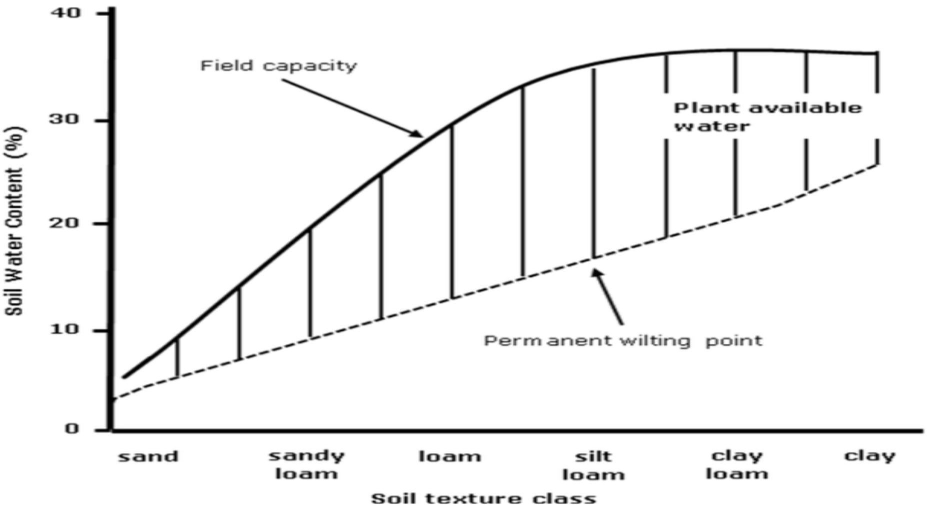

Figure 5: Generalized relationship between soil texture classes and plant available water holding capacity. (Nature Education, 2012)

Water movement in the Soil

Water movement in soil is closely linked with storage because water potential is a function of water content (Vogel, 2008). Water flow is also influenced by texture and structure, and other factors such as the layering of soil profiles. The rate of water flow is a function of the potential energy gradient and the ease with which water is transmitted through soil, termed saturated hydraulic conductivity, which is governed by pore size distribution and tortuosity of flow paths (Vogel, 2008). Clay-rich soils have low saturated hydraulic conductivity due to a highly tortuous flow path. Conversely, sandy soils have larger pores and lower tortuosity that facilitate rapid water flow. The National Cooperative Soil Survey identifies the following permeability classes based on soil texture (Table 1). These classes can be modified (qualitatively) by the degree of soil structure. Strong soil structure, consisting of very fine and fine aggregates (e.g., granular, fine and medium angular blocky and subangular blocky) facilitate rapid drainage of soil by increasing macroporosity. In contrast, weak structures or coarse-sized structural units (prismatic or blocky) and platy structures can inhibit flow, creating a more tortuous flow path constraining water to inter-structural voids. Soil structure is highly relevant to water management in soils because it is subject to change either through deterioration by improper management or to improvement through additions of soil organic matter. In contrast, it is usually infeasible to change the texture.

Table 1: Permeability classes based on soil texture

Permeability Class	Permeability (cm/hr)	Textural class
Very slow	<0.13	clay
Slow	0.13–0.5	sandy clay, silty clay
Moderately slow	0.05–2.0	clay loam, sandy clay loam, silty clay loam
Moderate	2.0–6.3	very fine sandy loam, loam, silt loam, silty clay loam, silt
Moderately rapid	6.3–12.7	sandy loam, fine sandy loam
Rapid	12.7–25.4	sand, loamy sand
Very Rapid	>25.4	coarse sand

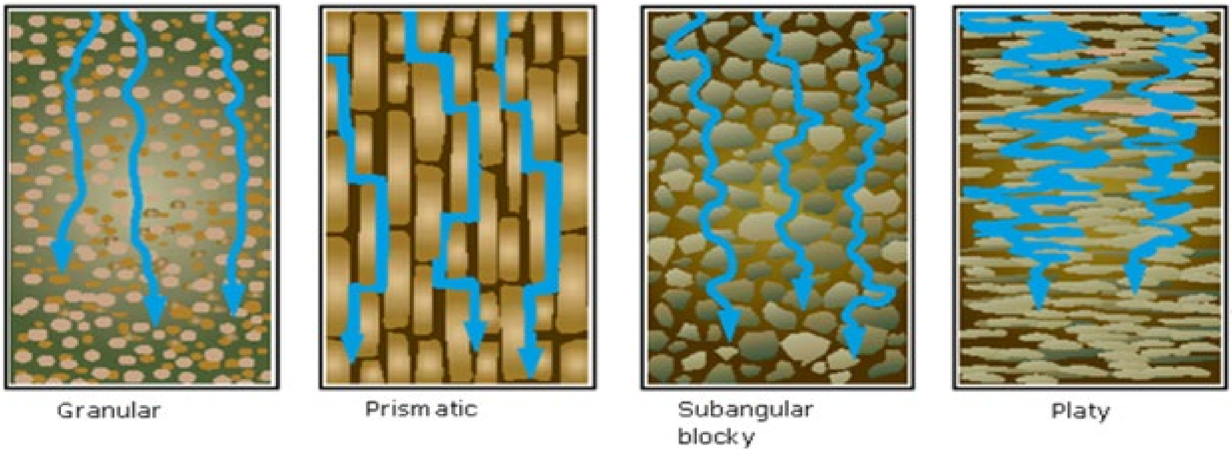

Figure 6: Water movement through different soil structure shapes. Developed by USDA-NRCS. (Nature Education, 2012)

The measurement of water content in the soil is of great importance in many investigations and applications in agriculture, hydrology, meteorology, hydraulic engineering, and soil mechanics. In the fields of agronomy and forestry, the amount of water contained in the soil affects plant growth and diffusion of nutrients toward the plant roots, as well as acting on soil aeration and gaseous exchanges, with direct consequences for root respiration. Also, continuous monitoring of soil water content can support the setting up of optimal strategies for the use of irrigation water. In hydrology, moisture condition in the uppermost soil horizon plays an important role in determining the amount of incident water either rainfall or irrigation water that becomes runoff. Evapotranspiration processes, transport of solute and pollutants, and numerous hydraulic (e.g., retention, conductivity) or mechanical (e.g., consistency, plasticity, strength) soil properties depend on soil water content (Kutilek, and Nielsen, 1994).

Several methods have been proposed to determine water content in the soil, especially under field conditions. Soil water content can be measured by direct or indirect methods

Direct Methods Direct methods involve removing a soil sample and evaluating the amount of water that it contains. Their use necessarily entails the destruction of the sample and hence the inability to repeat the measurement in the same location. The most widely used direct method is the thermogravimetric method, often considered a reference procedure because it is straightforward, accurate, and inexpensive in terms of equipment. This method consists of collecting a disturbed or undisturbed soil sample (usually of about 100–200 g taken with an auger or sampling tube) from the appropriate soil depth, weighing it, and sealing it carefully to prevent water evaporation or the gaining of moisture before it is analyzed. Then, the soil sample is placed in an oven and dried at 105–110◦C. The residence time in the oven should be such that a condition of stable weight is attained, and it depends not only on the type of soil and size of the sample but also on the efficiency and load of the oven. The usual values of the residence time in the oven are about 12 h if a forced-draft oven is used, or 24 h in a convection oven (Romano, 2014)

After the drying phase, the sample is removed from the oven, cooled in a desiccator with active desiccant, and weighed again. The gravimetric soil water content is calculated as follows:

$$W = [\ (W_w + t_a)\ - (W_d + t_a)] \ / \ [(W_d + t_d) - t_a \qquad (5)$$

Indirect methods consist of measuring some soil's physical or physicochemical properties that are highly dependent on the water content in the soil. In general, they do not involve destructive procedures and use equipment that also can be placed permanently in the soil, or remote sensors located on airborne platforms and satellites. Thus, indirect methods are well suited for carrying out measurements on a repetitive basis and in some cases also enable data to be recorded automatically, but require the knowledge of accurate calibration curves. The main indirect methods are gamma attenuation, neutron thermalization, electrical resistance, and time-domain reflectometry (TDR). Other indirect methods are low-resolution nuclear magnetic resonance imaging and remote-sensing techniques (Romano, 2014)

Drainage Property in Soil Moisture Dynamics

Soil drainage is one of the important soil properties affecting plant growth, water transfer and solute transport in soils. Soil drainage is also an environmental component affecting irrigation and soil reclamation, land capability for agriculture, flood control systems, engineering, health and infectious diseases (Campling *et al*., 2002).

The ease with which water drains from the soil is equally as important as storage. For example, most terrestrial plants need to assimilate oxygen through roots, but oxygen is scarce in saturated soils. Moreover, microbial decomposition of organic matter is greatest (by orders of magnitude) under aerobic conditions. Poorly drained soils have limitations for a variety of land-use practices. The recognition of poor drainage in soils is also used in wetland delineation efforts (Fausey, 2005).

Drainage capacity can be identified through careful observation of soil properties. Poorly drained Drainage soils result in episodes of prolonged saturation, while excessively drained soils commonly experience water deficits (Encyclopedia of soil, 2005). The most common redoximorphic features in soil are iron and manganese concentrations and iron depletion. These features arise through microbial decomposition of soil organic matter under anaerobic conditions. Anaerobic conditions arise because the diffusion of oxygen in saturated soil is very slow and does not keep up with the oxygen demands of aerobic respiration by microbes. When oxygen is depleted, facultative microbes utilize iron (Fe^{3+}) and manganese (Mn^{4+}) as terminal electron acceptors to make energy. In doing so, these elements are reduced and become soluble in soil solution. As water mobilizes these soluble constituents, they eventually encounter air (e.g., in root channels or other macropores) where they oxidize and re-precipitate as iron and manganese concentrations. Iron concentrations are coloured (red or orange) when rusted. Manganese concentrations are gunmetal blue, almost black. Redox depletions arise in microsites of extreme reducing conditions where Fe^{3+} has been completely removed. Redox depletions are typically dull in colour and have blue, green, pale brown or yellow hues that reflect the colouration of primary minerals. The depth at which redoximorphic features occur is used to describe the extent of saturated conditions within a soil profile (Jacobs *et al.* 2002).

The National Cooperative Soil Survey describes five soil drainage classes determined by the rate at which water drains from soil and the height of the water table during the growing season (Table 2). Drainage classes are used for a variety of land-use decisions such as soil suitability for groundwater banking, land application of wastes, engineering and construction, septic system development, crop selection, land capability classification and wetland habitat.

Table 2: Drainage classes for a variety of land use decision

Drainage Class	**Water Removed**	**Redoximorphic Features**	**Water Table Height (m)**
Excessively drained	Very rapid	None	>1.5
Somewhat excessively drained	Rapid	None	>1.5
Well-drained	Readily not rapidly	Below 1 m	1.0–1.5
Moderately well-drained	Somewhat slowly	Below 0.5 m	0.5–1.0
Somewhat poorly drained	Slowly	Below 0.25 m	0.25–0.5
Poorly drained	Very slowly	Gleyed or at or near soil surface	<0.25
Very poorly drained	Persistent saturation throughout the growing season		

Source**:** Nature Education, 2012

Conclusion

Water storage dynamics and flow facilitate the four basic soil-forming processes: translocations, transformations, additions and losses of soil constituents in a soil profile. These processes determine the chemical, morphological and physical properties of soil such as the variation of texture with depth. Hydrological processes active in the soil contribute to weathering processes, and indicators of these processes are preserved by the soil profile in the form of observable and measurable soil characteristics. Other soil morphologic indicators of the hydrologic process include redoximorphic features, abrupt accumulation of clay in the subsoil, development of soil structure, and presence of cemented layers. Thus, soil resource inventories (e.g., soil surveys), which document soil properties, can be used to infer hydrologic processes.

Because of the importance of Soil Moisture Dynamics and its process in the hydrologic cycle, the phenomenon deserves special attention and study. In these regards, it would be expected that a complete understanding of the process and factors affecting it would assist the hydrologist in quantitatively evaluating infiltration amounts and hence increase his confidence and competence in water balance, hydrologic design and other studies therefore an understanding of soil moisture dynamics will be fundamental to most land-use decisions in Nigeria agricultural lands.

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DEVELOPMENT OF A SOIL MOISTURE SENSOR

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Abstract

Soil moisture is of paramount importance in agriculture because it influences plant growth. Efficient agricultural management practices based on the monitoring of the moisture in the soil provide great benefit for the appropriate amount of water applied in the fields. This study was aimed at developing a soil moisture sensor to effectively monitor moisture levels for optimum crop growth. The sensor was made using a programmed Arduino microcontroller. It is attached to a sensing panel with two probes made of nickel that measure the volumetric content of water in the soil. The probes were non-corrosive and robust materials suitable for use in agricultural-related applications. The developed moisture meter was tested and evaluated. The two-legged Lead (probes) goes into the soil where water content was to be measured by passing a current through the soil and then reading the resistance to get the moisture level. Nine different soil classification samples (Sandy Clay, Fine Sandy Loam, Sandy Loam, Salty Loam, Loamy Sand, Coarse Sand, Fine Sand, Sandy Clay Loam and clay soils) at different depths were used to analyze the moisture meter at three different portions of each soil sample. Findings from the tests conducted showed that the developed soil moisture sensor is effective and of very high precision with less effort. Results were also displayed faster (maximum of 3 minutes). Results obtained indicate that there was a progressive increase in moisture levels the more the sensor was being dipped into the soil. This could be attributed to the fact that heat intensity from the sun was more intense on the upper surface. Results obtained also show that eight out of the nine soil samples analyzed were within an acceptable range of accuracy. The moisture meter was found to be a suitable guide for the farmer in determining soil moisture levels.

Keywords: Moisture, Sensor, Soil Classification, Probe

Introduction

Soil moisture is of paramount importance in agriculture because it influences plant growth and crop production. Over the years, there has been a growing interest in soil moisture. Most studies related to the soil-plant relationship are invariably pivoted on accurate measurement of soil moisture either by direct or indirect methods (Adamhameed, 2014). Gravimetric measurement of soil moisture content requires excavating, drying, and weighting of samples has been associated with drudgery. Soil moisture meters measure the volumetric water content in the soil indirectly by using some other property of the soil, such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content of the soil. As electrical resistance between the electrodes varies with soil moisture content (Mukhtar 2010). The relation between the measured property and soil moisture must be calibrated and may vary depending on environmental factors such as soil type, temperature, or electric conductivity (Carter and Gregorich, 2006).

Soil is a mixture of mineral and organic matter that contains air, water, and micro-organisms. It provides a medium in which plants grow, a habitat for animals, and storage for water. The size of the mineral particles is a key soil property and provides the basis for the classification of soils. Many processes take place in soils including the recycling of nutrients, purification of water, and exchange of gases with the atmosphere. (Carter and Gregorich, (2006); Jeff and Mark. (2003)). The range of soil textures can be used as a quick means of assessing possible land uses. It also determines its water holding capacity.

For profitable agricultural production, the non-uniform moisture distribution of soils constitutes a bottleneck for optimum crop growth. Sampling and moisture content testing is a routine operation, most often performed manually. By necessity, for practical purposes, indirect electrical moisture content measurement methods have been developed that are based on correlations between the electrical properties of soil and its moisture content (Nelson, 1991; Mukhta, 2010).

There is not much new land waiting to be opened up for agriculture, increase in food supplies has to come from making better use of the land already farmed (Mohamed and Tessema, 2013) More efficient crop production methods are required. However, rainfall is still a limiting factor necessary for profitable crop production. Plants will grow best with their roots in the soil if the right quantity of water is applied at the right time; Blake and Hartge, (1986).

Small scale farmers in Nigeria and most African countries do not use soil moisture measurements. Similarly, estimates of crop evapotranspiration for irrigation scheduling are mostly measurements employing old and outdated old methods like excavating, tensiometers, neutron probes and gypsum blocks are very expensive to afford coupled. The drudgery was also high.

Thus this research seeks to design and develop an effective soil moisture meter that enables peasant farmers to ascertain moisture levels with minimum effort for optimum crop growth.

Materials and Methods

Materials

Arduino UNO board

The main material component of the study was the Arduino UNO and the Soil Moisture Sensor. The Arduino UNO board is the most popular in the Arduino board family (Figure 1).

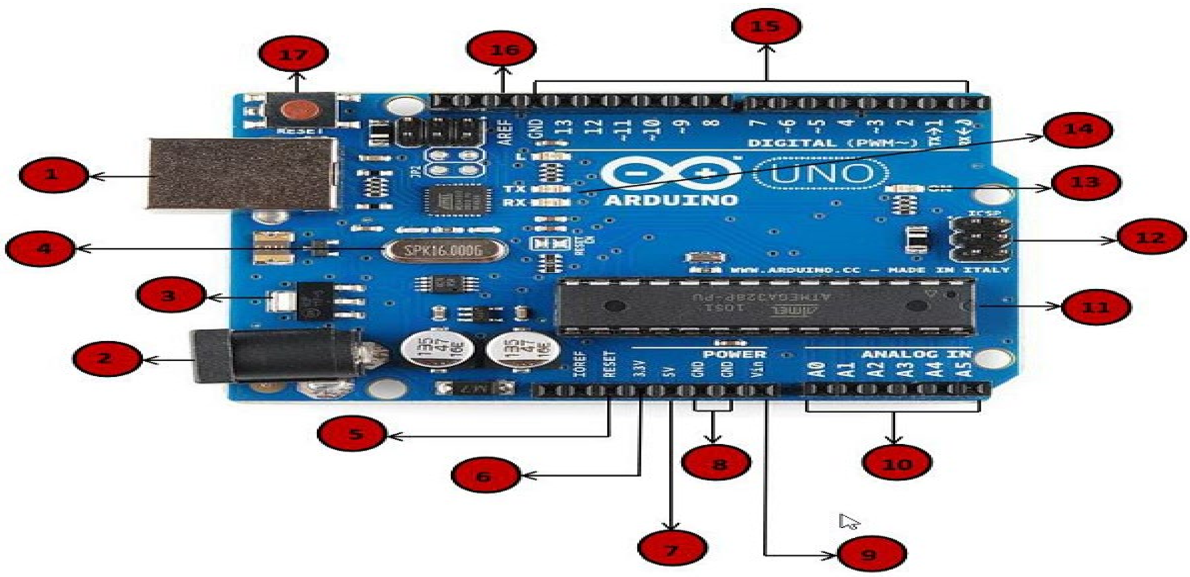

Figure 1: Arduino UNO board with component illustration (Source: www.arduino.cc)
where: 1 – Power USB, 2 – Power (Barrel Jack); 3 – Voltage Regulator; 4 – Crystal Oscillator; 5, 10 and 17 – Arduino Reset; 6, 7, 8 and 9 – Pins (3.3, 5, GND, Vin); 11 – Main microcontroller; 12 – ICSP pin: 13 – Power LED indicator; 14 – TX and RX LEDs; 15 – Digital I/O; 16 – AREF.

Soil Moisture Sensor board

The Soil Moisture Sensor board consists of a couple of conductive probes that can be used to measure the volumetric content of water in the soil. The soil moisture sensor board consists of two parts: The main Sensor and the Control Board.

A two-legged Lead (Figure 2), goes into the soil where water content has to be measured. This sensor uses the two probes to pass current through the soil and reads its resistance to get the moisture level. More water makes the soil conduct electricity more easily (less resistance), while dry soil conducts electricity poorly (more resistance). The probe has two header pins that are connected to an Amplifier/A-D circuit which is in turn connected to the Arduino. The Amplifier has a VIN, Gnd, Analog and Digital Data Pins. This means that the values could both be displayed in Analog and Digital forms.

Figure 2: Soil Moisture Sensor (Source: www.arduino.cc)

The Control Board is made up of LM393 IC, which is a voltage comparator. The board also consists of other components like connectors, LEDs, resistors etc. to measure the soil moisture. Additionally, there is an option to adjust the sensitivity of the module with the help of a potentiometer. The board has a power supply of: 3.3v or 5v, an output voltage signal of: 0~4.2v, Current of 35mA. Other components of the moisture meter include:

LCD Display – An LCD is an electronic display module which uses liquid crystals to produce a visible image. The 16×2 LCD is a very basic module commonly used in DIYs and circuits. The 16×2 translates to a display of 16 characters per line. Each character is displayed in a 5×7 pixel matrix.

10KΩ Potentiometer (for LCD) – this is essentially a voltage divider used for measuring electric potential (voltage).

Breadboard – A breadboard is a solderless device for temporary prototypes with electronics and test circuit designs. Most electronic components in electronic circuits can be interconnected by inserting their leads or terminals into the holes and then making connections through wires where appropriate.

Connecting wires – Connecting wires allows an electrical current to travel from one point on a circuit to another. It thus serves as needs a medium through which current moves. Most of the connecting wires are made up of copper or aluminium. Copper is cheap and has good conductivity.

Power Supply - power supply is an electrical device that supplies electric power to an electrical load. Its primary function is to convert electric current from the source to the correct voltage, current, and frequency to power the load.

Design Methods
Circuit Design

The circuit is designed by connecting the probe to the board and providing a power supply to the board. The analogue out pin from the board is connected to the Analog IN pinA0 of the Arduino. For the results display, a 16×2 LCD Display is used, where its data pins D4 – D7 are connected to Arduino Pins 5 – 2. All the additional connections are mentioned in the circuit diagram.

Code Design and Set up

There are two important variables in the code design: the soil moisture sensor pin and the other for storing the output of the sensor. In the setup function, the "Serial. begin (9600)" command will help in communication between the Arduino and serial monitor. Then, it will print "Reading" from the Sensor on the serial monitor. The loop function will display the reading from the sensor analogue pin and store the values in the "output_ value" variable.

Sensor Calibration

Connecting wires were used to connect the sensor with the breadboard. The SIG is connected on the sensor breadboard and the GND together and then connected with ACC. The breadboard was then connected to a computer, the Arduino program launched and the sensor code activated. After verifying the code, it would be uploaded to the board and the serial monitor opened. The sensor would be calibrated by inputting the sensor code to the practical samples and the sensor data on the monitor kept changing when the sensor leads id dipped in water and when dry. These values could be used as a threshold to trigger an action based on these values.

Working principle of soil moisture meter

The working of the Soil Moisture Sensor is very simple. It works on the principle of voltage comparison. The circuit in Figure 3 explains the working of the soil moisture sensor.

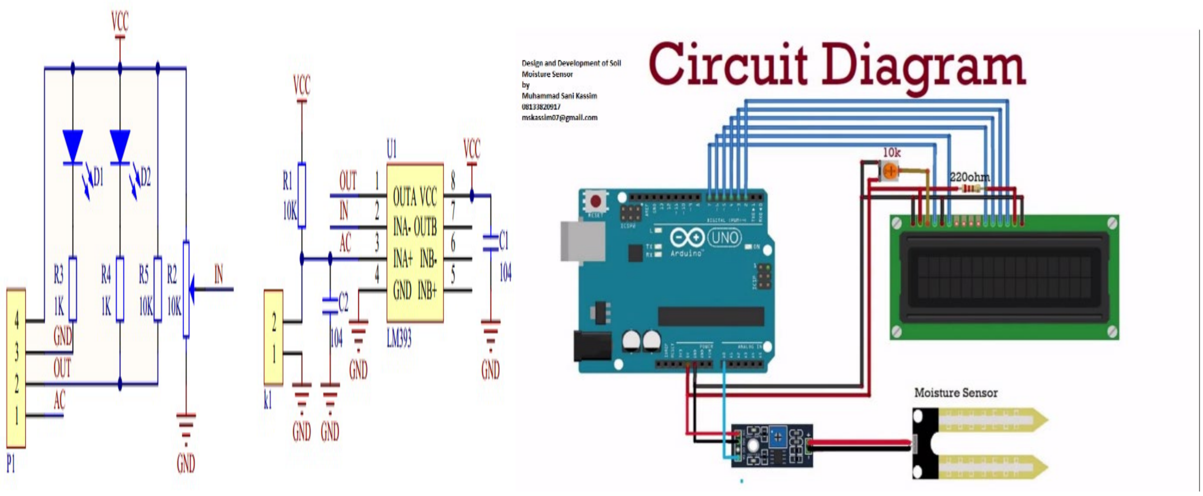

Figure 3: Working principle circuit and Circuit Diagram (Source: www.arduino.cc)

From the figure, one input of the comparator is connected to a 10KΩ Potentiometer while the other input is connected to a voltage divider network formed by a 10KΩ Resistor and the Soil Moisture Probe. Based on the amount of water in the soil, the conductivity of the probe varies. If the water content is less, the conductivity through the probe is also less and hence the input to the comparator will be high. This means that the output of the comparator is high and as a result, the LED will be off and descends. Similarly, when there is adequate water, the conductivity of the probe increases and the output of the comparator becomes low. The LED then starts glowing and ascends. The estimated cost of producing one sensor unit of the moisture meter is given in Appendix A.

Results and Discussion

Samples of nine different soil classifications at different depths were analyzed at three different points denoted as A, B and C respectively. The sensor was inserted at each point on five different levels leading to an overall of 135 points analyzed. The Soil Moisture Sensor of 14.3 mm length was divided into five proportional intervals of 3, 6, 9, 12 and 14.3 mm, respectively. This is to ensure accuracy and reasonable distribution within the sample.

Results of the moisture contents of the nine samples using the developed moisture sensor were shown in Table 1. Results obtained are observed to be within a reasonable range as compared with what was obtained when the oven-dry method was used to determine the moisture contents of the same samples.

Table 1: Mean moisture content analysis

Soil Type	**Overall Mean Value of Moisture Content** (%)	**Oven Dry Mean Value of Moisture Content** (%)	**Variance of Moisture Content** (%)*	**Remarks**
Silt Loam	70.11	62	8.11	*Not Acceptable*
Fine Sandy Loam	60.86	60	0.86	*Acceptable*
Sandy Loam	59.7	55	4.7	*Acceptable*
Sandy Clay	71.4	70	1.4	*Acceptable*
Fine Sand	54.06	54	0.06	*Acceptable*
Sandy Clay Loam	70.6	71	0.04	*Acceptable*
Clay	81.5	78	3.5	*Acceptable*
Loamy Sand	55.93	57	1.07	*Acceptable*
Coarse Sand	53.47	55	1.53	*Acceptable*

*Key: - (1-5%) Acceptable (5-100%) Not Acceptable**

Except for Silt Loam with a mean moisture content value of 70.11% and mean oven-dry moisture content value of 62% with a mean variance of 8.11%, all the values obtained for the other soil samples fall within the acceptable range. Results obtained also indicate that there was a progressive increase in moisture levels as the sensor was dipped into the soil. This was true for all the three points tested for all the soil samples. This could be attributed to the fact that the intensity of heat from the sun was more intense on the upper surface, perhaps because from logical reasoning, the upper portions of the selected places were dryer while the lower parts were moister.

Generally, the results show that the developed moisture sensor is effective. As for the moisture level of the silt loam obtained, the unacceptable result could likely be attributed to errors occurred due to human error, random error, equipment defects and other engineering associated errors.

Conclusion

This study aimed to design, develop and evaluate a soil moisture sensor to monitor moisture levels for optimum crop growth. The sensor was developed with the use of Arduino studio robotics and a low-corrosive sensing panel. Nine different soil samples were collected and analyzed. The results obtained were compared with what was obtained using the oven-dry method. There was a progressive increase in moisture levels as the depth of inserting the sensor into the soil increased. Results obtained also show that all the moisture values obtained for the other soil samples fall within the acceptable range except for silt loam with the mean moisture content value falling outside the range of acceptable values when compared with the mean oven-dry moisture content value.

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www.arduino.cc

Appendix I

Bill of Engineering and Materials Evaluation

S/No.	Items	Prices (₦)
1	Arduino UNO board	5000
2	Breadboard	1500
3	Soil Moisture Sensor	3000

4	Hook-up Wires	300
5	Casing	1000
6	Power Light Emitting Diode indicator	2000
7	Digital Emitter	2000
8	Battery	5000
9	Resistor	2500
Total		₦22,300:00

DEVELOPMENT AND PERFORMANCE EVALUATION OF MANUALLY POWERED MACHINES FOR WET-SIEVE ANALYSIS OF AGRICULTURAL SOILS

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Abstract

To overcome the drudgery and other inconveniences encountered when carrying out wet sieving analysis, 2 simple manually powered machines were designed and the prototype for each was constructed from locally available materials. The shaft diameters of the Rotary Handle and Reciprocating Handle wet sieving machine were 14 and 17 mm, respectively. The machines were evaluated using agricultural soil on a set of mesh sizes of 2 mm, 1mm, 0.25mm, 0.05 and <0.05mm. It was observed that both machines performed better than the manual method of wet sieving. Moreover, while the Rotary Handle prototype completed the wet sieving in a shorter time, the reciprocating handle type took a longer time than both the rotary handle and the manual wet sieving method.

Keywords: Rotary handle, Prototype manual machine, Wet Sieving

1. Introduction

Sieving of granular materials is widely applied for the analysis of particle sizes in many fields. Earth sciences analyze gravels, sands, silts, and clays to describe deposits of sediments and ascertain the origins of the deposits. Powder technology analyzes manmade powders and other chemicals for quality control (Syvitski, 1991; Anonymous, 2001). Sieving has been defined as the separation of fine materials using the meshed or perforated vessel (Anonymous, 2001; Fayose, 2008). While dry sieving has been applied in many industries such as petroleum, mining, agriculture, forestry, space programme, biomedical and military research; wet sieving is commonly used in food processing, pharmaceutical production and soil analysis (Syvitski, 1991; Fayose 2008).

Soil structure or architecture is a crucial property which plays an *important role* in maintaining the many *essential* processes related to soil productive capacity, environmental quality, and agricultural sustainability (Kay and Munkholm, 2004). Soil structure plays an *indispensable part* in the development of roots, retention of water, the capacity of infiltration and porosity of soil (Neves *et al.*, 2003). Wet sieving is commonly used in soil laboratories for the characterization of the soil of different forms and sizes and this knowledge of the aggregate size distribution is essential. Factory size equipment such as the wet sieving apparatus. The costs of the available equipment are another issue with wet sieving analysis apparatus, where those available are expensive and difficult to maintain. With respect to soil structural analysis, and due to the cost and non-availability of such equipment in small laboratories and workshops, users adopt manual methods of wet sieving that simulate the process when specialized equipment is used. The wet sieving technique described by Kemper and Rosenau (1986) is the most widely adopted approach used for aggregate stability testing. It involves the cyclic submergence and sieving of soil in water which simulates the natural process that occurs in water entry into soil aggregates (Marquez *et al.,* 2004). Wet sieving is usually carried out with a nest of sieves of varying diameters or a single sieve and the method was applied by several researchers such as Elliot (1986) and Six *et al.* (2000), with the use of a set-up or the wet sieving apparatus. The hand-lifting manual method of wet sieving soils is prone to drudgery and errors because of inconsistency with stroke height and energy exerted to lift a sieve from the water bath.

Fayose (2008) observed that manually performing wet-sieving analysis in food processing is energy and time consuming, tedious, and back straining. Manual wet-sieving analysis of soil materials is time-consuming and labour intensive because it is often conducted while standing, squatting, or sitting on a stool depending on the height where the bucket/bath of water is placed. Often operators prefer standing with legs slightly apart, bending over at the waist, the hands holding firm the frame of the sieve containing the soil, to immerse it into and raise it above the water bath in a repetitive up-down motive. The posture taken and mode of operation in performing the analysis cause stress in many parts of the body, the legs, arm, back, neck and head. Bending of body joints including the elbows, shoulder and back is not easy on the operator. Soon, the waist and wrist experience fatigue because of the repetitive movement; and the amplitude and frequency of the action are gradually damped. These result in loss of concentration and loss of count which compel operators to restart the process all over and increase the chances of inducing errors in the data. There is a need to standardize the amplitude and energy of stroke with the manual method of wet soil sieving because of subjective biases induced by individuals of different characteristics (strength, endurance, and height).

More so, in cold weather conditions, operators are reluctant to do wet sieve analysis because of chills experienced when hands are immersed in water. Thus, this study aims to develop two simple, cheap manually operated machines each capable of being used to carry out wet sieving of soils for structural analysis.

The objectives of the study are to design and fabricate low-cost apparatus from locally available materials for wet sieving of analysis of soils and to carry out the performance evaluation of each of the machines compared with the hand-lifting manual method.

2. Materials and Methods

2.1 Construction materials

Locally available materials used for the construction of the two machine areas are listed in Table 1. The market prices of the materials (in Naira, ₦) as of October 2019 and where each material was used are given in the Table. The sum of the material purchase and the total cost of the construction of the two machines was ₦ 17, 250:00 and ₦30, 250:00 respectively.

Table 1: List of materials and costs for the construction of the machines

Material Description	Where used	Quantity	Unit price (₦)	Component	Price (₦)
16mm Angle bar	Both	1 length	8000	Frame	8000
Iron rod	Both	¼ length	4000	Shaft	1000
Hollow Pipe	Both	1 length	1500	hung	1500
5mm metal sheet	Press	¼ length	5000	Base	1250
Ball bearings	Both	3 sets	500	Rotary Parts	1500
12cm pulley	Rotary	1	4000	Handle	4000
Labour	Both		8000		8000
Miscellaneous	Both		5000		5000

Total	30 250

2.2 Design considerations

The considerations used in the designs of the machines were availability of materials locally, reduced tendencies to corrosion of materials, strength requirement of components, the durability of the machine, simplicity of operation, portability, ease of being dismantled and recoupled, ergonomics ofa single operator to power each machine with least drudgery and machines been fit to man.

2.3 Design of machines

Table 2 shows the summary of the procedure for the design of the machines. The weight of the soil sample and the sieves loaded on the machine in each analysis was assumed as 30 N. Average power which an operator can deliver without stressing the individual was taken as 75 W (Eugene, 2007). While the span for the Rotary Wet-Sieving Machine was 600 mm (Figure 1) that of the Reciprocating Wet-Sieving machine was 225 mm (Figure 2). Taking the necessary assumptions and using the formulae given by Kurmi and Gupta (2005), the values obtained are as tabulated in the Table. The number of resolutions in the Rotary Wet-Sieving Machine with the least random oscillation of the hung sieves, with the gear to spur ratio of 3, was 160 rpm. The bending moment and torque of the rotary machine were calculated as 4500 and 448 Nmm respectively. The twisting and bending moments of the same machine are 6783.4 and 6716.7 Nmm. The factor of safety of 1.5 was used to obtain the diameter of 14 mm used in the fabrication of the machine.

Table 2: Summary of the systematic procedure of the design of the machines

Parameters	**Descriptions/ Formula**	**Value/Results**
Load (W)	Weight of test soil + sieve	W=30 N
Power (P)	Power of average operator	P=75 W
Length (L)	Span between the supports	L= 600mm
Moment (M)	$M = \frac{W\ x\ L}{4}$	M= 4500 Nmm
Speed (N)	Number of Revolution	N= 160rpm
Torque (T)	$T = \frac{P\ x\ 60}{2\pi N}$	T=448 Nmm
Bending Constant (K_m)	Bending shock & fatigue factor	K_m = 1.5
Tension Constant (K_t)	Tension shock & fatigue factor	K_t = 1.5
Twisting Moment (T_e)	$T_e = \sqrt{(K_m \times M)^2 + (K_t \times T)^2}$	T_e = 6783.4Nmm
Bending Moment (M_e)	$Me = \frac{K_m\ x\ M + T_e}{2}$	T_e = 6716.7Nmm
AllowableTwisting Stress(τ_{max})	Constant	τ_{max}= 56Mpa

Calculated Diameter (d_1)	$T_e = \frac{\pi}{16} \times \tau_{max} \times d^3$	d_1= 9.4 mm
Shaft Diameter (D_1)	D_1= 1.5 d_1 (factor of safety =1.5)	D_1= 14 mm
Diameter of Rotary Wet-Sieving Machine		D_1= 14 mm
Allowable Bending Stress (σ_{max})	Constant	σ_{max}=112MPa
Length (l)	Length of lever	l= 225mm
Bending Moment (M_b)	M = W x l	M_b= 6750 Nmm
Calculated Diameter (d_2)	$M_b = \frac{\pi d^3 \sigma}{32}$	d_2= 8.5 mm
Shaft Diameter (D_2)	D_1= 2.0 d_2 (factor of safety =2.0)	D_2= 17 mm
Diameter of Reciprocating Wet-Sieving Machine		D_2= 17 mm

All formulae obtained from Kurmi & Gupta (2005)

In the Reciprocating (Press) Wet-Sieving Machine, using the bending moment was 6750 Nmm and the maximum allowable stress of 112 MPa (Kurmi & Gupta, 2005), the calculated diameter for the level was obtained as 8.5 mm. But the factor of safety of 2.0 (according to Kurmin and Gupta, (2005)) was used to obtain a diameter of 17 mm for the fabrication of the machine. Both machines were fabricated at the workshop of the Department of Agricultural and Bioresources Engineering of the Institute for Agricultural Researches (IAR), Ahmadu Bello University, Zaria, Nigeria. Plates 1 and 2 show the fabricated Reciprocating and Rotary Wet-Sieving machines respectively.

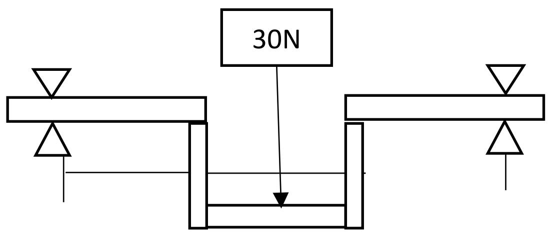

Figure 1. Schematic diagram of the Rotary Sieving Machine

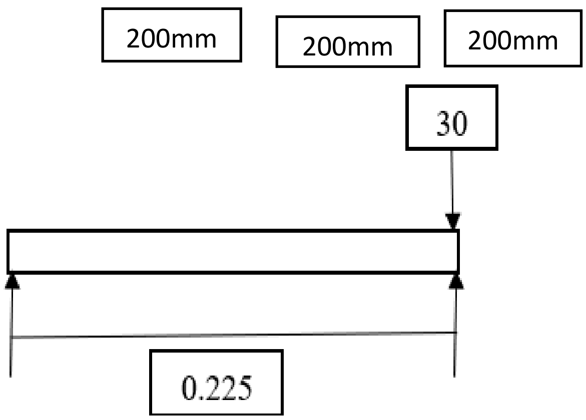

Figure 2. Schematic diagram of the Reciprocating Sieving Machine

2.4 Working Principles of the machines

A ring of a diameter of 205 mm hung on each of the machines was to hold the sieve on the machine. The ring was made in such a way to allow for swift and easy attachment and detachment of the sieve to the machine. In the Reciprocating Handle Wet-sieving machine, the operator depressed the handle of the machine making the sieve and content raise above the bucket of water placed on the base of the machine. When released the weight of the sieve and its content counterbalanced the freed handle of the machine and thus the sieve and its content are immersed in the water in the bucket. The procedure is repeated for the 50 immersions required for wet sieving. In the Rotary Handle, the circular movement of the handle as delivered by the operator is changed into an up and down movement by the crank arrangement. And the sieve containing the soil sample oscillatory up and down as stated for the other machine.

2.5 Materials used for the evaluation of machines

The apparatus used for the evaluation of the 2 machines are a stopwatch, weight scale of sensitivity of 0.01g oven drier, cans of known weights, a bucket of 15 000 cm^3 capacity which is three-quarter filled with water and a set of sieves of different mesh sizes. Three subjects, very conversant with wet-sieving analysis, evaluated the machine independently on soil samples collected from a demonstration farm proximate to the Laboratory. The test was done at the Soil Physics Laboratory of the Department of Soil Science, Ahmadu Bello University. Water from the tap in the Laboratory used for other experimental purposes was used in the analysis. The subjects were carefully selected for their skills and previous experiences in the laboratory. Each of them also carried out wet sieving analysis on the soil sample in the conventional manual way in which it was done without the machines.

2.5 Evaluation procedure

Two hundred grams of the soil sample were weighed on a weighing scale and poured into the sieve mesh of 2.00 mm perforation hung on the holder of the Rotary Handle machine. The stopwatch was used to measure the time taken for 50 complete immersion of the hung sieve and its content in water in the bucket using the Machine. Residue retained on the sieve was poured into a can and dried at 105 ℃ in the oven drier until the weight remained constant. The time is taken and the weight of the retained soils was recorded. The procedure is repeated for 1.00, 0.25, 0.05 and <0.05 mm mesh sizes while the number of stroke/immersion were 50, 45, 35 and 35 respectively following known standards. The time taken for each procedure was recorded accordingly. The entire process was repeated by the same subject/operator using the Reciprocating Handle Machine and manual up and down strokes without the machine

2.6 Statistical Analysis

Analysis of variance (ANOVA) was used to compare the two machines with the conventional method for the subjects. The weight of residue retained on each mesh size and the time used by the three subjects to complete the process were analyzed to know if there was a significant difference (at $\alpha=0.05$) between the two machines and the conventional method results. The least significant difference (LSD) was used to compare the methods where there was a significant difference in the result of analysis of variance (ANOVA).

3. Results and Discussion

Results of the machine evaluation are shown in Table 3.

Table 3: Summary of the Machine Evaluation

			Mass of soil Retained on Mesh (g)			Time is taken for operation (sec)		
Mesh Diameter mm	Number of Strokes	Subjects	Rotary	Reciproc-ting	Manual	Rotary	Reciproc-ting	Manual
2.00	50	A	16.7	16.6	16.0	34	66	40
		B	18.4	18.9	16.9	36	60	39
		C	17.2	16.8	16.8	32	61	40
1.00	50	A	8.0	9.0	9.4	32	63	39
		B	8.7	10.0	9.0	34	58	36
		C	8.2	9.2	9.7	30	58	41
0.25	45	A	17.7	18.4	17.8	27	57	34
		B	18.7	18.3	18.8	29	54	32
		C	18.0	18.8	18.9	25	54	34
0.05	35	A	79.9	79.8	81.5	20	48	27
		B	81.4	80.0	82.0	21	49	24
		C	80.2	80.2	82.3	20	50	26
<0.05	35	A	50.0	50.0	50.7	19	50	28
		B	51.2	52.3	53.0	20	47	23
		C	50.7	51.0	51.3	19	47	28

Table 4 is the ANOVA of the evaluation of the methods used for the wet sieving. The probability greater than the F value (Pr> F) of 0.9983 means that the soil analysis by the different methods is not significant and implies that either of the machines can be used to do wet sieving as well as the conventional method. Time spent doing the work is not significant for the subjects (Pr>F with a value of 0.8589). This means that the subjects carried out the work with equal dexterity and statistically equivalent time. But the different methods have a highly significant difference (Pr> F of 0.001) in time spent. Table 5 gives the least significant difference ranking of the time spent. It confirms that the rotary handle machine was able to carry out the job in the least time, while the Reciprocating handle machine would take more time to do the same analysis than the conventional manual method. Table 3 shows the result of the evaluation of the machine in comparison to the manual method. From the table, the largest mass of soil of about 80 g was retained on the 0.05 mm mesh. This implies that 40 % of the soil sample are less than 0.25 but greater than or equal to 0.05 mm. The Table shows that 8.2 to 10 g of the soil sample were retained on the 1.00 mm. mesh size, which forms the least proportion of the soil sample. The

Reciprocating Handle Machine took the largest time for each operation and was subject to a range of 47 to 66 sec to carry the sieving. Rotary Handle Machine took the least time with the range of 19 to 36 sec, but the conventional manual method ranges from 23 to 41 sec depending on the required number of strokes and/or the mesh.

Table 4. ANOVA of the Methods Evaluation

Source	DF	Mass Retained on Mesh	Time spent
Machine	2	0.9983 ns	0.001**
Subject	2	0.9948 ns	0.8589 ns
Error	40		
Total	44		

Table 5. LSD rating means time for wet sieving

Methods	Mean Time (sec)
Reciprocating Handle Machine	55.42a
Conventional manual method	32.73b
Rotary Handle machine	21.53c

4. Conclusion

Two manually powered wet sieving machines were designed, fabricated and evaluated in comparison with the old manual method of wet sieving analysis of Agricultural soils. The machines were able to do the job as well as the manual method, only while the Rotary Handle Machine did the job in a shorter time, the Reciprocating Handle Machine did it in a longer time than the conventional manual method.

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Plate 1. Reciprocating Sieving Machine

Plate 2. Rotary Sieving Machine

COPULA BASED MODELLING OF HYDROLOGICAL DROUGHT SEVERITY-DURATION-FREQUENCY RELATIONSHIP OF SOKOTO RIVER RIMA BASIN NIGERIA

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Abstract

The seeming frequent occurrence of hydrological extremes (e.g., flood and drought) of late has become a matter of serious concern within the hydrological community. In view of this, the study examined the hydrological drought Severity-Duration-Frequency relationship, based on the copula modelling strategy for Sokoto-Rima River Basin, Nigeria. Secondary hydro-meteorological data of the basin was employed. The protocol used for this study includes (1) extraction of severity and duration series (2) probability distribution fitting for the drought severity and the associated duration series, and (3) selection of the best candidate bivariate copula modelling for the Severity-Duration dependence using test statistics and (4) establishment of drought-severity risk assessment curve for the basin. For copula modelling of the dependence between the drought severity and duration, the results showed that the dominance of Gamma probability marginal (67%) for severity series and Weibull distribution marginal for the duration (67%); i.e. in all the gauging stations relatively to logistic-normal and extreme value probability distributions, while for bivariate copula modelling of the dependence structure, the Frank copula of the Archimedean family was adjudged the most suitable model based on minimal AIC (-4.2780) and SIC (-8.2780) statistics. Based on the copula results, the mean hydrological drought severity for the basin is 17Mm^3 with a duration of 5 months duration and a corresponding return period of 3 years. The result shows that Frank copula has the capacity to modelling drought events in the basin. However, it is recommended that for effective risk assessment, trivariate copula should be considered because of the high volatility and the presence of leptokurtic behaviour of hydroclimatic processes, especially in light of climate change.

Keywords: Stochastic, Time Series, Modelling, Drought, Severity, Copula, Statistics

1. Introduction

Considering the recent and potential future increases in global temperatures and changes in precipitation, indicated that climate change may come with changes in the frequency and severity of extreme events such as drought and flood (Intergovernmental Panel on Climate Change (IPCC), 2007). Therefore, drought analysis has become a global issue that attracts the attention of various water resource experts. In this context, drought and floods are considered debilitating hazards within the general horizon of water resources development and management (Wilhite, 2000a). Generally, drought is a period of below-average precipitation in a given region, resulting in prolonged shortages in the water supply, whether atmospheric, surface water or groundwater. It is imperative to note that, drought produces a complex web of impacts capable of transforming itself from one form to another; that is, for instance, from meteorological to hydrological and subsequently to agricultural (Sergiusz, 2015). As reported by Van loon *et al*. (2015) more types of drought impacts are related to hydrological drought than to meteorological. Thus, there is a general emphasis on hydrological drought. It is against this backdrop that the study of hydrological drought and its associated characteristics; in terms of deficit volume (severity), sustain period for drought event occurrence (duration) and return period of drought event (frequency) becomes essential for water resource management and planning.

Hydrological variables are characterized by significant stochastic and bivariate components, the development of models capable of describing such complex phenomena is a growing area of research (Chowdhary et al.,2009). The last couple of decades has seen remarkable progress in the ability to develop accurate hydrologic models. Moreover, in these times of phenomenal growth in computing ability, newer methods based on pattern recognition and statistical inference need to be explored to describe the inherent spatial and temporal variability as well as the relationships among individual and multiple hydrological variables (Marshall, 1996). Therefore most hydrological designs and management strategies are based on severity, duration and frequency analysis (Chowdhary *et al*., 2009). It suffices to note, that there is a growing realization that hydrological design and risk management procedures can benefit from the multivariate consideration of the involved processes (Chebana *et al*., 2009; Clarke, 1994). The multivariate treatment provides a comprehensive view of the efficiency of hydrological design and management strategies (Yue et al., 1999). It is in the light of this, that it becomes pertinent that a robust approach to modelling drought severity - duration - frequency should be considered. A drought is a multivariate event characterized by its Severity, Duration, and frequency which are mutually correlated (Ganguli et al., 2013). Thus, a better approach for describing drought characteristics is to derive the joint distribution of drought based on its characteristics (Ganguli et al., 2013). Complex hydrological phenomena such as droughts are generally characterized by several correlated variables (Shiau, 2003).

In this regard, Copulas are mapping functions that capture the rank-invariant dependence structure among random variables, which are obtained by joining marginal distribution of any form (Sklar, 1959). The Copula modelling strategy has received a lot of attention with considerable adoption in flood and drought forecasting; is driven by the fact that univariate drought characteristic analysis, though a well-developed technique applied in hydrology for decades, often associated with singular variables has proven inadequate in quantifying drought bivariate nature (Yevjevich,1967). In addition, bivariate distribution is often explored in hydrological extremes studies. Examples, bivariate normal distribution (Goel *et al*., 1998), bivariate exponential distribution (Bacchi *et al*., 1994), bivariate gamma distribution (Yue, *et al*., 2001), and bivariate extreme value distribution (Shiau, 2003) The major drawbacks of these bivariate distributions as indicated by Frees and Valdez (1998), is that the same family is needed for each marginal distribution, requires more data, sophisticated mathematical treatment, and a limited number of available models. In this regard, it is important to note, that bivariate distribution cannot be applied to correlated hydrological variables with differentia marginal distributions, common in drought analysis.

In recognition of these, physical models, based on bivariate Copula strategy stand out in quantitative drought characterization. This approach is fast becoming an attractive alternative and offers various benefits ahead of the traditional statistically approach (Abrahart,1999); some of the benefits in line with the guiding principles of hydrological modelling are parsimony, modesty, and testability (Hillel, 1986); Invariant under strictly increasing transformations of the random variables (Marshall,1996); Typical data transformation methods, such as taking the logarithm or performing a uniform scores transformation, will have no impact on the Copula (Shiau, 2003). In addition, a powerful tool for modelling and sampling multivariate data that are nonlinearly interrelated (Mckee., *et al* 1995). Taking into cognizance all these, before any surmised engineering projects can be undertaken to address water management problems or take advantage of the opportunity for increased economic, ecological, environmental and social benefits, need to be planned in line with hydrological variability (drought and flood). Over the years the hydrological drought studies, as well as Copula drought modelling approaches, have been seldom researched and there are no single drought quantification indices ever formulated for this basin, in line with this, this study sought to fill such gap. Thus, aimed, to find a realistic bivariate Copula model and Tail dependence for the drought series in the basin and establish coherent Severity- Duration- Frequency (SDF) Curves for Risk Assessment.

2.Methodology

Data collection and management

For this study, secondary data on precipitation and streamflow was mobilized; both the precipitation and streamflow time sequence was based on monthly temporal resolutions respectively. The time sequences of precipitation and streamflow ranged from 1901-to 2010 years. Consistency tests and continuity tests were done; based on these tests, non-continuous data years were removed. These data were obtained from NIMET and Sokoto- Rima River Basin Development Authority Zonal offices across the catchment States.

Statistical distribution functions

The variable threshold level method was employed for the determination of drought threshold, and by extension quantification of the volume of deficit or severity and by extension quantification of the volume of deficit or severity. Variable thresholds of 30th, 20th and 10th were used due to the probability of seasonal variability in the streamflow series. Threshold, was defined for each month, say P_{20},T; T = 1, 2, 3, . . . ,12. Based on this, the cumulative volume of deficits was taken as the temporal extent of severity and the corresponding time was noted as the duration

The time series of duration D and severity S was then fitted to a range of cumulative distribution functions. Gamma, Weibull and General Extreme Value as well as lognormal distribution were explored to select the probable best candidate distribution or marginal for the drought series. The best-fitted distribution was determined using Akaike's Information Criterion (AIC) and Schwarz Information Criterion (SIC or BIC). Criterions with the lowest value was chosen as the best candidate model. The best fitted univariate probability models were linked using Copula, thus constructing the joint cumulative distribution function (JCDF) of drought severity and duration. For this study, the Gumbel – Hougaard, Frank, and Clayton Copulas were explored to determine the most suitable Copula in this regard, it suffices to note that these Copulas belong to the group of Archimedean Copulas.

These copulas with their respective generators are as given below

Gumbel- Hougaard Copula

For a bivariate condition as in this study, this is expressed as

$$C_{\emptyset}(u,v) = C_{\emptyset}[F_x(x).F_y(y)] = F_{xy}(x,y)$$

$$= \mathrm{Exp}\left\{-[-\mathrm{in}(u))^{\theta} + (-\mathrm{In}(v))^{\theta}]^{\frac{1}{\theta}}\right\} \quad (2)$$

$\tau = 1 - \theta^{-1}$, $\theta \in [1, \infty]$

$\emptyset(t) = (-\mathrm{In}(t))^{\theta}$ is the generating function and θ the parameter, while τ is Kendall's τau depicting the coefficient of correlation.

Frank Copula

Here,

$$\emptyset(t) = \mathrm{In}\left[\frac{\exp(\theta t)-1}{\exp(\theta)-1}\right] \quad (3)$$

$\tau = 1\text{-}\frac{4}{\theta}[D_1(-\theta) - 1]$

where,

D_1 = first order Debye function; this is computed according to as

Positive argument:

$$D_k(\theta) = \frac{K}{x^k}\int_0^{\theta} \frac{t^k}{\exp(t) - 1}\,dt, \qquad \theta > 0$$

Negative argument

$$D_k(-\theta) = D_k(\theta) + \frac{K\theta}{K+1}$$

The Copula is expressed as:

$$C_\emptyset(u,v) = C_\emptyset[F_x(x).F_y(y)] = F_{xy}(x,y)$$
$$= \frac{1}{\theta} \text{In} \left[1 + \frac{ex(\theta u)-1][exp(\theta v)-1]}{exp(\theta)-1}\right], \theta \neq 0 \quad (4)$$

Clayton Copula

Both the generating function and the Copula are respectively,

$$\phi(t) = t^{-\theta} - 1 \quad (5)$$

$$C_\emptyset(u,v) = C_\emptyset[F_x(x).F_y(y)] = F_{xy}(x,y)$$
$$= [u^{-\theta} + v^{-\theta} - 1]^{-\frac{1}{\theta}}, \theta \geq 0, \quad (6)$$
$$\tau = \frac{\theta}{\theta+2}$$

The best-fitted Copula parameter was selected based on test statistics, thus using Akaike's Information Criterion (AIC) and Schwarz Information Criterion (SIC or BIC).

Development of Hydrological Drought Severity- Duration – Frequency (SDF) Curves for Risk Assessment.

In order to explore the correlated characteristics for risk assessment, the SDF curve was established. To achieve this, the conditional probability of the duration given that the severity is less than a certain amount(s) was computed as:

$$P(D < d/S<s) = \frac{P(D<d,S<s)}{P(S<s)}$$
$$\frac{C(D<d,S<s)}{F(s)} \quad (7)$$

Similarly, for the conditional probability of severity of hydrological drought given that the duration is less than a specified amount given below

$$P(S < s / D<d) = \frac{P(D < d,S<s)}{P(D < d)} = \frac{C(D<d .S<s)}{F(d)} \quad (8)$$

On the other hand, the relation between hydrological drought severity, duration and frequency (in terms of recurrence interval: T) for drought events were analysed based on the following Scenarios

Return period for D > d and S > s and

Return period for D > d or S > s

These scenarios were analysed for purpose of risk assessment thus:

Case I: $D \geq d$ and $S \geq s; D \geq d \; or \; S \geq s$

Both joint return periods for the Copula based events are represented as

$$T_{DS} = \frac{E(L)}{P(D \geq d .S \geq s)} = \frac{E(L)}{1-F_D(d)-F_S(s)+C(F_D(d).F_S(s))} \quad (9)$$

$$T'_{DS} = \frac{E(L)}{P(D \, T_S d \; or \; S \geq s)} = \frac{E(L)}{1-(F_D(d).F_S(s))} \quad (10)$$

Case II:

The focus of this work is to determine the joint return period of hydrological drought duration given (1) drought severity exceeding a certain threshold and (2) return period of drought severity given drought duration exceeding a particular threshold. This scheme was implemented mathematically according as:

$$T_{D/S \geq s} = \frac{T_S}{P(D \geq d.S \geq s)}$$
$$= \frac{E(L)}{[1- F_S(s)][1-F_D(d) - F_S(s) + C(F_D(d).F_S(s)]} \quad (11)$$

$$T_{S/D} \geq d = \frac{T_D}{P(D \geq d.S \geq s)}$$
$$\frac{E(L)}{[1- F_D(d)][1-F_D(d) - F_S(s) + (F_D(d).F_S(s)]} \quad (12)$$

3. Results and Discussions

3.1 Seasonality and Catchment Goodness-of-Fit of Responses

Adopted Threshold Level:

Sequel to the result of variable threshold levels generated from the basin as depicted in Table 1. Suffices to know that, the deficit volume and number of drought occurrences recorded by 30% threshold level was a better representative of the basin hydrological drought phenomenon, this is further buttressed by the fact, that the incidence of a drought cut across critical months like Apr June, July August and September and these are surmised peak period of rainfall. In addition, the pattern of drought incidence distribution with a 30% Threshold was the same as the result of trend analysis, specifically Z-Statistical. A z-Statistical analysis earlier portrays a significant decrease in rainfall pattern in the first quarter and partly second quarter of the year in stations near cities; which is in line with the thought of Yarahmad (2009).

Table 1: Overview of Drought Severity Series of the Basin

Threshold	Drought Occurrence	Deficit Volume (Mm3)
10%	83	1491.19
20%	90	1771.48
30%	103	2190.03

Probability Distribution Fittings

Tables 2 – 3 clearly show the performance of each of the probability distributions namely, extreme value, log-normal, gamma, Weibull in terms of AIC and BIC goodness-of-fit criteria. It is glaring that 67% of the station's drought severity series obeys gamma distribution as shown in **Table 2**, which is in confirmation with the thought (Shiau, 2006). In line with the findings of Shiau (2003), **Table 3** reveals that 67% of the station's duration series obeys the Weibull distribution. Therefore, it is pertinent to note that this research used Weibull Distribution to simulate drought duration and Gamma Distribution to simulate drought severity and the independent univariate marginal of the drought component was then modelled using copular strategies. Figure 1 presents a visual appreciation of drought characteristics - severity and duration, which shows that there is a non-linear relationship that exists between the variable. Thus, establishing a need for an invariant bivariate model, capable of capturing the independent univariate marginal of severity and duration.

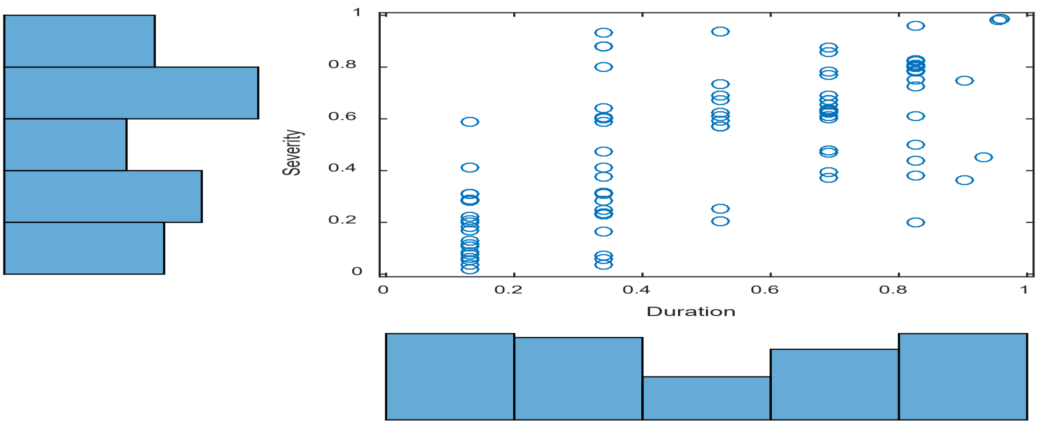

Figure 1: Scatter plot of severity and duration and marginal histogram

Table 2: Probability Distribution and their Test Statistic for Severity Series

Station	Distribution	Test Statistics		95% Cl	Estimated Parameter
		AIC	BIC	(Upper and lower Interval)	(Shape and Scale)
Gusau	Gamma	-445.0458	-441.0058	[89.1862 0.2749] [565.2275 1.7459]	[224.5229 0.6928]
Zobe	Extreme value	-29.9402	24.7021	[10.8852 4.8359] [23.0551 14.2015]	[16.9701 8.2872]
Goronyo Pre-Dam	Gamma	1.7308	0.0671	[0.6000 19.9319] [2.1455 97.6901]	[1.1346 44.1265]
Goronyo Post-Dam	Gamma	2.2090	1.9012	[0.5217 59.0259] [1.5373 245.0048]	[0.8955 120.2565
Bakalori	Gamma	-153.1748	-152.0748	[0.2684 36.4111] [1.0108 283.8406]	[0.5208 101.6609]
Jibiyia	Extreme value	-209.7244	-209.7244	[96.2402 14.1254] [117.484 27.3778]	[106.8622 19.6652]

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3.2 Copula modelling and tail dependence analysis

Test of fitness criteria; AIC and the SIC show that the Frank copula provides the best fit to the data since it has the lowest values for both criteria: AIC and SIC. As noted in Table 4. It is imperative to note that the Frank copula allows the maximum range of dependence. This implies that the dependence parameter of the Frank copula permits the approximation of the upper and the lower Fréchet-Hoeffding bounds and thus the Frank copula permits modelling positive as negative dependence in the data. When θ approaches ∞ and $-\infty$ the Fréchet-Hoeffding upper and lower bound will be attained. The independence case will be attained when ∞ approaches zero. However, the Frank copula has neither lower nor upper tail dependence which makes it suitable for modelling drought and this agreed with the finding of Ganguli et al. (2012) who relate, that Frank Copula perform best when analysing the bivariate drought dependence structure of drought variables such as severity and duration. In addition, the inference here is that the drought characteristics in the basin neither have lower nor upper tail dependence. It is evident because the Frank Copula model was able to model the dependent variables of the drought event in the basin. It was based on this, that the independent univariate probability distributions of duration and severity were fitted into the Frank Copula model, to construct a bivariate joint distribution of D and S (Sklar,1959) as shown in equation 12. Considering all these, the Frank Copula can allow the maximum range of the dependence and hence permits the modelling of positive as well as negative dependence in a data series. Figure 2 gives more insight on the dependence structure given by this copula, plots of the copula joint CDF of the drought of duration and severity of the basin, As expected from the estimated copula parameter, the plots of the copula illustrated in **Figure 2** show that the estimated Frank copula is characterised by neither lower nor upper tail dependence. From **Table 5** it is succinctly clear that there is a dependence between the upper tail and lower dependence, the value for the Clayton and Gumbel attest to this. This is purely typical of volatility clustering and thus lends credence to the universality of the Frank Copula in this regard.

$$C^{Fr}\left(F_{duration}(D), F_{severity}(S)\right) = 6.1390^{-1}\log\left\{\mathbf{1} + \frac{\left(e^{-6.1390F_{duration}}-\mathbf{1}\right)\left(e^{-6.1390F_{severity}}-\mathbf{1}\right)}{\left(e^{-6.1390}-\mathbf{1}\right)}\right\} \quad 12$$

$F_{duration}(D)$ = Cumulative distribution frequency (CDF) of duration

$F_{severity}(S)$ = Cumulative distribution frequency (CDF) of severity
θ = 6.1390

Table 4: Copula Parameter Estimation

Copula	Estimated Parameter	95% Cl	AIC	BIC
Clayton	2.3131	[1.6581,2.9680]	-0.6262	3.3738
Gumbel	2.0713	[1.7960,2.3467]	-0.1426	3.8574
Frank	6.1390	[4.7647,7.5134]	-8.2780	-4.2780

Note: Formula: Clayton: $\lambda_L = 2^{\frac{-1}{\theta}}$;

Gumbel = $\lambda_L = 0$, $\lambda_U = 2^{\frac{-1}{\theta}}$; Frank: $\lambda_L = 0$; $\lambda_L = 0$

Table 5: Tail Dependence Analysis

Copula	Parameter (θ)	Confidence Interval	
		λ_L(lower)	λ_U(upper)
Clayton	2.3131	0.7411	NA
Gumbel	2.0713	0.000	0.6026
Frank	6.1390	0.000	0

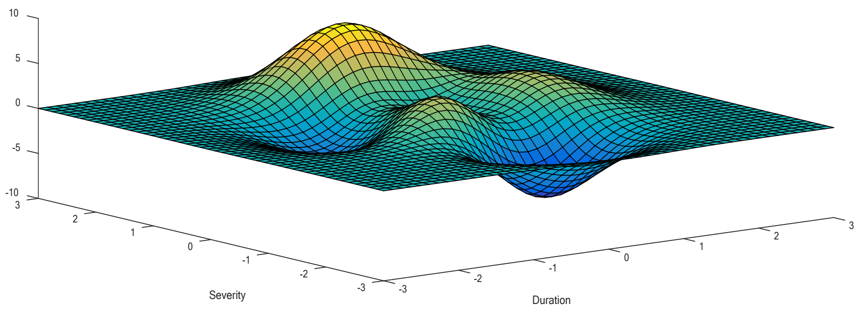

Figure 2: Joint CDF of drought severity and duration

3.3 Establishment of Severity- Duration- Frequency (SDF) Curves for Risk Assessment

The Frank copula probability model was used to estimate the joint Return period for severity and duration series and the mean value for each return period is shown in Table 6. The development of S-D-F for risk assessment was done by interpolating, that is the mean values of the return period for the corresponding severity and duration. Extrapolating the mean value as indicated can also be done for long-term purposes. This means a pool of information can be generated based on available hydrological data. Accordingly, it becomes possible to combine many droughts duration and severity in the same return period, and the bivariate return period can be expressed in Figure 3. Approximation was done in the form of the drought duration – severity, as a function of the return periods or frequency. By placing duration on the x-axis, and severity on the y-axis, an SDF curve was drawn, which was used to estimate the probability of drought amount or deficit volume. Utilising the SDF curve in Figure 3, it is possible to calculate the probable deficit volume and it could be used as an important preliminary data analysis to deal with future droughts or to quantify drought risk. For example, if there were to be a plan to deal with droughts lasting 3 months within 5 year return period by the Sokoto-Rima River Basin Authority, measures need to be taken corresponding to the approximate deficit volume of 17Mm3. This information can help design proper water harvesting and conservation structures (such as check dams and percolation tanks) that can increase water availability in drought years. The S-D-F curve is a useful tool to understand the temporal characteristics of a drought event, which can be used in taking future drought mitigation strategies. In this regard, the S-D-F curve was used for drought risk assessment in the basin. That is because of the ability of the S-D-F curve to give corresponding deficit volume for every identified duration as a function of a return period.

Table 5: Joint Return Periods for Drought Variables

Return Period (Yr)	Duration (months)	Severity (Mm^3)
1	1.4301	6.7940
2	1.8880	28.905
3	2.000	63.960
5	6.0321	4.5600
6	2.600	187.920

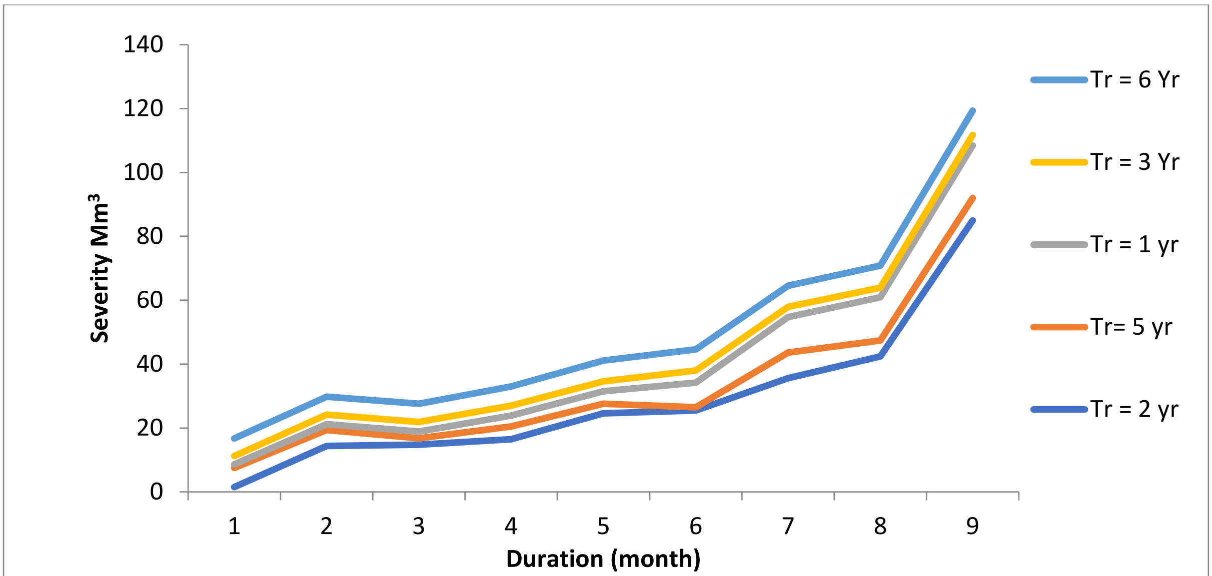

Figure 3: S-D-F Curve for Sokoto-Rima Basin based on Frank Copula

4. Conclusions

Based on the results obtained in all instances, the following conclusions were drawn, namely:
The univariate hydrological drought severity and duration respectively obey Gamma and Weibull cumulative distribution functions.
On average, both the severity and duration of hydrological drought in the Basin are mild and may become deleterious.
The Frank copula of the Archimedean family was adjudged the most suitable model based on minimal AIC (-4.2780) and SIC (-8.2780) statistics. Frank copula since has the capacity of modelling both negative and positive tail dependence.
Based on the Copula results, the mean hydrological drought severity for the basin is 17Mm3 with a duration of 5 months and a corresponding return period of 3 years.
It is imperative to conclude that the bivariate dependence of hydrological drought characteristics can effectively be modelled by the copula strategy as it allows for the determination of joint probability distribution and return period for risk assessment of drought in both the short and long term.
Thus resulting from the conclusions drawn, the following recommendations are proffered, namely:
Since the hydroclimatic process exhibit high volatility and leptokurtosis, before the adoption of the bivariate copula, ARMA-GARCH modelling should be made to reduce high incidences of perturbation.
For effective risk assessment of hydrological drought phenomena, a trivariate copula should be adopted**.**

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CONSTRUCTED WETLAND TREATMENT SYSTEMS: AN INNOVATIVE AND INDIGENOUS TECHNOLOGY FOR SUSTAINABLE WASTEWATER MANAGEMENT AND ENERGY PRODUCTION

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Abstract

The need for sustaining an alternative source of energy cannot be overemphasized. Constructed wetlands are a sustainable and viable green environmentally friendly technology that offers a lower construction and maintenance cost for wastewater treatment and this is particularly suitable for developing countries. Thus, this poster aims to present the efficiency of vertical subsurface flow constructed wetlands planted with Typha latifolia in treating secondary refinery effluent below compliance limits and to evaluate the possibility of using harvested T. latifolia biomass for bioenergy production. The results from a 308 – day treatment showed gradual acclimatization of the treatment systems which also translated into gradual increment in plant growth and removal efficiencies. The average removal efficiency of 61%, 88%, 74%, 71%, 45%, 62% and 66% for total dissolved solids, turbidity, biological oxygen demand, chemical oxygen demand, phosphate, ammonia and nitrate, respectively were observed. The T. latifolia showed a steady increase in canopy height, the highest mean height recorded was 185 cm on day 181. Biomass production was determined by harvesting the plants at specified time intervals and measuring dry weight production. The average dry weight *production was equivalent to 175 t/ha/yr. The harvested biomass can be put into commercial products such as pellets and briquettes for bioenergy utilization for heating and cooking with less reliance on woods (hence, saving our environment from degradation due to deforestation). It thus proved that constructed wetlands can be effectively used for both wastewater treatment and bioenergy production.*

Keywords: Constructed wetlands, Energy production, Management, Sustainability, Treatment, Wastewater

1. Introduction

Constructed wetlands are a sustainable and viable green environmentally friendly technology that offers a lower construction and maintenance cost for wastewater treatment and this is particularly suitable for developing countries (Perbangkhem & Polprasert, 2010). Constructed wetlands have been used for decades in the developed world, and their efficiencies have been reported in various literature for the removal of organic, nutrients, heavy metals and bacteria from wastewater (Vymazal, 2008). Meanwhile, these technologies have been largely ignored in developing countries where effective, low-cost wastewater treatment strategies are critically needed (Mustapha, van Bruggen, & Lens, Vertical subsurface flow coonstructed wetlands for polishing secondary Kaduna refinery wastewater in Nigeria, 2015). The main components of a constructed wetland are plants, substrates and microorganisms (Perbangkhem & Polprasert, 2010). Some of the advantages of the use of constructed wetlands for wastewater treatment are water reuse and biomass utilization (Vera, Gutiérrez, Martel, Márquez, Salas, & Sardón, 2006). There is reported literature on biomass utilization from constructed wetland treatment plots. The economic benefits from constructed wetlands are an important consideration in developing countries where additional incentives are required to encourage communities to maintain treatment wetlands (Belmont, Cantellano, Thompson, Williamson, & S´anchez, 2004). Also, the gains in biomass production from constructed wetlands can provide economic returns to communities when harvested for biogas production, animal feed, fibre for papermaking and compost (Mustapha, 2016).

Typha spp. is an aquatic, emergent monocotyledon perennial herb of about 2.0 - 4.5 m high with linearly erect leaves and green stems extending well above the surface of the water as well as with extensive rhizomes and roots systems (Salako, Sawyerr, & Olalubi, 2016). It has a well-developed vascular system and supporting tissues (Kay, 2001). They can be beneficial or nuisance in aquatic systems depending on the defined uses of the aquatic systems (Mustapha, 2016). In addition, *Typha spp*. has been used in wastewater treatment to remove nutrients, organic matter (Mustapha, van Bruggen, & Lens, Vertical subsurface flow coonstructed wetlands for polishing secondary Kaduna refinery wastewater in Nigeria, 2015) and heavy metals (Mustapha, Rousseau, van Bruggen, & Lens, 2011). Thus, this poster presentation aims to present the efficiency of vertical subsurface flow constructed wetlands planted with *Typha latifolia* in treating secondary refinery wastewater below compliance limits and to evaluate the possibility of using harvested *T. latifolia* biomass for bioenergy production.

2. Materials and Methods

Two microcosm constructed wetlands with dimensions of 47 cm x 55 cm (diameter x height) were used for the treatment of total dissolved solids, turbidity, biological oxygen demand, chemical oxygen demand, phosphate, ammonia and nitrate in secondary treated refinery wastewater. Gravel mixed with coarse sand was used as the substrate materials. The vertical subsurface flow constructed wetlands treatment systems were filled with these substrate materials in three layers starting from the bottom 20 cm depth of 60 – 80 mm, middle layer 20 cm depth of 6 - 12 mm and the top which supports plant roots 15 cm depth of 1 – 2 mm (Fig. 1). The wastewater was fed continuously into the wetland units for 308 days (Table 1). The influent and effluent samples were collected from the constructed wetlands for determination of total dissolved solids, turbidity, biological oxygen demand, chemical oxygen demand, phosphate, ammonia and nitrate following the standard Methods for Examination of Water and Wastewater (APHA, 1989). The ability of the constructed wetland to reduce pollutant concentrations is calculated by subtracting the initial concentrations of pollutants from the final concentrations. This is expressed as:

$$Removal\ efficiency\ (\%) = \frac{Concentrations_{Final} - Concentrations_{Initial}}{Concentrations_{final}}$$

Table 1. Hybrid wetlands design considerations for the study

Description	**CWI**
Treatment system	VSSF
Dimension (cm)	47x55(Ø x h)
Plant	*Typha latifolia*
Substrate	Gravel
Loading method	Continuous
Flow rate	20L/day
Hydraulic Retention Time	4days

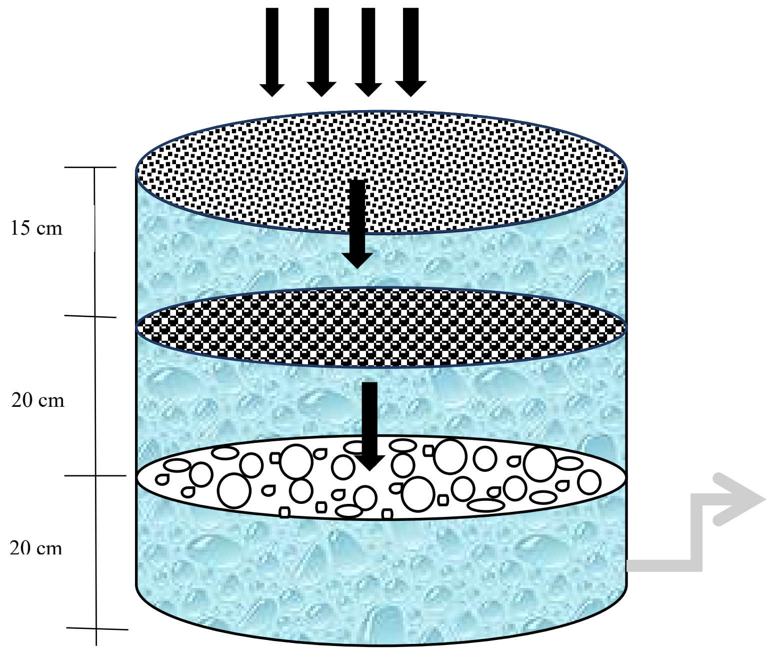

Fig. 1. Vertical subsurface flow constructed wetland showing substrate arrangement and design of hydrologic flow pattern.

T. latifolia was selected for the study. Its growth was monitored by determining plant height, number of leaves per plant, number of new shoots added and density of plants per constructed wetland at the start and end of the 120-day experiment. They were done by manually counting the number of leaves per plant and density of plants per bioreactors while the plant canopy (heights) was measured with a ruler to the nearest centimetres. Plant above and below biomasses of *T. latifolia* per constructed wetland harvested was determined for their productivity at the end of the experiment. The calorific value of *T.*

latifolia was determined using the mathematical expression given by Kwaghger, Enyejoh, & Iortyer, (2017)

3. Results

The results from the vertical subsurface flow constructed wetland treatment system showed gradual acclimatization of the treatment systems which also translated into gradual increment in plant growth and removal efficiencies. The average removal efficiency of 61%, 88%, 74%, 71%, 45%, 62% and 66% for total dissolved solids, turbidity, biological oxygen demand, chemical oxygen demand, phosphate, ammonia and nitrate, respectively were observed (Fig. 2) with turbidity and phosphate showing the highest and the lowest removal efficiencies.

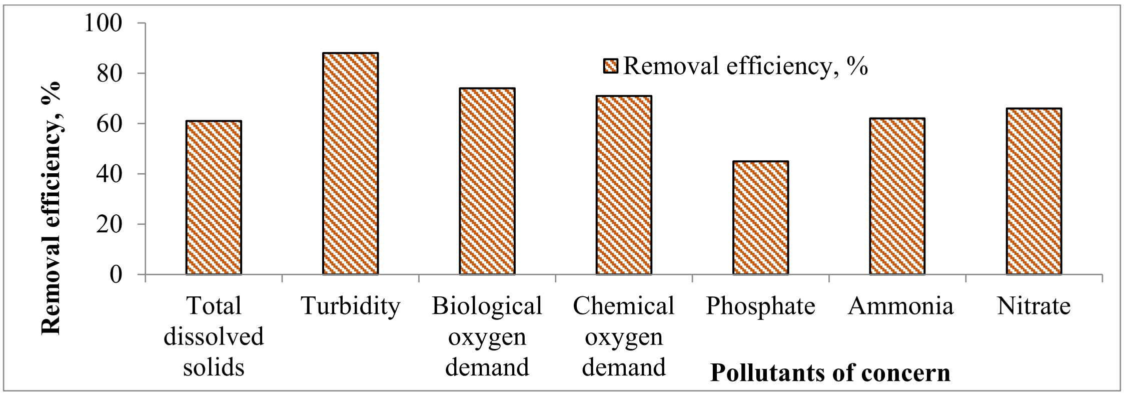

Fig. 2. The percentage removal efficiency of vertical subsurface flow constructed wetlands

Typha latifolia responded positively well in secondary refinery wastewater by showing no negative effect on both plant live stem density and height throughout the study. This is presented in Fig. 1. Fifteen shoots were initially transplanted at the startup which averagely increased to 50, 87 and 128 corresponding to 42 cm, 96 cm and 134 cm, respectively.

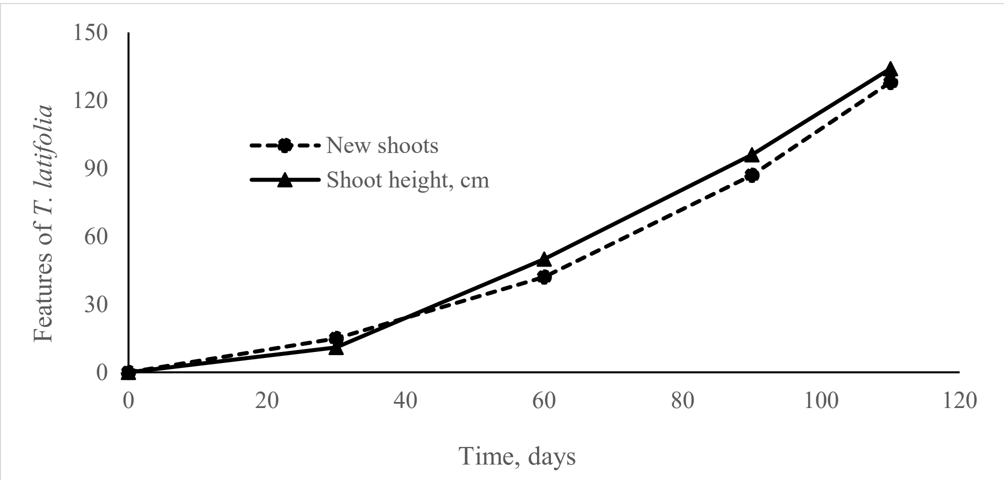

Fig. 1. Growth of *T. latifolia* in terms of shoot height and density

The harvested aboveground biomass of *T. latifolia* had an initial average wet weight of 4.0 kg which was taken before transplanting and at the end of the experiment (7.8 kg). There was an increased wet weight corresponding to new shoot production (2.8 kg). The sorted *T. latifolia* tissues at startup were oven-dry corresponding to 0.48 kg, 0.08 kg and 0.04 kg for roots, stem and leave respectively and at the 120 days were 1.05 kg, 0.17 kg and 0.09 kg for roots, stem and leaves respectively (Fig. 2). The roots (0.40 – 1.1 kg/pot) and leaves (0.04 – 0.09 kg/pot) produced the highest and lowest biomass, respectively both at the start-up and end of the experiments. Also, the tissues of *T. latifolia* contained moisture content of 76, 90 and 86% for roots, stems and leaves respectively.

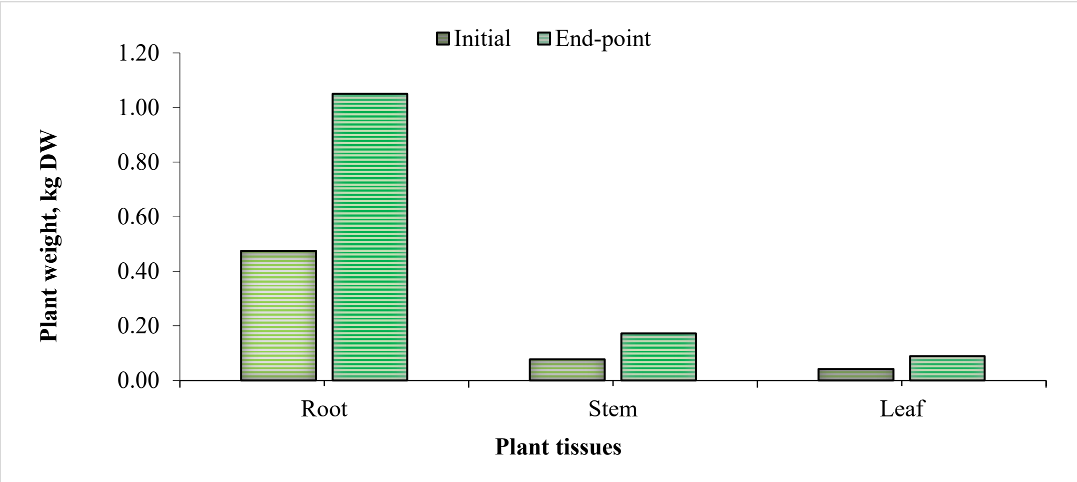

Fig. 2. Typha latifolia biomass production from constructed wetlands

4. Discussion

Removal of biological oxygen demand and chemical oxygen demand in the treatment wetlands were commendable. This observation is similar to other findings reported in the literature; thus, the degradation of organics was due to the absorption of pollutants by plant roots and the breakdown of organic compounds by the associated microorganisms (Worku et al., 2018). The removal performance of ammonia and nitrate is often low, in contrast, this study showed a higher performance. This can be explained by the low nitrogen concentrations in the influent.

T. latifolia plant species is a perennial plant species, its contaminant degradation efficiency can be affected by the aboveground biomass (McIntosh, Kuzovkina, Schulthess, & Guillard, 2016). In this study, *T. latifolia* plant species actively grew well in the constructed wetlands constant increase without showing any sign of phytotoxicity throughout the 120-day study period. *T. latifolia* thus demonstrated high resistance to petroleum contaminants (McIntosh et al., 2017). The progressive increase in growth of *T. latifolia* corresponded to an increase in the number of shoots, plant density and height. This increment may be due to abundant sunshine in the tropics since the actual yield of energy in the plant depends on the product of solar input and the efficiency with which the solar energy is transformed into the harvested product (Perbangkhem & Polprasert, 2010). However, it was observed that they were variations in plant density among the constructed wetland treatment systems. This may be related to the health conditions of the individual plant species that may have affected its multiplication (Worku, Tefera, Kloos, & Benor, 2018). Generally, *T. latifolia* is known for its high biomass productivity. The average estimated fresh biomass of *T. latifolia* harvested from this experiment varied from 27 to 52 kg/m^2 per constructed wetlands. This was higher than the estimated value (9.20 – 12.96 kg/m^2) from Worku et al. (2018). Accordingly, Liu et al. (2012) reported that energy output from existing constructed wetlands in China is 237% of the input for biofuel production and this can be enhanced through optimizing nitrogen supply, hydrologic flow patterns and plant species selection. Thus, biomass production from T. latifolia is adequate for biofuel production and the harvested biomass can be put to various economic uses.

5. Conclusions

Constructed wetlands are sustainable and viable alternatives for different types of wastewater treatment.

The average dry weight production was equivalent to 175 t/ha/yr.

Harvested biomass from treatment wetlands can serve as raw materials for biogas production, animal feed, fibre for papermaking and compost.

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SIMULATION OF LAND AND WATER PRODUCTIVITY OF SOYBEANS UNDER DIFFERENT SOIL FERTILITY USING FAO AQUACROP MODEL IN SUB-HUMID AREA OF NIGERIA

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Abstract

Modelling the effects of water and different levels of nitrogen on evapotranspiration and water productivity of rain-fed soybeans is very important in optimising resource use in the production of the crop. The objective of the study was to model evapotranspiration, soil water storage and water productivity of rain-fed soybeans under different levels of nitrogen fertilizer by using the FAO AquaCrop model. Field experiments were conducted at the Teaching and Research Farms of Obafemi Awolowo University, Nigeria in the rainy seasons of 2015 and 2016. There were five levels of nitrogen, which are 00, 25, 50, 75 and 100% of the recommended nitrogen applications and two varieties of soybeans, which produced a 2 by 5 factorial experimental design. The data of the wetter in the year 2015, were used for calibration of the AquaCrop model because AquaCrop is water driven. The 2016 data were used for the calibration and validation respectively. The AquaCrop model simulated canopy cover with R^2 and EF > 0.90, d-index ≥ 0.99. The model captured the trend of the soil water storage well, R^2 and EF ≥ 0.70. The AquaCrop model-simulated soil water storage below wilting point for seasonal rainfall less than 600 mm, and it did not overestimate it. The model predicted evapotranspiration with R^2 and EF ≥ 0.89, d-index = 1.00. Above-ground biomass was overestimated even though R^2 ≥ 0.98. Although nitrogen stress reduced seed yield and water productivity, there was no under or overestimation of the seed yields. They were predicted with low error under the different levels of nitrogen fertilizer, R^2 ≥ 0.99, EF and d-index ≥ 0.99. The AquaCrop model is suitable for simulating canopy cover, soil water storage, evapotranspiration, and seed yield of rain-fed soybeans with different levels of nitrogen fertilizer under the temporal distribution of seasonal rainfall. Therefore, it can serve as a useful tool for smallholder farmers in predicting the productivity *of soybeans as well as optimising land use, resource allocation, and water use in tropical farming systems. We recommend simulation of the effects of pests on biomass, seed yield and water productivity by subsequent versions of the AquaCrop model. In addition, incorporating an economic sub-unit in the model will enable users to make financial decisions.*

Keywords: AquaCrop, soybeans, Nitrogen fertilizer, Process-based model, Nigeria

1. Introduction

Soybean, *Glycine max* L. merr) is the most important and cultivated legume in the world because it has the largest harvested area (Stagnari et al. 2017). The harvested area and total production in 2017 were 118 million ha and 307 million respectively and production of the crop from Nigeria constituted about 0.6% of global production (FAO 2017). It will continue to play prominent roles in the production of protein for the consumption of man and animal and the production of biodiesel fuels (da Silva César et al. 2019).

Nitrogen is a crucial element in the soil and its concentration determines the productivity of crops. The global use of nitrogen fertilizers has increased sevenfold in parallel with the doubling of agricultural food production. Therefore, the use of nitrogen fertilizer in the production of soybeans and other crops is one of the major factors for producing sufficient food to meet the demand of the increasing human population over the last four decades (Fischer et al. 2009).

Rain-fed agriculture is the predominant agricultural production system worldwide. In sub-Saharan Africa (SSA), crop production is largely rain-fed (FAO 2011). In SSA, productivity has been identified to be low for most crops because of the inherent low fertility of the soil and poor management of water under rain-fed agriculture. The potential impact of the application of fertilizer on the production of crops has been studied in the laboratory for many years. However, data on the effects of nitrogen on the productivity of soybeans in large fields are scarce in Nigeria because it is labour and capital intensive. Therefore, sustainable management of land and water to increase the productivity of soybeans may demand an appropriate addition of mineral nitrogen fertilizers to improve soil fertility (Giller et al. 2011). Process-based crop simulation models can contribute immensely to achieving this task.

Models are mathematical representations of mechanisms that govern natural phenomena that are not fully recognized, controlled, or understood. In order to study the responses of crops to soil fertility and environmental conditions, crop models are often used to complement field experiments (Myers 2005). Crop growth simulation models are recognized as useful tools in agricultural research, they have been used for many years to test the responses of crops to changes in environmental conditions (Corbeels et al. 2018), and to develop alternative strategies for managing soil fertility (Doltra et al. 2019). These models include (STICS) Simulator multidisciplinary for Crop Standard (Brisson et al. 2003); for water management practices, for instance (DSSAT), Decision Support System for Agro-technology Transfer (Jones et al. 2003). These simulation models typically adopt a nutrient-balance technique to model the effects of soil fertility on the production of crops. One of the disadvantages of the approaches in simulating the effects of soil fertility on crops is the requirement of a vast input of data. The nutrient balances are mostly simulated for soil selected nutrients and in most cases nitrogen, which is not always the only nutrient that limits the growth and development of field crops. This challenge prevents the application of complex nutrient-balance-based crop simulation models by smallholder farming systems in developing countries (Probert and Dimes 2004).

Crop growth models enable a good understanding of the influence of environment and plant characteristics on the development of crops (Brisson et al. 2003). Models can help to compare findings of experimental studies across climatic locations, extrapolate field data to a larger environment, explore the impacts of climate change on yield predictions, and develop decision-support systems that can aid management recommendations. Simulation models that are user friendly can be used for managing resource input for land and water development, teaching, and research. It has been observed that most of the existing models are very sophisticated and require advanced scientific and computational skills and input of many parameters that are not easily obtainable for many crops and agro-ecological environments. These input parameters are mostly determined during field or laboratory experiments. Therefore, they are mechanistic as well as suitable for scientific research and theoretical analyses of systems only. They are difficult to apply in large-scale field situations or by smallholder farmers due to the large number of required inputs that are often difficult to acquire (Addiscott 2003). Extension practitioners, government agencies, non-governmental organizations, farmers' unions, and consultants who are the end-users of the models may experience huge difficulties in using the models. This restricts their usage to scientists only. The reliability of the complex models is very high, but their application requires more advanced mathematical and analytical skills than simple and robust crop yield models (Sinclair and Seligman 1996). This makes it challenging for simulation models to find relevance in real-world agriculture, especially in developing countries (Carberry et al. 2004). Therefore, there was a need to balance simplicity and accuracy to achieve broad usage of the models by the end-users. The Food and Agriculture Organization of the United Nations (FAO) addressed this concern by developing a simple and robust model called AquaCrop. The AquaCrop model requires relatively few explicit inputs. Further, they are largely intuitive input variables, which require simple procedures for their estimation or measurement (Steduto et al. 2009). AquaCrop evolved from the original concept of crop yield response to water availability developed by (Doorenbos and Kassam 1979). The conceptual framework and solutions to the algorithms are described fully in (Steduto et al. 2009) and (Raes et al. 2009). Although the AquaCrop model is straightforward and simple to apply, it is based on complex scientific biophysical processes to quantitatively assess the impacts of environmental and management factors on the productivity of crops (Hsiao et al. 2009). In AquaCrop, the calibration of the model is crop-specific.

The AquaCrop model has a water-driven growth engine for herbaceous field crops and a growth module that uses the conservative behaviour of biomass per unit transpiration (T_r) relationship (Steduto *et al.*, 2007). It has an interface and is a menu-driven program, with a set of input files describing the soil–water–crop–atmosphere environment and also captures field and management practices. AquaCrop models agronomic parameters in calendar days in daily time steps or thermal time-growing degree-days (GDD).

The effects of nitrogen fertilizer on rainfed soybeans for smallholder' farmers in Southwest Nigeria and the performance of the AquaCrop model in managing soil fertility for the crop have not been investigated. It is important to study the contributions of nitrogen to the development and yields of crops, especially under rain-fed conditions, to maximize productivity. Therefore, the objective of the study was to simulate canopy cover, yield and water productivity of soybeans under varied nitrogen fertilization by using the AquaCrop model and investigating the effects of nitrogen on the seed yield of the crop.

2.Materials and Methods

2.1 Study area

The experiments were carried out during the rainy seasons of 2015 and 2016 at the Teaching and Research Farms of Obafemi Awolowo University, Ile-Ife, Nigeria, latitude 7° 33′ 0″N and longitude 4° 34′ 0″E, 271 m+MSL (mean sea level).

2.2 Environmental data

The VISALA HMP45 was used to measure the daily air temperature (°C) and relative humidity (%) at intervals of 10 min and an ultrasonic anemometer (Campbell Scientific, USA) was used to measure wind speed at an elevation of 2 m above ground level. A Pyrometer (Apogee Instruments, USA) was used to measure daily global solar radiation (MJ m^{-2} day^{-1}). Daily rainfall was measured throughout the growing seasons by using a standard rain gauge. The Penman-Monteith formula was used to determine reference evapotranspiration (ET_o) under standard environmental conditions (Allen et al. 1998). Seasonal rainfall in the years 2015 and 2016 were 557 and 542 mm respectively and were higher than the peak seasonal (September - December) rainfall in the study area in the past thirty-two years (Fig. 1). In 2015, the maximum and minimum air temperatures were 36.2 and 15.1 °C (September – December) while in 2016, the comparative air temperatures were 31.3 and 19.1 °C respectively. In the study area, the peak air temperature (September to December) during the past thirty-two (32) years was 33.7 °C while the minimum was 13.6 °C. The seasonal air temperature in 2015 was higher than that of 2016.

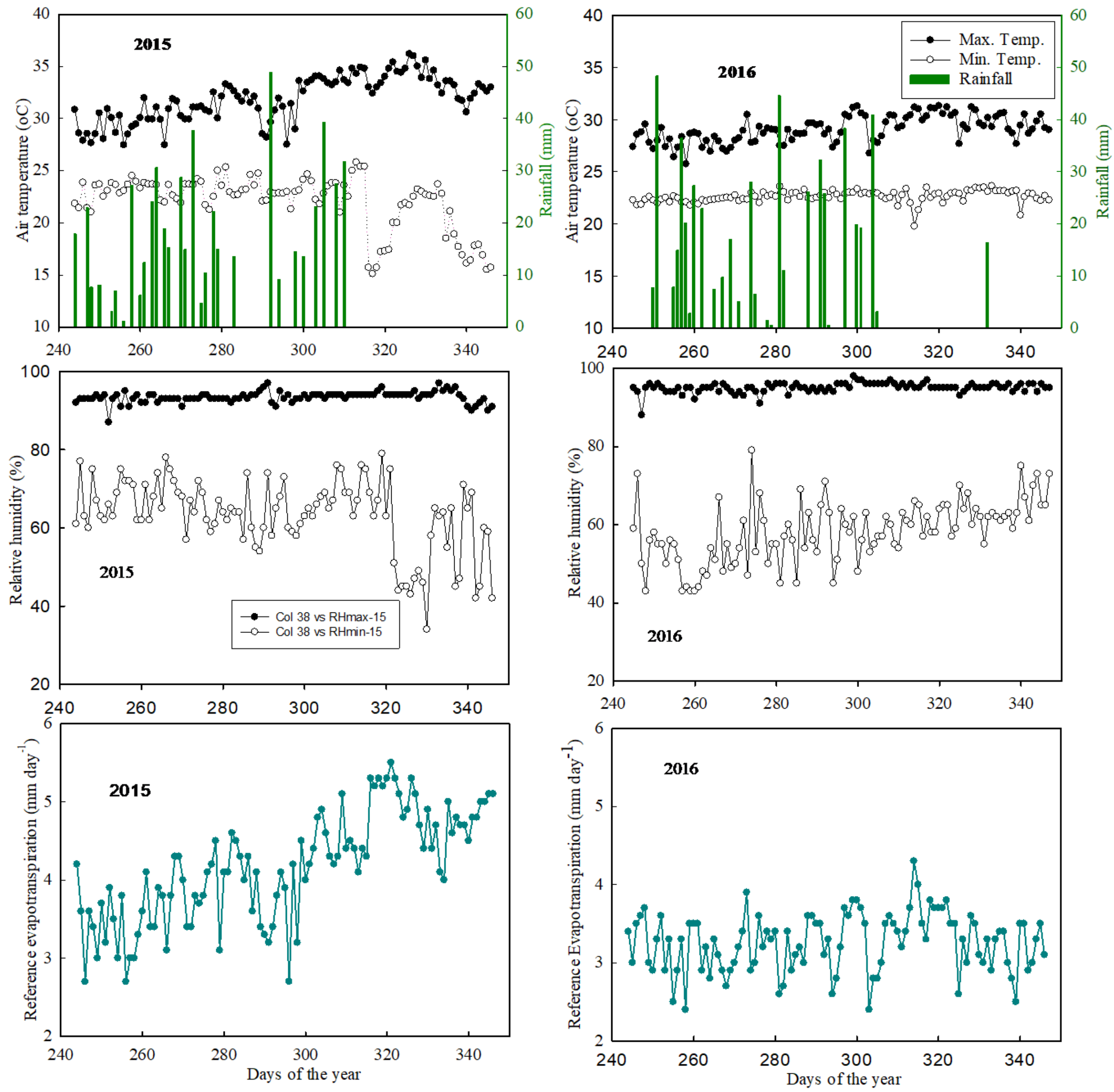

Fig. 1 Environmental conditions of the experimental field during the cropping seasons

2.3 Soil data

A 53 mm core sampler was used to sample the soil profile to a depth of 100 cm in the field. Laboratory analyses of the physical properties revealed that the study area is sandy clay loam (Vertisol). Saturated hydraulic conductivity (K_{sat}) was determined in-situ using the Guelph permeameter (Reynolds and Lewis 2012). Sandy loam was prominent in the upper 40 cm, while the lower 40 – 80 cm was sandy clay loam (Table 1). The bulk density was lower in the upper 60 cm than in the lower 60 to 100 cm. Organic matter was higher in the upper 60 cm than the lower 100 cm. Soil pH in the upper 60 cm is adequate for the cultivation of soybeans. The characteristics of the soil profiles were used as input to the soil component of the AquaCrop 6.1 model during the simulation.

Table 1 Physical and chemical properties of the soil at the experimental field

Soil depth (cm)	00 - 20	20 - 40	40 - 60	60 - 80	80 - 100
Sand (%)	75	74	59	57	63
Clay (%)	11	16	19	30	18
Silt (%)	14	10	22	13	19
Texture class*	Sandy loam	Sandy loam	Sandy clay loam	Sandy clay loam	Sandy loam
BD (g cm^{-3})	1.49	1.56	1.58	1.57	1.62
OM (%)	1.28	0.74	0.61	0.44	0.34
FC (m^3 m^{-3})	0.18	0.27	0.2	0.31	0.29
PWP (m^3 m^{-3})	0.08	0.13	0.09	0.21	0.19
TAW (m^3 m^{-3})	0.10	0.10	0.12	0.10	0.10
K_{sat} (mm day^{-1})	880	570	415	350	580

BD, Bulk density; FC, Field capacity; *PWP*, permanent wilting point; *TAW*, Total available water; *OM*, Organic matter; **USDA* Classification

2.4 Experimental design

Experimental treatments

Two varieties of soybeans, TGX-1448 2E and TGX-1440 were used. There were five levels of soil fertility and these were 0, 25, 50, 75 and 100% of the current N rate recommendation. The combination produced a 2 × 5 factorial set of experiments (Table 2). After ploughing and harrowing annually, the ten treatments were laid out in a randomized complete block design in triplicates. Soybeans were planted on September 2nd, the Day of the year (245 DOY) in 2015 (first season) and September 1st (246 DOY) in 2016 (second season). The intra-row and inter-row plant spacings were 0.3 m and 0.6 m respectively and each plot was 4 m by 4 m (16 m^2). The plots were separated by an alleyway of 1 m and 2 m. Runoff from the nearby field was diverted from the experimental fields by a 0.3 m deep and 0.3 m wide trench. Four seeds were planted per hole at a depth of 4 cm (Steduto et al. 2012) and produced a plant population of 222,220 plants ha^{-1}. The plots were thinned to three plants per stand 20 days after germination. The recommended dosage of nitrogen in the form of NPK was 20 kg ha^{-1}(Dugje et al. 2009) and was applied 35 days after planting (*DAP*). Magic Force™ at 1.5 L ha^{-1} was used to control insects. After physiological maturity, on December 12th in the seasons, crops within an area of 10 m^2 on each plot were harvested and the fresh seed yields were estimated (t ha^{-1}).

Table 2 Experimental treatments during the seasons.

s/n	Treatment label	Description
1	V_1N_{00}	TGX-1448 2E plus zero nitrogen application which relied on the indigenous nitrogen fertilizer
2	V_1N_{25}	TGX-1448 2E plus 25% of recommended fertilizer application
3	V_1N_{50}	TGX-1448 2E plus 50% of recommended fertilizer application

4	V_1N_{75}	TGX-1448 2E plus 75% of recommended fertilizer application
5	V_1N_{100}	TGX-1448 2E plus 100% of recommended fertilizer application
6	V_2N_{00}	TGX-1440 plus zero fertilizer application
7	V_2N_{25}	TGX-1440 plus 25% of recommended fertilizer application
8	V_2N_{50}	TGX-1440 plus 50% of recommended fertilizer application
9	V_2N_{75}	TGX-1440 plus 75% of recommended fertilizer application
10	V_2N_{100}	TGX-1440 plus 100% of recommended fertilizer application

Soil water storage

Soil moisture sensors, TEROS 12 (Meter Groups, USA) were installed from 00 to 60 cm soil depth at intervals of 10 cm in each plot. Subsequently, the soil water contents in the profiles were measured at intervals of seven days until maturity. The soil water storage (*SWS*) was determined by multiplying the soil water contents (m^3 m^{-3}) by the soil depth (mm) (Adeboye et al. 2017b). The computed soil *SWS* was used for the simulation in the AquaCrop model

Biomass

Above ground, biomass was measured at intervals of 1 week from 32 days after planting (*DAP*). Two plants were harvested and oven-dried at 70ºC (Memmert, Sweden) for 48 h. The oven-dried mass was multiplied by the plant population in each plot and the biomass (t ha^{-1}) was estimated.

Canopy cover

Photosynthetically active radiation (PAR), was measured using AccuPAR LP 80 (Meter Group, USA) near solar noon at average intervals of seven days. Ten measurements of the below and above PARs were taken by placing the line sensor perpendicularly to the rows above and below the plant canopy (Adeboye et al. 2019a). Canopy cover (*CC*) was determined by using Eq. (1) (Adeboye et al. 2019b):

$$CC = \left[1 - \left(PAR_{below} / PAR_{above}\right)\right] \times 100 \qquad (1)$$

Seasonal evapotranspiration

Surface runoff from each plot was channelled to a graduated drum stationed at about 0.8 m from metallic drums installed within 0.716 m^2 of the plots. Percolation beyond the root zone was determined from the soil moisture content measured periodically. However, it was assumed negligible for depths beyond 100 cm. The groundwater table was deeper than 60 m and its contribution to the root zone was ignored. Change in the *SWS* was determined by the difference between water storage on the sampling dates. Therefore, the ET_a was determined by using the soil water balance, which is expressed in Eq. (2) (Ghiberto et al. 2011):

$$ET = P - RO - DP \pm (\Delta S_2 - \Delta S_1) \qquad (2)$$

where:

ET = actual evapotranspiration (mm)

P = rainfall (mm)

DP = percolation (mm)

RO = surface runoff (mm)

$\Delta S_2 - \Delta S_2$ = change in SWS over the season (mm)

AquaCrop model

The AquaCrop model is a crop growth model that simulates potential yields of herbaceous crops as a function of water transpired. It is a water-driven model because, in the growth engine, transpiration is translated into biomass using conservative crop parameters, the biomass water productivity, normalized for atmospheric evaporative demand and the concentration of CO_2 in the air using Eq. (3) (Steduto et al. 2012):

$$B_n = WP^* \times \sum_{i=1}^{n} \left(\frac{T_{r_i}}{ET_{o_i}} \right) \qquad (3)$$

where:

B_n = cumulative aboveground biomass production after n days (g m^{-2});

T_{ri} = daily crop transpiration (mm day^{-1});

ET_{oi} = daily reference evapotranspiration (mm day^{-1});

n = sequential days of the period when biomass is produced;

WP* = normalized crop water productivity (g m^{-2}). It is the *WP* normalized for atmospheric evaporative demand (ET_o) and the CO_2 concentration of the atmosphere. The *WP** is nearly constant for a specific crop when mineral nutrients and water are not limiting except for extremely severe cases.

The AquaCrop model uses the normalization of water productivity to make it suitable for many agro-ecological conditions and cropping seasons. The AquaCrop model simulates transpiration and separates evaporation from productive transpiration by using *CC,* which can be estimated visually or from remote sensing sources, unlike the leaf area index which requires sophisticated equipment (Steduto et al. 2009). AquaCrop needs local rainfall, air temperature and reference evapotranspiration (ET_o) to simulate the daily growth and development of the crop. It simulates the responses of crops to water deficit using four coefficients. These are canopy expansion, stomata control of transpiration, canopy senescence, and harvest index (*HI*). The *HI* can be adjusted depending on the degree, duration and timing of the water stress.

Conservative and non-conservative parameters

The AquaCrop model uses conservative and non-conservative parameters for the simulation. Conservative parameters do not change by location, management, cultivars, and time (Raes et al. 2012). The conservative parameters need to be adjusted to improve the simulations in the model (Paredes et al. 2015). They include canopy cover (*CC*); canopy growth coefficient (*CGC*); canopy decline coefficient (*CDC*); crop coefficient for transpiration at full CC; WP* for biomass formation; coefficients for adjusting the HI concerning inhibition of leaf growth and stomatal conductance, soil water depletion thresholds for inhibition of leaf growth and stomatal conductance and the acceleration of canopy senescence (Raes et al. 2012). The non-conservative parameters were adjusted during simulation (Table 3).

2.5 Model input and calibration

AquaCrop model ver. 6.1 was used. This version uses four components for the simulation of parameters. These are climate, crop, management, and soil. The minimum and maximum air temperatures, rainfall and ET_o were entered into the climate component of the model. The AquaCrop model was run in GDD. We estimated the non-conservative parameters by using the data obtained during the 2015 and 2016 cropping seasons. 2015 was wetter and therefore was used for the calibration of the model because of the sensitivity of the model to water. The sowing date, plant population, and time to attain maximum *CC*. We simulated seed yield by entering the date and duration of flowering, reference harvest index (HI_o) and duration of building up of HI. N_{00}, N_{25} and N_{50} represent 100, 75 and 50% soil fertility stresses, respectively, while N_{75} and N_{100} indicated 25 and 0% soil fertility stresses, respectively. The impacts of soil fertility on seed and biomass yields were simulated in the crop subcomponent of the model by selecting the degree of the effects of soil fertility. N_{00}, N_{25} and N_{50} represented very poor, poor and about half while N_{75} and N_{100} represented moderate and non-limiting soil fertilities. Response of the crop to soil fertility stress was calibrated by using the data measured in 2015. The biomass yields for N_{00} that is, full fertility stress without water stress are divided by a reference biomass yield (B_{ref}) where there was no soil fertility and water stresses (Eq. (4)). The calibrated crop response to soil fertility stress was later used to predict yields for other

treatments (Fig. 2).

Soil water storage was simulated in the soil component of the model by entering the measured physical characteristics of the soil profile. *C3* plants are legumes in which a 3-carbon intermediate acid is the first stable product during the fixation of CO_2 (Kubota 2016). A WP* of 17 g m^{-2} was used to improve the predictions in the AquaCrop model (Adeboye et al. 2017a). During simulation, the crop coefficient for transpiration ($K_cT_{r,x}$) and the readily evaporable water were adjusted to ensure a good correlation between the observed and predicted data.

Table 3 Non-conservative parameters used in calibrating and validating the model for simulating the response of Soybeans to the practices.

Parameter/Treatment Label	**Value**	**Unit**
Canopy Growth Coefficient (CGC)	12.2	% per day
Canopy Decline Coefficient (CDC) at senescence	0.466	per GDD
Crop coefficient for transpiration at CC = 100%	1.15	Full canopy transpiration relative to ET_o
*WP for ET_o and CO_2	17.6	g m^{-2}, (biomass)
Soil water depletion for lower canopy expansion	0.60	Leaf growth stops completely at this value
Leaf growth stress coefficient curve shape	3.3	Moderately convex shape
Soil water depletion threshold for upper stomata control	0.50	Above this stoma begins to close
Stomata stress coefficient curve shape	3.0	Convex curve
Shape factor for water stress coefficient for canopy senescence	3.0	Convex curve
Maximum basal crop coefficient K_{cb}	1.14	
Time from sowing to emergence	216	GDD
Time from sowing to start of flowering	954	GDD
Duration of flowering	429	GDD
Time from sowing to maximum canopy	1445	GDD
Time from sowing to start of senescence	1570	GDD
Time from sowing to maturity	2065	GDD
Duration of building up of the HI	1029	GDD
Time from sowing to maximum effective rooting depth	1570	GDD

Maximum effective rooting depth	0.6	m

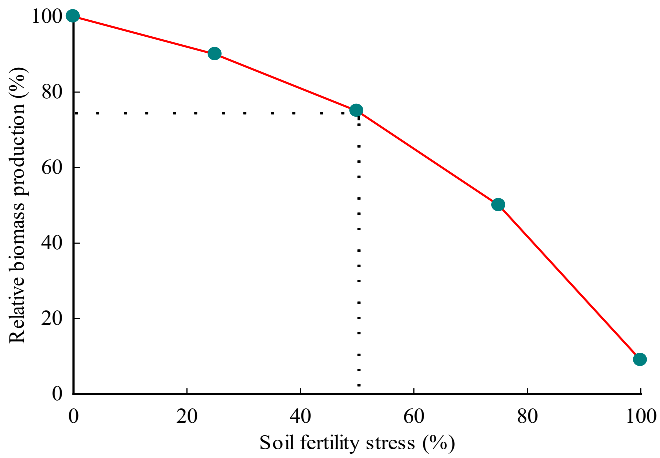

Fig. 2 Stress curves which show the responses of the crop (B_{rel}) to soil fertility stress. The dotted line shows the point of calibration for full soil fertility stress (severe stress) and it was used to determine the orientation of the curve

2.6 Evaluation of model performance

Model performance criteria

In this study, *CC*, *SWS*, above the root zone, seed yield, *DAB*, crop *ET*, and *WP*, were considered. A single measurement cannot be used to judge the goodness of fit of an agronomic model (Ma et al. 2012). The first approach is the use of the regression coefficient (*b*) when a regression line is forced through the origin of the line that relates to the predicted and observed data (Ran et al. 2020). Values of *b* close to 1.0 mean that the observed and predicted data are statistically close. Other statistical indicators used were coefficient of determination (R^2) ranging from 0 to 1. R^2 close to 1 show a good agreement between observed and predicted data set and that most of the variance of the observed data is explained by the model. $R^2 > 0.80$ is recommended for crop simulation studies (Ma et al. 2011). Percentage deviation (P_d), ranges between zero and infinity and values close to zero show better agreement between the predicted and observed data. A model is acceptable if P_d does not exceed 15%, a tolerance error range for field agronomic studies (Brisson et al. 2002). Root Mean Square Error (*RMSE*), ranges from 0 to +∞ with the former indicating optimal and the latter poor performance of a model. *RMSE* of 15% is considered "good" and 20% is "satisfactory" for crop simulation models. (Hanson et al. 1999) recommended a maximum of 15% error for seed and biomass yields. Normalised Root Mean Square Error (*NRMSE*) < 10% is considered excellent; 10 - 20 is good; 20 - 30 is fair and > 30% is poor (Jamieson et al. 1991). Nash-Sutcliffe efficiency coefficient (*EF*), shows how well the plots of observed and predicted data fit the 1:1 line. $-\infty \leq EF \leq 1.0$ (1 inclusive), with $EF = 1$ being the optimal and the target value for simulations. *EF* between 0.0 and 1.0 is generally considered acceptable performance. Willmott's index of agreement (*d-index*) ranges between 0 and 1. 1 means a perfect agreement between the observed and predicted data and 0, shows no agreement (Krause et al. 2005). A *d-index* greater than 0.7 is acceptable for calibration in agronomy (Saseendran et al. 2010):[Eq. (5) to Eq. (10)].

$$R^2 = \left(\frac{\sum_{i=1}^{n} (O_i - \overline{O})(P_i - \overline{P})}{\sqrt{\sum_{i=1}^{n} (O_i - \overline{O})^2} \sqrt{\sum_{i=1}^{n} (P_i - \overline{P})^2}} \right)^2 \quad (5)$$

$$P_d = \frac{P_i - O_i}{O_i} \times 100 \quad (6)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}} \tag{7}$$

$$NRMSE = \frac{1}{\overline{O}}\sqrt{\frac{\sum_{i=1}^{n}(P_i - O_i)^2}{n}} \times 100 \tag{8}$$

$$EF = 1 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}(O_i - \overline{O})^2} \tag{9}$$

$$d - index = 1 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}\left(\left|P_i - \overline{O}\right| + \left|O_i - \overline{O}\right|\right)^2} \tag{10}$$

where:

O_i = observed data

$\overline{O}$ = mean of observed data

P_i = simulated data

$\overline{P}$ = average of simulated data.

N =number of measurements taken

3. Results and Discussion

3.1 Canopy cover

There was a good correlation between the observed and predicted *CC* for the calibrated data ($0.90 \leq R^2 \geq 0.97$). This means that the AquaCrop model accounted for 90 to 97% of the variability in annual *CC* (Fig. 3). The *RMSE* ≤ 7.3% and *NRMSE* ≤ 11.8% were low and considered good for the calibration of *CC*. The 0.90 ≤ *EF* ≥ 1.00 showed that the model simulated *CC* optimally. The *d-index* (0.98 – 1.00) clearly showed that the AquaCrop model simulated *CC* very well under soil fertility management practices. Generally, the AquaCrop model did not overestimate *CC* under soil fertility management except in V_1N_{75}, V_1N_{100} and V_2N_{50} for the calibrated data and V_1N_{25} –V_2N_{75}. The slight overestimations could be attributed to the response of the model in simulating canopy expansion under soil fertility management. (Adeboye et al. 2019b) reported that the AquaCrop model simulated *CC* with $R^2 \geq 0.95$, *NRMSE* ≤ 14.3%, *d-index* ≥ 0.97, *EF* ≥ 0.84.

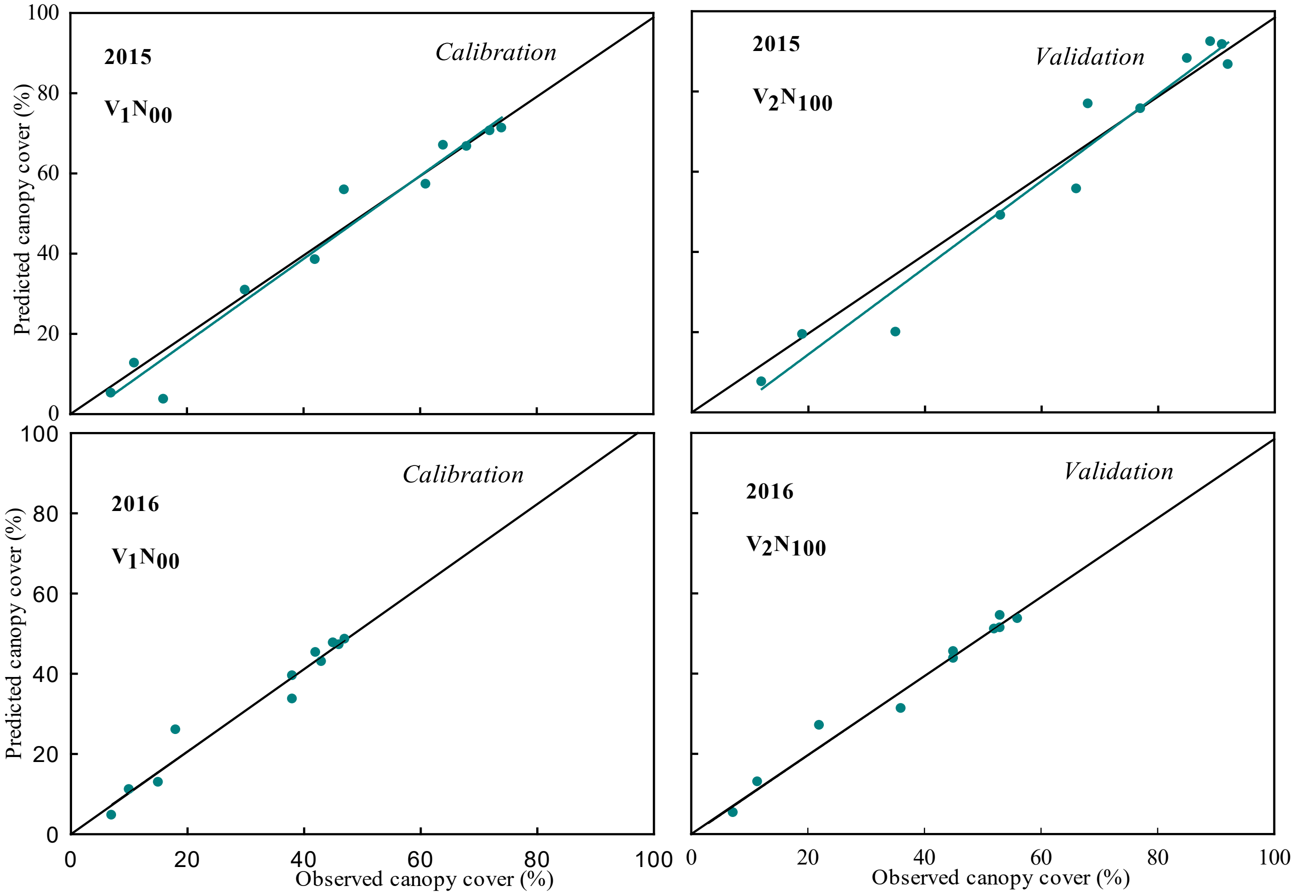

Fig. 3 Canopy cover of rainfed soybeans in 2015 under different levels of nitrogen fertilizer in Ile-Ife, Nigeria

3.2 Soil water storage

The *RMSE* ≤ 11.5 mm is low and less than 8.81% of the means of observed *SWS* and is judged very good for the calibration of agricultural models (Ma et al. 2011). The *EF* > 0.81; *d-index* > 0.85; *NRMSE* < 9.01 is acceptable for calibration of crop simulation models (Saseendran et al. 2008). For the validation data, $R^2 > 0.84$, *RMSE* ≤ 10.8 mm and *NRMSE* ≤ 4.0% indicate that there was an improvement in the simulation of *SWS* by using the model. *EF* ≥ 0.70 and positive for the calibrated and validated data means that the performance of the model in simulating *SWS* under soil fertility is good. The *d-index* > 0.91 shows that there was a good correlation between the observed and predicted *SWS*. The *b* for the calibrated and validated data means that the model did not overestimate *SWS* in the seasons. However, the model simulated *SWS* below *FC* in all the treatments unlike it did for *SWS* (Adeboye et al. 2019b). This could be attributed to lower seasonal rainfall during the cropping seasons in the area. Similarly, the AquaCrop model simulated *SWS* below the permanent wilting point for V_1N_{25}, V_1N_{50} and V_2N_{00} to V_2N_{100} during maturity (95 – 102 DAP) for the calibrated data. This could be attributed to a reduction in the soil water at 30 cm depth during the late growing stage (Fig. 4). Generally, the AquaCrop model initiates drainage of more soil water than at *FC*. However, in this study, drainage could have commenced at a lower level than *FC*. Although the *SWS* was below *WP* in the stated treatments, it could not subject the crop to noticeable stress and reduction in productivity because it had reached physiological maturity.

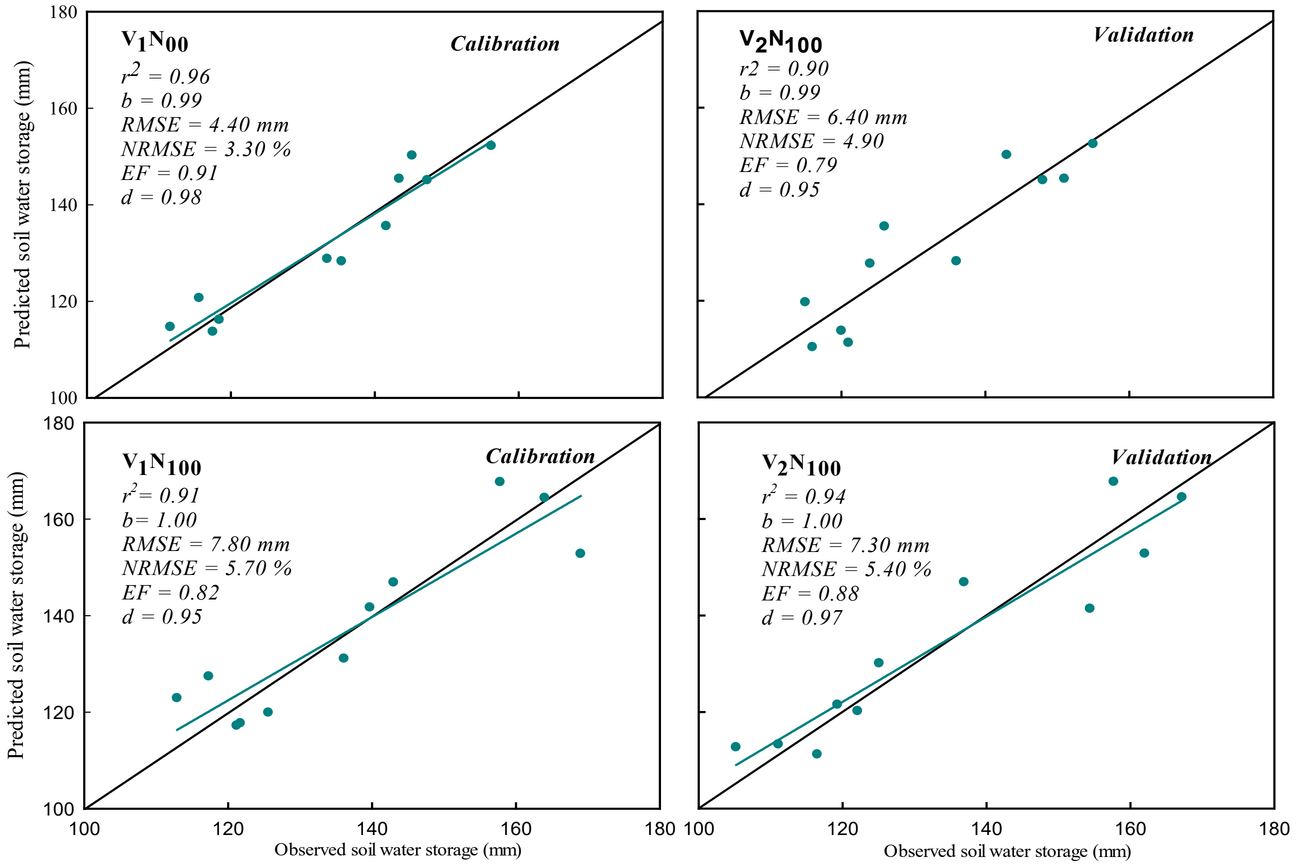

Fig. 4 Observed and simulated soil water storage for soybeans under different levels of nitrogen fertilizer in 2015 in Ile-Ife, Nigeria

3.3 Seasonal evapotranspiration

The AquaCrop model overestimated ET_a during validation (slope = 1.07 and intercept = -31 mm). The P_d ranged from -1.16 for V_2N_{00} to 2.02 for V_1N_{75} during calibration and from -1.14 for V_1N_{50} to 0.99 for V_1N_{25} during validation. AquaCrop simulated ET_a well because the P_d was far below the range proposed for agronomic studies (Brisson et al. 2002). The AquaCrop model explained at least 89% of the variance (Fig. 5) and therefore is judged satisfactory for agronomic simulations (Wang et al. 2014).

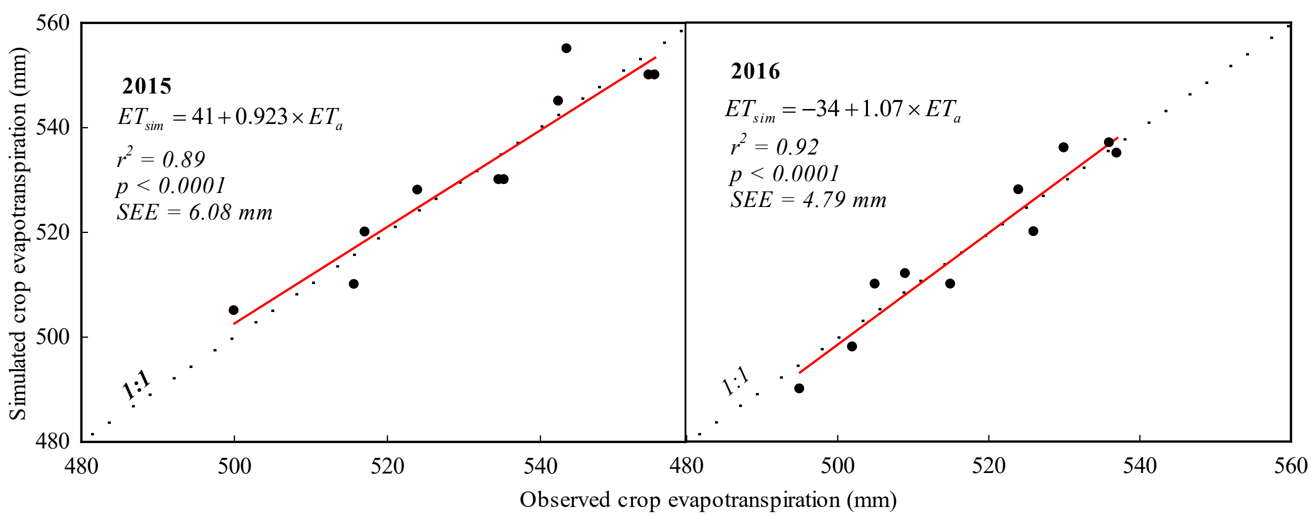

Fig. 5 Observed and simulated evapotranspiration of soybeans under different levels of nitrogen fertilizer and temporal distribution of seasonal rainfall

3.4 Accumulation of biomass

For the validated data, $0.05 \leq RMSE \leq 0.20$ t ha^{-1} was lower than for the calibrated data set, $0.06 \leq RMSE \leq 5.20$ t ha^{-1}. This testifies the appropriateness of the calibration of the model to ensure optimum performance. There was a high overestimation of the biomass in the calibrated data ($0.95 \leq b \leq 1.06$) for V_1N_{100}, V_2N_{00}, V_2N_{25}, V_2N_{50} and V_2N_{100}, and in the validated data ($1.00 \leq b \leq 1.07$) except for V_1N_{50} (Fig. 6).

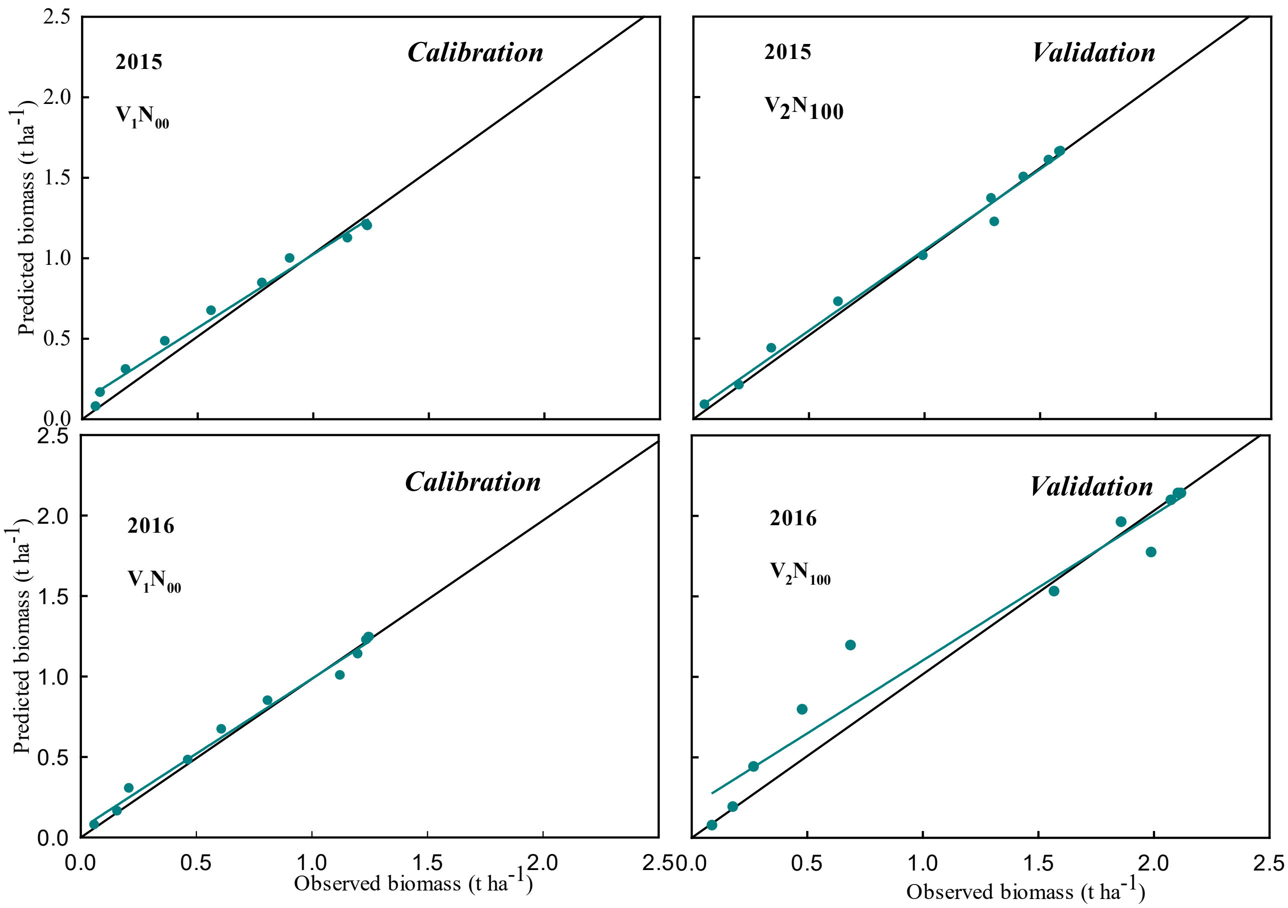

Fig. 6 Trend of observed and simulated above ground biomass for different levels of nitrogen fertilizer in 2015 in Ile-Ife, Nigeria

3.5 Yield

Deviations of the seed yields for the validated data set were less (-1.18 to 1.12 %) compared to the calibrated data (-2.50 to 3.23%). The correlations between the predicted and observed seed yields were high (Fig. 7), *RMSE* = 0.01 t ha^{-1} and represented about 0.54% of the means of the observed seed yields, *NRMSE* = 0.54%, *EF* and *d-index* = 1.00 for the calibrated data and *RMSE* = 0.01 t ha^{-1} which accounted for 0.56% of the average seed yields, *NRMSE* = 0.81%, *EF* = 0.99, *d-index* = 1.00 for the validated data. The variations in the yields for the calibrated data were below 13.5% recommended for process-based crop models by Asseng et al. (Asseng et al. 2013). The simulation of the seed yields could be rated excellent due to high correlation coefficients and low estimation errors (Ahuja and Ma 2002; Qi et al. 2011). The *b* shows that the seed yield fitted well in the 1:1 line. Overall assessment of the deviations between the predicted and calibrated data is far below the 15% recommended for study in crop modelling (Hanson et al. 1999). There was no overestimation or underestimation of seed yields with $b = 1.00$ in the seasons. This testifies the goodness of the AquaCrop model in simulating yields of soybeans under soil fertility management. The AquaCrop model compares well with the hybrid models DSSAT and CROPGRO-Soybean, which simulated seed yields with *NRMSE* ≤ 17% (Liu et al. 2013).

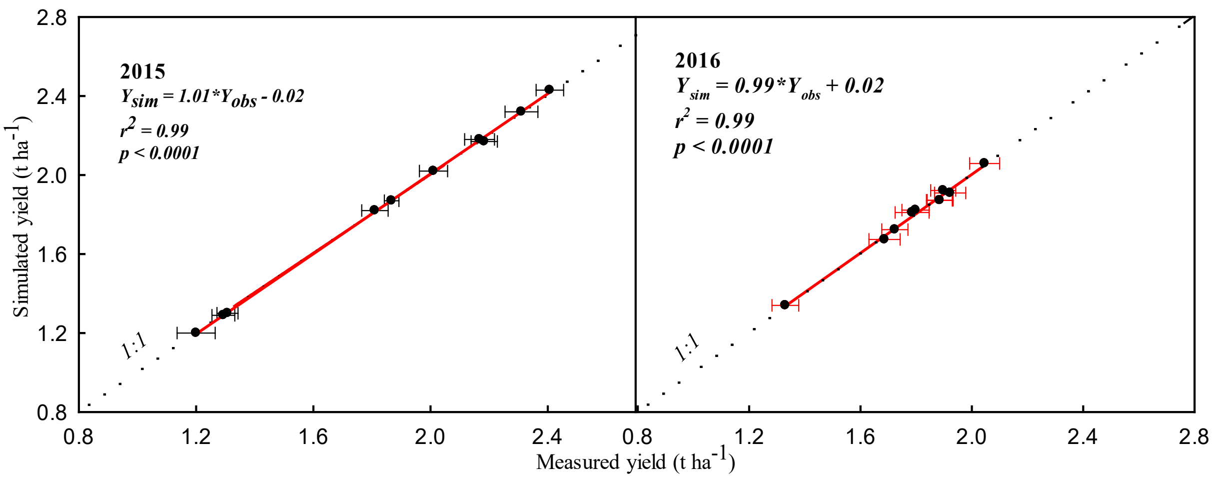

Fig. 7 Correlations between the observed and predicted seed yields under different levels of nitrogen fertilizer

3.5 Crop water productivity

The AquaCrop model explained 99% of the variance in the observed *WP* for the calibrated and validated data (Fig. 8). The *RMSE* = 0.01 kg m^{-3} accounted for 2.89% of the mean of the *WP* in 2015. The *NRMSE* = 1.42%, *EF* = 1.00 and *d-index* = 1.00 show that there was a good correlation between the observed and predicted *WP* of the crop.

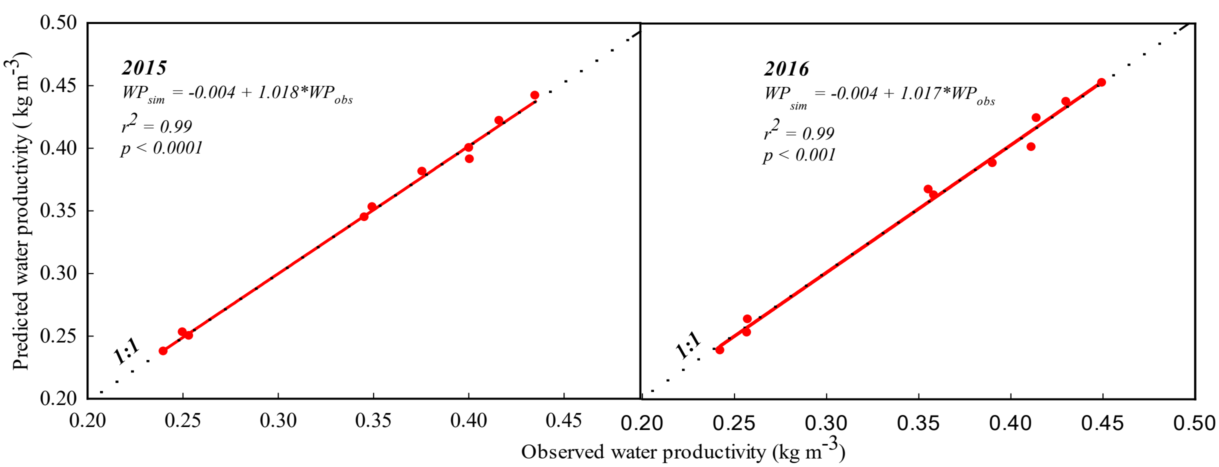

Fig. 8 Correlations between observed and predicted water productivity for soybeans under varying levels of nitrogen fertilizer

For the validated data, it was *RMSE* = 0.004 kg m^{-3}, which is about 1.25% of the means of the observed *WP*, *NRMSE* = 1.28%, *EF* = 0.98 and *d-index* = 1.00. High and positive *EF* indicates that the AquaCrop model captured the trends in the *WP* in the seasons and the high *d-index* shows a perfect and acceptable calibration of the model (Ahuja and Ma 2002; Ma et al. 2011; Saseendran et al. 2010). Deviations of the observed *WP* from the predicted *WP* were low for the calibrated and validated data and within the range recommended for crop simulations (Brisson et al. 2002). The AquaCrop model overestimated *WP* with, $1.01 \leq b \leq 1.02$.

In the current study, there were variabilities in the reductions in the yields due to soil fertility stress. The seed yields of V_1N_{00}, V_1N_{25} were reduced by 93 and 28% while those of V_1N_{50} and V_1N_{75} were reduced by 24 and 6% respectively compared to V_1N_{100} for the calibrated data. For the validated data, the yields reduced by 44 and 14% for V_1N_{00}, V_1N_{25}, while for V_1N_{50} and V_1N_{75}, they reduced by 7 and 2% respectively. Furthermore, there were 87, 84, 20 and 11% reductions in the seed yields for V_2N_{00}, V_2N_{25}, V_2N_{50} and V_2N_{100} respectively in 2015, while in 2016, the comparative reductions were 16, 13, 8 and 7%. The variabilities in the yield reductions could be attributed to genetic traits of the crop, changes in the environmental conditions during the cropping seasons and soil fertility management. This is similar to the findings of Van Roekel et al. (Van Roekel et al. 2015); Cafaro La Menza (Cafaro La Menza et al. 2017) and Mourtzinis et al. (Mourtzinis et al. 2018). Our study shows that the application of nitrogen fertilizer improved the seed yield of the crop. Application of full dosage nitrogen fertilizer increased water productivity of soybeans by a range of 3-43% compared to situations where there were nitrogen stresses.

Smallholder farmers in the study area could adapt our calibrations to optimize nitrogen fertilizer for the productivity of land and water for the crop under the predominant rainfed farming system. Other parameters could be adjusted until there is a good match between observed and predicted data. Agricultural extension agents can use the output of our study to advise farmers on strategies to maximize nitrogen fertilizer to achieve a higher income. River basins can use our results to plan effective water storage systems during peak flows and sustainable allocation of water and application of nitrogen fertilizer for crop production. Economists and policymakers can use our calibration and outputs to plan monetary allocations for the production of the crop.

4. Conclusions

Field experiments were carried out on the impacts of nitrogen fertilizer on the productivity of rainfed soybeans for two agronomic seasons. AquaCrop ver. 6.1 was used to model the effects of soil fertility on canopy cover, soil water storage, biomass accumulation, evapotranspiration, and water productivity of the crop. Although the AquaCrop model overestimated the canopy cover of soybeans when soil fertility was reduced by 0, 25 and 50%, there was a good correlation between the observed and predicted canopy cover. The AquaCrop model-simulated soil water storage below field capacity when seasonal rainfall was less than 600 mm. Indeed, it simulated soil water storage below the permanent wilting point when nitrogen in the soil was reduced by 0, 50, 75 and 100%. AquaCrop under and overestimated evapotranspiration for soybeans when nitrogen in the soil was reduced by 0, 25 and 75%. Despite under and overestimation of the evapotranspiration, the model explained most of the variances in the predicted evapotranspiration and compared well with other process-based crop models. The AquaCrop model overestimated dry above-ground biomass when the soil is subjected to nitrogen fertility stress. This could be described as a key weakness of the model. Nitrogen stress reduced seed yield and water productivity of soybean by about 48 and 43 % respectively. The AquaCrop model captured the simulation of seed yields of the crop well because there was no under or overestimation and the prediction error was very low under soil fertility management.

We recommend simulation of the effects of pests on biomass, seed yield and water productivity by subsequent versions of the AquaCrop model. Doing this could improve the precision of the model because, in many regions, pest affects the growth, seed yield and water productivity of crops. In addition, incorporating an economic sub-unit in the model will enable the users to see at a glance the effects of inputs on marketable seed yields, and the profitability of the investment. The AquaCrop model could be used for predicting and simulating land and water productivity and responses of soybeans to nitrogen fertilizer requirements.

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PERSPECTIVES ON ECONOMIC EFFECTS OF ANTHROPOGENIC ACTIVITIES ON SURFACE WATER QUALITY

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Abstract

Although water constitutes 71% of the earth's surface, only 0.3% of it is available as freshwater for human use. Moreover, the quality of fresh water in the ground and surface systems is of great concern, as potable water needs to have appropriate mineral content. Ground and surface water quality in rural and urban environments are affected by both natural processes and anthropogenic influences. Because of this, water is becoming scarcer as the population increases across the world. Anthropogenic factors affecting water quality include impacts due to agriculture, use of fertilizers, manures and pesticides, animal husbandry activities, inefficient irrigation practices, deforestation of woods, aquaculture, pollution due to industrial effluents and domestic sewage, mining, and recreational activities. These anthropogenic influences cause elevated concentrations of heavy metals, mercury, coliforms and nutrient loads. This paper presents an overview of the effects of natural processes and human influences on rural and urban aquatic systems. Pollution due to environmental parameters such as heavy metal pollution, heavy metals and bacterial and pathogenic contamination of both urban and rural areas are presented herein.

Keywords: Anthropogenic activities, surface water, heavy metals

1. Introduction

Water is an indispensable natural resource (Adebayo, 2005). It is evident by the seeming fact that all life including human beings depends on it for sustenance. Water is essential for the development and maintenance of the dynamics of every facet of society. In this context freshwater is of particular interest freshwater is a finite resource, essential for agriculture, industry and even human existence. Without fresh water, fish has no life as it supports the different phases of fish life; that is, fish lives and carries out activities in water such as breeding, movement, and respiration (UNCSD, 2000). Physical and chemical parameters of water are very important as these parameters are vital, in that they affect the biotic components of an aquatic environment and human health which depends largely on it. In view of this, monitoring water quality on a temporal basis is essential. This is so because its integrity can be compromised by a host of factors, for instance, biotic and abiotic effects. Basically, water quality refers to the chemical, physical, biological and radiological characteristics of water. It is a measure of the condition of water relative to the requirement of one or more biotic species and any human need. It is most frequently used by reference to a set of standards which is generally achieved through the treatment of the water (Diersing; 2009). Anthropogenic influences are known sources of water pollution. These activities include urban, industrial and agricultural activities with increasing exploitation of water resources as well as natural processes, such as precipitation inputs, erosion and weathering of crustal materials degrade surface waters and damage their use for drinking water, recreational and other purposes (Irfan and Shaki, 2012).

2. Materials and Methods

2.1 Microbial Perspective of Water Pollution and Remediation

The role of microbes is obvious where microorganisms actively carry out biodegradation of organic matter in the aqueous portion produced after the first stage. For instance, the biodegradation of materials, such as paper and petroleum, is by bacteria, algae, and protozoa. When water is exposed to air, soil as well as effluents, it gains saprobic microorganisms and can also pick up pathogens such as *Cryptosporidium, Campylobacter, Salmonella, Shigella,* etc (Inyinbor *et al.*, 2018). Monitoring water for each of these pathogens may not be possible but detection of faecal contamination is an easier way of spotting contamination.

In view of this control of pathogens in water is important to prevent waterborne diseases; this can effectively be done using a multiple barrier approach. Microbial treatment methods go further than traditional municipal wastewater treatment because it takes into consideration the removal of nutrients (e.g., nitrate and phosphate) and easily degradable organic compounds as well. Biological treatment processes may consist of the following; lagoon treatment activated sludge as well as fixed film bioreactors. In the case of facultative ponds, there is an aerobic surface and an anaerobic bottom. The top aerobic layer facilitates the treatment of dissolved organic compounds as well as odorous compounds. Another biological treatment process of interest is the activated sludge. It is made up of an aeration basin where aeration equipment provides both oxygen and adequate mixing of wastewater to maintain uniformly mixed liquor suspended solids (MLSS).

Several modern methods of water purification have been well embraced in our society today. However, some rural dwellers that may not be able to afford these modern treatment methods still have water pollution as a major challenge. Furthermore, the disinfection by-products which remain after treatment is another reason why herbal attempts in water treatment should be encouraged (Adebayo and Adediran 2005). It is important to note that not many researchers apply their antimicrobial extract or fractions directly in water treatment. Many groups stop at establishing the antimicrobial potential of their study plant, whereas others go further to apply the extracts in water treatment. For instance, a reported work used alcoholic, aqueous, and fresh juice extracts of *Ocimum sanctum* (tulsi) and *Azadirachta indica* (neem) and applied them in vitro against salmonella, which was chosen as an indicator organism. but a notable observation is the fact that a mixture of 1% concentration of each herb is not as efficient as the synergistic combination of the three (Dvorak *et al.*, 2016). An indirect application of herbs in water purification is their use in the synthesis of nanoparticles, which are afterwards applied to remove contaminants from water (Das and Mandal, 2015). These extracts influence the surface properties of the nanoparticles, thus dictating their unique properties owing to the obvious advantages of natural disinfection.

2.2 Role of Anthropogenic Activities

Ground and surface water quality in rural and urban environments are affected by both natural processes and anthropogenic influences (Dvořák *et al.*, 2016). As a consequence, Anthropogenic factors affecting water quality include agricultural practices like the use of fertilizers, manures and pesticides, animal husbandry, inefficient irrigation practices, deforestation of woods, aquaculture, to this regards pollution due to industrial effluents and domestic sewage, mining, and recreational activities (Adebayo and Adediran 2005) are worthy of mentioning. These anthropogenic influences cause elevated concentrations of heavy metals, mercury, coliforms and nutrient loads.

It is imperative to note in addition that urbanization-related activities have been found to increase nitrogen, phosphorus, alkalinity, and the total dissolved solids in surface waters. Degraded streams and rivers that drain urbanized landscapes often have higher nutrient\ loads and contaminant concentrations, as well as altered stream morphology and reduced biodiversity (Shannon *et al.*, 2007). For instance, heavy metal pollution is considered to be point source pollution and is primarily discharged from smelting and heavy industrial enterprises (Zhang *et al*, 2009) however, nutrient and organic pollution includes point source and nonpoint source pollution, such as domestic wastewater, effluent from wastewater treatment plants and agricultural run-off. Industrial, agricultural and other anthropogenic activities often lead to an increased input of metals in soils and natural water. It has been demonstrated that besides all these events, Lead is well-known as the cumulative poison that has several damaging effects on public health trace concentration in the body of humans and organisms and concentration beyond the recommended standard is detrimental to health (Hong *et al.*, 2014). The high concentration of lead in soil could be attributed to the impact of anthropogenic activities at dumping sites of wastes which eventually leach directly into the River (Onuoha *et al*., 2018).

2.3 Factors that affect Water Quality

The integrity of water is compromised by a variety of factors. Some of these factors are:

Agricultural run-off: This is one of the nonpoint sources of pollution that affect water quality. Agricultural activities that can cause pollution include poor animal husbandry practices; overgrazed grasslands; over and excessive use including the untimely application of pesticides, ploughing over irrigated fields and application of fertilizers. There is considerable agreement in recent studies that amounts of nitrogen and phosphorus in surface waters are significantly influenced by anthropogenic inputs associated with land cover, land use and point sources Valiela *et.al* (2002). Pollutants that result from farming and cattle breeding are comprised of nutrients, sediments, pathogens, pesticides, metals and salts; these affect the quality of water to varying degrees.

Sedimentation: The most common agricultural water pollution is the loss of topsoil that is washed from fields. Rainwater carries soil particles or sediments and deposits them in lakes or streams nearby, thus affecting water quality. Other pollutants such as fertilizers, pesticides, and heavy metals that stick to the soil particles are also washed into the water bodies. These pollutants cause algal blooms and deplete oxygen, threatening aquatic life. (Nitasha *et al.*, 2015)

Nutrients: Nutrient (nitrogen and phosphorus) loading in waters through point and nonpoint sources is an ecological concern and affects water quality in surface water bodies. Nutrients are essential to the survival of aquatic organisms, but excess nutrient loading to water bodies can impact the designated uses of water (Freeman *et al*., 2009) Nitrates can be leached or transported in run-off. Nitrates are strongly associated with agricultural land and grasslands and concentrations are highest in spring and conjunction with high run-off events. The antecedent conditions – topography, soil type, farming practice and crop type – influence the movement of water as well as pesticide dispersal (Iyinbor *et al.*, 2018). All such factors are more significant than the physicochemical parameters of the ingredients in determining the run-off potential of the compound (Hopkins, 2009).

Livestock grazing: Overgrazing by livestock leads to exposure to soil and increased erosion. This can result in ecosystem regression, encouraging the invasion of unwanted species, destruction of stream banks, flood plain vegetation and fish habitats. It thus not only affects water quality filtration but also the habitat of flora and fauna (Freeman *et al*., 2009).

Irrigation: The objective of irrigation is to supplement the natural precipitation and to protect crops against freezing or wilting, depending upon the location of the farm. Inappropriate irrigation can cause water quality problems. In arid/dry areas, for example, rainwater does not carry the minerals deep into the soil, leading to evaporation of irrigation water and overconcentration of salts in soils. Over-irrigating a field may lead to soil erosion, and transportation of nutrients, pesticides and heavy metals. It may reduce the natural surface flow in streams and rivers (Kora *et al.*, 2017)

Pesticides: According to Nitasha *et al.*, (2015), insecticides, herbicides and fungicides are used to kill agricultural pests. They may enter the water due to run-off from the fields of atmospheric deposition, or even due to direct application. Water may become polluted with a range of contaminants due to the use of land for agriculture these pollutants, dissolved organic carbon, and nutrients (nitrogen and phosphorus). Pesticide occurrence in water supplies is a concern for water-quality assessment since a huge number of pesticides are widely used in agriculture. Pesticides are a group of hazardous materials with potential risk to human health Herbicides are the most widely used pesticides, constituting more than 40% of total use, while insecticides account for approximately 30% and fungicides for some 20%. Pesticides play an important role in harvest quality and food protection, providing enormous benefits in increasing production, as pests and diseases damage up to a third of crops. As a result of massive global consumption, pesticides as well as their degraded products spread through the environment and can contaminate water resources (Filho *et al*. 2010). Pesticide residues from agricultural fields contaminate water sources through nonpoint and point pollution sources, for instance, leaching or run-off directly from fields, or dumping or washing of used containers impact greatly on the quality of water. The extent of pollution of surface water and groundwater by pesticides depends on the physicochemical characteristics of the compounds. These characteristics include water-solubility, retention by soil components, degradation rate, the properties of the medium in which they are applied, and their abiotic and biotic degradation (Caracciolo *et al.*, 2010).

3. Results and Discussion

3.1 Water Quality Parameters and Their Indices

Water quality is measured by assessing the physio-chemical and biological properties against a set of standards. This is used to determine whether water is suitable for consumption or safe for the environment. Some of the parameters include the following namely;

Biological Oxygen Demand and Chemical Oxygen Demand (BOD and COD): they give an estimate of organic pollution in water and wastewater. They are important to waste water parameters as they are used to measure the efficiency of most wastewater treatment facilities. Surface water is expected to have low BOD/COD values to sustain aquatic life. High levels of BOD and COD can cause harm to aquatic life. Low levels of BOD and COD in river systems indicate good water quality while high levels indicate polluted water (Onuoha *et al.*, 2018).
pH (Hydrogen Ion Concentration): This is used to measure or determine the level of alkalinity of the wastewater. This parameter mainly informs the level of acid-base neutralization, softening, precipitation, coagulation, disinfection and corrosion control that is required to bring the water to a quality that is suitable enough for drinking (Freeman *et al.*, 2009).P^H value below-set standard the water will affect the mucus membrane of aquatic life and the water supply system.
Total Suspended Solids (TSS), is the measure of the amount and composition of solids that cannot dissolve in water and are not heavy enough to sink (Paul and Meyer, 2001).
The Electrical Conductivity (EC) of water is directly related to the concentration of dissolved ionized solids in the water. Ions from the dissolved solids in water create the ability for that water to conduct an electrical current (Shahzad *et al.*, 2015).
Hardness. The result from the presence of divalent metallic actions of which calcium and magnesium are the most abundant in groundwater. These ions react with soap to form a precipitate and with certain anions present in the water to form a scale. Because of their adverse action on soap, hard waters are unsatisfactory for household cleaning purposes (Kora et al., 2017).
Total Dissolved Solids (TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid molecular, ionized or micro-granular suspended form (Rajesh *et al.*, 2016).
Alkalinity: alkalinity in wastewater results from the presence of hydroxides, carbonate and bicarbonates of reactive metals like calcium and magnesium (Sharrer *et al.*, 2010).
Dissolved Oxygen (DO): it is used to measure the quantity of oxygen dissolved in water and it is necessary to determine if the water under scrutiny can support aquatic life (Zhang *et al.*, 200

Table1: Water Quality Standards

Parameters	Values (NSDWQ) mg/L	WHO (mg/L)	FAO (mg/L)
Dissolved oxygen	>4	4.0 – 6.0	-
Alkalinity	600	-	-

Nitrate	45	-	< 5
Phosphate	100	-	0 – 2
Total Hardness	500	300	0 – 460
Temperature	20 -30	-	-
Ph	6.5 – 8.5	6.5 – 8.5	6.0 – 8.5
Electric conductivity	1000	-	-
Total dissolved solid	500	250	0 – 2000
Chloride	250	-	-
Sulphate	100	200	-
Zinc	3	3.0	5.0
COD	150	1.0	-
BOD	50	0.3	-
TSS	300	-	-

3.2 Sources of Water Pollution

Water pollution can happen due to a host of factors resulting from a variety of sources.
Some of the sources responsible for water pollution based on physical categorization are according as;
Rural run-off loads:
Agricultural lands, including pastures and grasslands;
Forest watersheds.
Barnyards and feedlots;
Wasteland and storage facilities in form of seepages or discharges; and
Construction sites.
Atmospheric loads:
wet/dry deposition
Externalities (i.e common sources of water quality impairment)
Channelization;
Animal husbandry;
Industrial wastewater;
Increased flows due to harvesting of trees;
Seepages from municipal solid waste disposal sites;

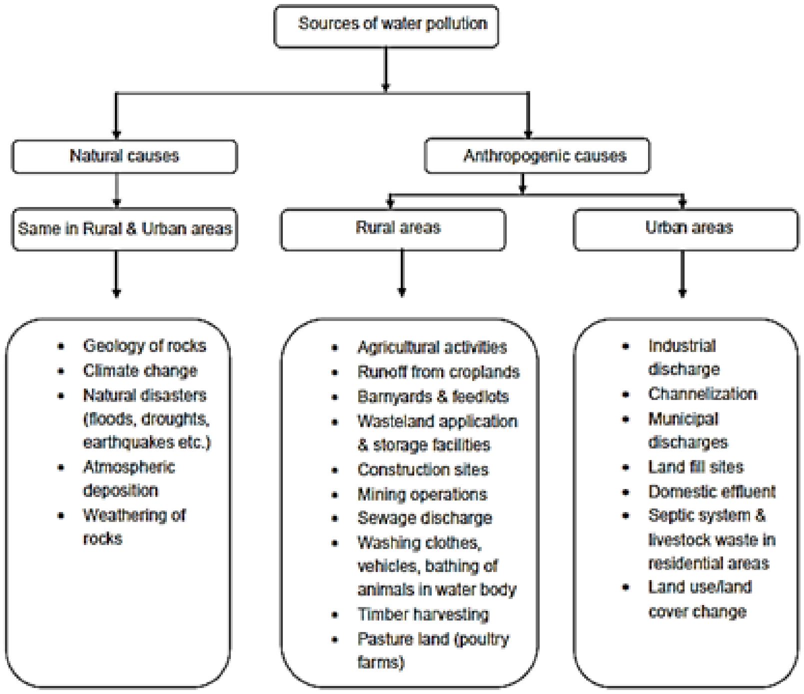

Figure 1: Flowchart showing natural and anthropogenic sources of water pollution in rural and urban areas

4. Conclusion

Freshwater is a precious resource as it constitutes only 0.3% of total water resources across the globe. But the availability of water is subject to natural influences and anthropogenic activities. It is noted that anthropogenic influences on water quality have the most impact on life. Anthropogenic factors affecting water quality in rural areas differ from those in urban areas. In rural areas, they include agricultural practices, e.g. use of fertilizers, herbicides and pesticides; river siltation due to erosion; nutrient loading in waters; run-off from degraded forest areas; and animal husbandry. Anthropogenic factors that affect water quality in urban areas include industrialization, sewage discharge and other domestic activities. In addition changes in land use patterns including changes in land cover also adversely affect water flow and quality. In rural environments, especially in developing countries, the anthropogenic influences are less profound; those due to industrialization and commercialization may not be present at all. It suffices to note that water pollution due to industrial wastewater is absent in rural areas, the rural environment is thus a pristine one. The quality of surface water and groundwater is a sensitive issue as far as health is concerned thus Contamination of these resources should be prevented, controlled and reduced.

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DESIGN AND FABRICATION OF A MICRO-SPRINKLER IRRIGATION SYSTEM USING A PLASTIC BOTTLE AS A SPRINKLER HEAD

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Abstract

Irrigation has undergone several forms of modernization. The Sprinkler system is one of those improvements in water application techniques in agriculture but the high initial installation costs and other relevant factors led to the design and development of a micro-sprinkler irrigation system using plastic bottle water as a sprinkler head to bridge the gap. Plastic bottle water was used for this design because is locally available and also a biodegradable material that causes a lot of pollution around the world. In this study, a sprinkler system was designed, developed and installed using a fixed sprinkler system to irrigate a small size plot for preliminary performance evaluation. The plastic bottle nozzle height varies from 5cm and 15cm from the bottle head and it also has a variation punch point of 6 to 7 round the bottle with different nozzle diameters from 2.5mm to 5mm. The results show that the plastic nozzle height of 15cm, 7 punch points and a nozzle diameter of 2.5mm gave the best coefficient of uniformity, distribution uniformity, the radius of spray and wetted parameter.

Keywords: plastic bottle, sprinkler head, irrigation system.

1.Introduction

Irrigation is simply the application of water artificially to the land for crop production (Egharevba, 2009). One of the methods of water application is the sprinkler system of irrigation. It involves the application of water in the form of a spray formed from the flow of water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping, although it may be obtained by gravity if the water source is high enough above the area irrigated (NEH, 2016). Sprinkler systems have revolutionized the development of irrigated agriculture. Efficient water application with sprinkler irrigation involves the design and operation of pumps, pipes, and sprinkler devices to match soil, crop, and resource conditions. Thus, sprinkler systems can be designed and operated for efficient irrigation for a wide array of conditions. Sprinkler irrigation also facilitated the expansion of irrigated agriculture onto lands classified as unsuitable for surface irrigation. National Engineering Handbook (NEH, 2016) indicated that sprinkling devices were used as early as 1873. By 1898 seventeen patents had been issued for sprinkler devices. Since that early beginning, many developments have occurred. The patent for impact sprinklers as we know them today was issued in 1934. Aluminum pipe with rubber gaskets was first produced in the late 1940s while an early version of the side roll machine was first produced in the 1950s. Self-propelled centre pivot and lateral move systems were invented in the late 1940s. Producers quickly recognized that controlling an irrigation system was essential for proper performance. One of the first controllers for sprinkler irrigation was installed in 1924. These early developments laid the foundation for the growth of sprinkler irrigation. In the late 1940s and early 1950s development began in earnest and continued with large increases in the 1960s and 1970s when automated systems were commercialized. The amount of land irrigated with sprinkler systems continues to increase. Most of the development today is devoted to automated and semi-automated sprinkler systems. In Nigeria, the history of irrigation can be traced back to the period of Colonial rule. However, it became more pronounced after the drought of the early 70s (postcolonial era), which led to severe hardship due to food shortages (Ugalahi *et al.,* 2016). As the need for irrigated crop cultivation grew between 1972 and 1974, three pilot public irrigation schemes were developed by the Federal Government of Nigeria namely; Bakori Scheme, the Kano River Irrigation Scheme and the Chad Basin Scheme (NINCID, 2015). In most parts of the country, irrigation has not gone beyond the usual surface type, which is mostly associated with poor designs leading to water wastages, excessive power usage, loss of fertile soils and drudgery. The objective of this study is to achieve the best sprinkler head height and nozzle diameter.

2.0 Materials and Methods

2.1 The Study Area

The experiment was conducted on a 20m x 20m piece of land behind the departmental laboratory of the Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Niger State. The geo-location of Minna is on the north and east hemisphere, stationed on Latitude $9^{o}36^{I}$ 54.86^{II} N and Longitude 6^{o} 32^{I} 51.94^{II} E. Politically, it is classified among the north-central states of Nigeria, with an estimated human population of approximately 304,113 as at 2006 (CENSUS, 2006).

2.2 Material

The items used to carry out this experiment include. sprinkler head and nozzle (plastic bottle), Storage tank, measuring tape, gum, catch cans (45 in numbers), pressure gauge, Stopwatch, The sprinkler set up consists of PVC pipe of mainline, lateral lines, risers, fittings (such as t-joint, elbow-joint, end-plug) Water pump machine (1.5hp).

2.3 Sprinkler System Design

The following factors were considered in designing the sprinkler system

i. The area to be irrigated was measured accurately.

ii. The sprinkler system was drawn on paper (Figure 1).

iii. The sprinkler head was also sketched out showing the punch point that was varied (figure 2).

iv. Construction/installations were done based on the design calculations. Sprinkler Irrigation Design and Installation Guide/Manual as presented in (Rainbird, 2012) was followed for the installation.

2.3.1 Factors Considered during Design

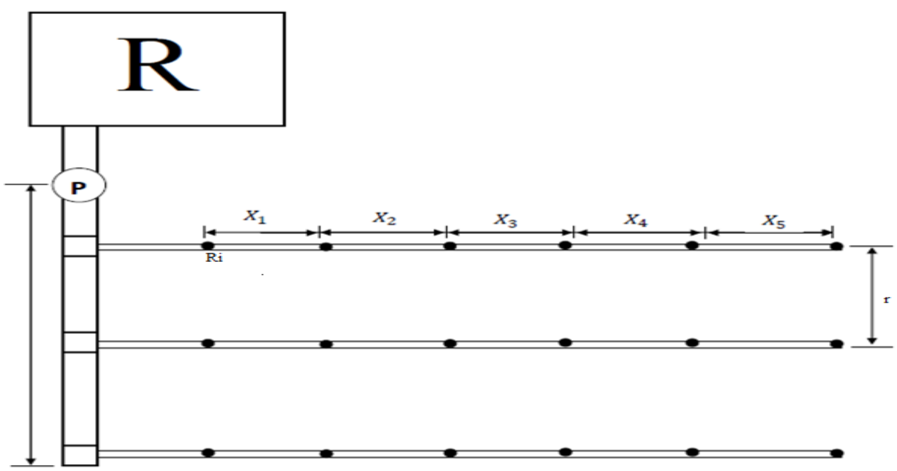
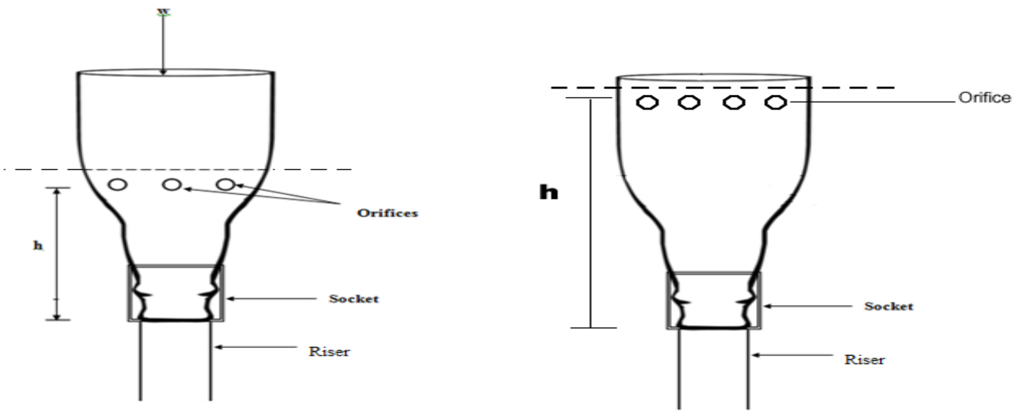


Fig1 Design used for the fabrication of the micro-sprinkler system

Source: author's conception

R= Reservoir, Ri = Riser, P = Water Pump, Xi = Distance between risers, r = Distance between laterals.

Fig 2: Sketch of the Sprinkler Head (Plastic Bottle)



Source: author

Where: h = Height of punch, w = punch at the top

2.3.2 Design of Sprinkler Head Irrigation System: A sprinkler head system was designed to suit the condition of a normal conventional sprinkler head (Table 2.1) and is specially designed to achieve high performance.

Table 2.1 Different sizes of nozzle diameter (Ngasoh *et al.*, 2018)

	Nozzle Size		
Sprinkler Made	**Large (mm)**	**Small (mm)**	**Riser (inch)**
Nelson	4.8	3.1	2
Somlo	4.8	3.2	2
Naan	4.4	2.5	2
Parrot	4.8	3.8	2

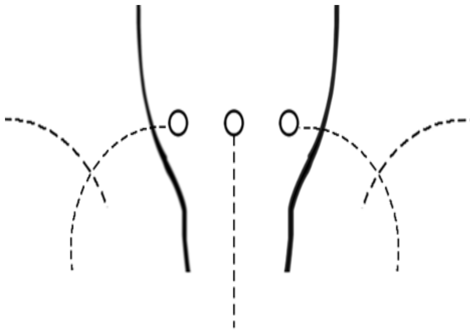


Fig. 3: Lapping of the Sprinkler Discharge

2.4 Determination of Radius of Spray

This is one of the most important parameters that was considered to determine the efficiency of a sprinkler irrigation design. The distance from the base of a riser to the point of the last spray is termed the radius of spray. This was determined in the field using a measuring tape, and parameters were noted and recorded.

2.4.1 Wetted Parameter

This is the sum of the length and breadth of that part of the field that water touches during spray. This also can be determined in the field using a measuring tape, the parameters were measured and recorded during the field experiment.

2.4.2 Coefficient of Uniformity (CU)

Calculated as a percentage (%) and also known as the Christianson uniformity coefficient, CU is defined as (Fikadu Kinfe *e tal*).2018

:$CU = \left(1 - \frac{\sum(x-\bar{X})}{n \times \bar{X}}\right) \times 100$

Where,

$\bar{X}$ = depth of water in the catch can;

x = mean depth caught in mm;

n= number of the sample (catch can).

2.4.3 Water Distribution Uniformity (U_d)

Distribution uniformity (U_d) is the percentage of the average application amount received in the least-watered quarter of the field. It is calculated mathematically as;

$$\boldsymbol{U}d = 100\left(\frac{Lq}{Xm}\right)$$

Where U_d = distribution of Uniformity.

L_q = Average low-quarter depth of water infiltrated (or caught),

X_m = Average depth of water infiltrated (or caught)

The distribution uniformity indicates the magnitude of the distribution problem. It can be defined as the percentage of average application amount in the lowest quarter of the field. (Fikadu Kinfe *e tal*).2018

2.5 Installation and Preliminary Test of the Sprinkler Irrigation System

The testing of the sprinkler irrigation system started by coupling the sprinkler head (plastic bottle) to the socket with gum and to the riser which was done carefully to avoid leakage, all joints were connected through the risers to the laterals and the main, the pump was connected to the reservoir tightly to avoid leakage and then the discharge outlet of the pump was connected to the main pipe via a 32mm, 19mm lateral line and 12mm riser line PVC pipe. The pump was first primed before starting and then water was pumped into the main pipe to the sprinkler nozzles via the laterals, risers and eventually the sprinklers started sprinkling water as expected and the preliminary test was carried out.

Plate 1- Installation and Settings and Fittings for the Sprinkler Head

3.0 Results and Discussion

3.1 Descriptive Performance Statistics of the Sprinkler Head

The result of the performance evaluation on the installed sprinkler system is presented in Table 3.1.

Table 3.1: Interaction of Sprinkler Head Height and Nozzle Diameter

Nozzle Head Height (cm)	Orifice Diameter (mm)	Distribution Uniformity (%)	Coefficient of Uniformity (%)	Wetted Parameter (m)	Radius of Spray (m)
5	2.5	59	58.4	38.6	1.63
15	2.5	86.7	94.4	93.6	4.18
5	5	38.4	35.9	25	0.8
15	5	46.8	46.1	29.6	1.18

The minimum acceptable performance level for economic system design for distribution uniformity DU > 65% and coefficient of uniformity CU > 78%. Table 2.2 revealed the interaction of sprinkler head height of 15 cm from bottle head and nozzle diameter of 2.5mm gave the best distribution uniformity index of 87.2%, coefficient of uniformity index of 98.1%, and the radius of spray index of 4.62m and wetted parameter index 104m. The work of Michael Cahn *et al*. 2018, and Rui Chen, *et al*. 2020 talked about the effect of nozzle diameter on the sprinkler irrigation system.

3.2 Statistical Analysis Result of Independent Sample Test for Equality of Variance

The statistical result presented in table 2.2 and table 2.3 show all the variances of the responses from the preliminary test using a group statistic method to show the statistical analysis test using the independent sample test of Levene's test for equality of variance and the T-test for equality of mean

Table 3.2: Levene's Test for Equality of Variances and t-test for Equality of Means for Sprinkler Head Height

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Distribution uniformity	Equal variances assumed	124.556	0.001	-1.791	10	0.103	-18.06667	10.08473	-40.53685	4.40351
	Equal variances not assumed			-1.791	7.532	0.113	-18.06667	10.08473	-41.57618	5.44284

Coefficient uniformity	Equal variances assumed	62.214	0.001	-1.920	10	0.084	-23.08333	12.02347	-49.87329	3.70662
	Equal variances not assumed			-1.920	7.045	0.096	-23.08333	12.02347	-51.47727	5.31060
Wetted parameter	Equal variances assumed	92.949	0.001	-2.009	10	0.072	-29.85000	14.85456	-62.94801	3.24801
	Equal variances not assumed			-2.009	5.453	0.096	-29.85000	14.85456	-67.10032	7.40032
Radius of spray	Equal variances assumed	80.366	0.001	-2.071	10	0.065	-1.45833	.70401	-3.02697	.11031
	Equal variances not assumed			-2.071	5.743	0.086	-1.45833	.70401	-3.19982	.28315

In this table height of the nozzle where vary using the independent sample test to show that the Levene's test has a significant variance on distribution uniformity of 0.001, coefficient of uniformity of 0.001 same to wetted parameter and radius of spray but the (2-tailed) means test shown no significant on the means data of distribution uniformity of equal variances assumed of 0.103 and equal variances not assumed of 0.113, coefficient of uniformity of equal variances assumed of 0.084 and equal variances not assumed of 0.096, the wetted parameter of equal variances assumed of 0.072 and equal variances not assumed of 0.096 and radius of the spray of equal variances assumed 0.065 and equal variances not assumed of 0.086. This is similar to the work of Dario Friso, *et al.* 2012. Shown a mathematical model that proves different nozzle heights do not show significant differences in the coefficient of uniformity unless the large diameter and lower height of the nozzle where the coefficient of uniformity get worse with a decrease in trajectory.

Table 3.3: Levene's Test for Equality of Variances and t-test for Equality of Means for Punch Diameter for orifice size.

	Levene's Test for Equality of Variances	t-test for Equality of Means

		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Distribution uniformity	Equal variances assumed	124.556	0.001	4.630	10	0.001	30.26667	6.53721	15.70086	44.83248
	Equal variances not assumed			4.630	6.077	0.003	30.26667	6.53721	14.31988	46.21345
Coefficient of uniformity	Equal variances assumed	62.214	0.001	4.151	10	0.002	35.38333	8.52348	16.39183	54.37484
	Equal variances not assumed			4.151	5.974	0.006	35.38333	8.52348	14.50475	56.26192
Wetted Parameter	Equal variances assumed	92.949	0.001	3.072	10	0.012	38.78333	12.62321	10.65707	66.90959
	Equal variances not assumed			3.072	5.096	0.027	38.78333	12.62321	6.51684	71.04982
Radius of spray	Equal variances assumed	84.529	0.001	3.230	10	0.009	1.90167	.58879	.58976	3.21358
	Equal variances not assumed			3.230	5.306	0.021	1.90167	.58879	.41401	3.38932

In this table nozzle diameter where vary using the independent sample test to show that Levene's test has a significant variance on distribution uniformity of 0.001, coefficient of uniformity of 0.001 same to wetted parameter and radius of spray, the (2-tailed) mean test also shown significant on the mean data of distribution uniformity of equal variances assumed of 0.001 and equal variances not assumed of 0.003, coefficient of uniformity of equal variances assumed of 0.002 and equal variances not assumed of 0.006, the wetted parameter of equal variances assumed of 0.012 and equal variances not assumed of 0.027 and radius of the spray of equal variances assumed 0.009 and equal variances not assumed of 0.021. This also corresponds with the work of Rui Chen, *et al*. 2020 which said that it is not recommended to equip the sprinkler with a large nozzle diameter under low working pressure, this means the best of our performance with respect to the pressure output was 2.5mm. It also shows that the confidence interval of both upper and lower difference is 95%, that statistical analysis for the t-test value of this experiment has higher certainty of the true data mean, while 5% won't be true.

4.0 Conclusion and Recommendations

4.1 Conclusion

Sprinkler irrigation was designed, fabricated and installed at the back of the Laboratory of the Department of Agricultural and Bioresources Engineering of the Federal University of Technology, Minna. The sprinkler head was designed for performance evaluation during the preliminary test. To close the gap by using plastic bottles as sprinkler heads due to the high cost of sprinkler components and also to reduce the pollution of biodegradable material since is abundantly available. The sprinkler head design that has the best performance after the preliminary test was 15cm punch height and 2.5mm orifice diameter of distribution uniformity index 87.2 %, coefficient of uniformity index 95.7 %, the wetted parameter of index 104 m and radius of spray index of 4.62 m has shown the best sprinkler irrigation system for the preliminary experiment on the developed sprinkler head. All the values gotten are all in an acceptable range. The benefit-cost of installing this sprinkler head is far cheaper than that of a conventional sprinkler head.

4.2 Recommendations

Based on the design, construction and installation of the sprinkler irrigation system, the following recommendations were suggested an orifice diameter of 2.5 mm and sprinkler head height of 15 cm is best recommended for the sprinkler head design for plastic bottles.

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DETERMINATION OF CROP WATER REQUIREMENT OF EGGPLANT IN MINNA USING WEIGHING LYSIMETER

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Abstract

Five mini weighing metallic lysimeters were fabricated with readily available local materials and utilized for the determination of crop water requirement as well as crop coefficients of eggplants at different stages of growth until maturity. In order to facilitate the research, the soil was collected from the permanent site of the Federal University of Technology Minna and filled to the 30 cm mark of the lysimeter tank and 3 weeks old eggplant seedlings were transplanted in each. A known quantity of water is applied daily and readings are also monitored every morning. Results obtained showed that the eggplant water required at its development, mid and late stages of growth are determined as 5.0 mmday^{-1}, 8.9 mmday^{-1} and 5.7 mmday^{-1} respectively. Also, the crop coefficients were determined as 0.9, 1.7 and 1.2 respectively. Seasonal water required for the crop was as well obtained as 588.0mm. In all, values obtained for both daily water requirement crop coefficients in all the stages of growth are not too far from the ones recorded in most literature. This research has been able to demonstrate that the crop water requirement of any plant using lysimeters fabricated with available local materials can be determined.

Keywords: Crop water requirement, crop coefficient, lysimeter, evaporation, transpiration.

1. Introduction

A lysimeter is derived from the Greek word (λύσɩϛ) meaning loosening, and combined with the suffix meter, is a measuring device which can be used to measure the actual amount of evapotranspiration from plants (Arora, 2002). According to the Encyclopedia of Environment (2005), Lysimeters are the foremost devices, typically tanks or containers, that define a specific boundary to contain soil water and permit measurement of either the soil-water balance or the volume of water percolating vertically and or its quality. This can be done using either disturbed or undisturbed soil. So many projects involving the measurement of water use by crops are effectively being carried out with the use of both disturbed and undisturbed soils in lysimeters. Lysimeters, certainly, have been widely used for the studies of evapotranspiration in various parts of the world. Although it is expensive to construct especially the sophisticated weighing type, its cost/benefits ratio proves very favourable for its development and use (Nathan *et al,* 2002). The use of lysimeters is a proven method for measuring the movements of water and chemicals through the soil profile.

A lysimeter by definition is a measuring device which can be used to measure the amount of actual evapotranspiration which is released by plants usually crops. Generally, it is known to be a tank of different sizes filled up with soil having plant grown on it. In its actual operation, the lysimeter is buried in excavation such that the top is flush with the excavated soil.

It is on record that in 1875 Edward Lewis Sturtevant, a botanist from Massachusetts built the first lysimeter in the United States. But the first lysimeter ever built for evaporation and evapotranspiration studies showing the difference between water input and output as reported by Ogbuu *et al.,* (2015), was constructed by John Dalton in 1796. It was also stressed in his report that the first lysimeter study for water use was done by De la Hire of France in the 17th century. Many other researchers have designed and constructed lysimeters to meet their specific needs and objectives. Thornthwaite was presumably the first to apply a lysimeter for the measurement of evapotranspiration in field conditions (Howell *et al.,* 2000). Many studies of crop water use have been undertaken for a variety of crops in many different locations and growing environments. Water-use and crop-coefficient curves have been developed from these studies. The results from one environment, however, may not be readily transferable to another (Piccini *et al.,* 2002).

Lysimeters of different types have been used to measure and study water use for a variety of crops. From literature 'lysimeter' as a term is used for different objectives such as suction cups, flux meters, etc (Weihermuller, *et al,* 2007). It is also known that lysimeter types vary according to the research interest of the researcher. Meanwhile, there are two main types of lysimeter. These are weighing and non-weighing lysimeters. This research paper, therefore, presents the utilization of a weighing type lysimeters to determine the crop water requirement of eggplants in Minna.

2. Materials and Method

The soil samples used for this research were collected at the Federal University of Technology, Gidan Kwano Campus, Minna. Minna, the capital city of Niger State falls under the Guinea Savanna of the tropical climate vegetation belt of Nigeria, having two (2) distinct seasons (rainy and dry seasons). The rainfall commences mostly in the months of March-April and terminates around October-November. The study area has an average annual rainfall amount of 1229mm, with the highest amount (260mm) mostly in September, and the least amount (0.1mm) in January. Average maximum and minimum monthly temperatures are 34 and 27 ^{o}C respectively. The geo-location of Minna is on the north and east hemispheres, stationed on Latitude $9^{o}\ 36^{I}\ 54.86^{II}$ N and Longitude $6^{o}\ 32^{I}\ 51.94^{II}$ E.

The items used include the locally made metallic lysimeter tank, wheel-barrow tube which serves as the weighing device, a transparent flexible hose fixed to a meter rule which serves as the manometer tube, wooden platforms upon which the setup is made, three weeks old garden egg seedlings and the soil sample used. The trial was carried out during the late 2020 rainy season at the permanent site of the Federal University of Technology, Gidan Kwano, Minna, Niger State. Five sets of locally made metallic lysimeters were assembled for this study as presented in Figures 2, 3 and 4. Each set of the mini-lysimeter consisted of a metallic container of 35 cm in diameter and 36 cm deep which serves as the lysimeter tank where the crop was planted, the weighing system and the drainage systems. The weighing system consisted of a wheelbarrow tube filled with water and connected with a rubber hose as a manometer tube of 1m long. Under the lysimeter tank is a provision for the collection of drainage water if any.

Thirty-centimetre depth of soil is collected into the five lysimeter tanks and 3weeks of garden egg seedlings are planted in each. Every five days, four (4) litres of water are added to the lysimeter tank. As a result, the pressure exerted on the tubes due to the increase in weight of the lysimeter tank caused a rise in water level in the manometer glass tube. Excess water beyond what the soil could hold is drained by gravity through the bottom of the lysimeter tank into the drainage collector.

The levels of water in the manometer tubes were monitored every hour each day throughout the crop growing season between 7:00 am and 6:00 pm. The drainage collectors were also inspected daily, and the depths of water found in them were also noted. The difference in weight of the lysimeter tank between two consecutive measurements indicated by the difference in the level of water in the manometer tube was a result of the water added artificially, crop water use (evapotranspiration) and water drained. When there is no drainage water, the difference in weight would be due to crop water use. The weight of the lysimeter tank on any given day was determined from the level of water in the manometer glass tube using a relationship earlier developed in the laboratory between the height of water in the manometer glass tube and known weight packed into the lysimeter tank (Igbadun, 2012). The relationship is:

$$W = 0.468 * H + 1.029 \qquad 2.1$$

Where, W is the weight of a lysimeter in kg and H is the height of water in the manometer glass tube in cm. For the daily crop water use, the expression used for the computation is given as:

$$CU_I = P_i - R_{fi} - D_i - \{(W_{i+1} - W_i) * Cf\} \quad 2.2$$

Where;

P_i is Rainfall amount (mm) on the day i collected in the rain gauge if any, R_{fi} is Runoff (mm) on the day i, if any, D_i is Drainage (mm) on the day I, W_i is Weight of the lysimeter soil on the day I, W_{i+1} is Weight of the lysimeter soil the next day at an interval of 24 hours, CU_i is Crop water use of day I, and cf is a factor for converting weight to equivalent depth of water.

All results were noted and tabulated for final computations. Calculating ET in units of the equivalent depth of water requires that the change in lysimeter mass be divided by the effective evaporating and transpiring area of the lysimeter, and was done as in (Moorhead, 2018).

3. Results and Discussions

The daily water loss from the lysimeter is represented by the level of water in the manometer glass tube. This level of water in the manometer glass tube was monitored daily until the end of the experiment and was as presented in Figure 3.1. From the Figure, it could be seen that level of water in the manometer tube at the initial and later days of the plant's growing period are lower when compared with the mid growing stage of the plants. The manometer level at the beginning of the setup, which is barely three weeks after the transplant is seen to be between 4 and 5cm. It rises to between 8 and 9cm in the mid-season and falls back to around 5cm. This phenomenon is typical of the true relationship of plants' water requirements with regard to their growing stages as described in FAO paper 54.

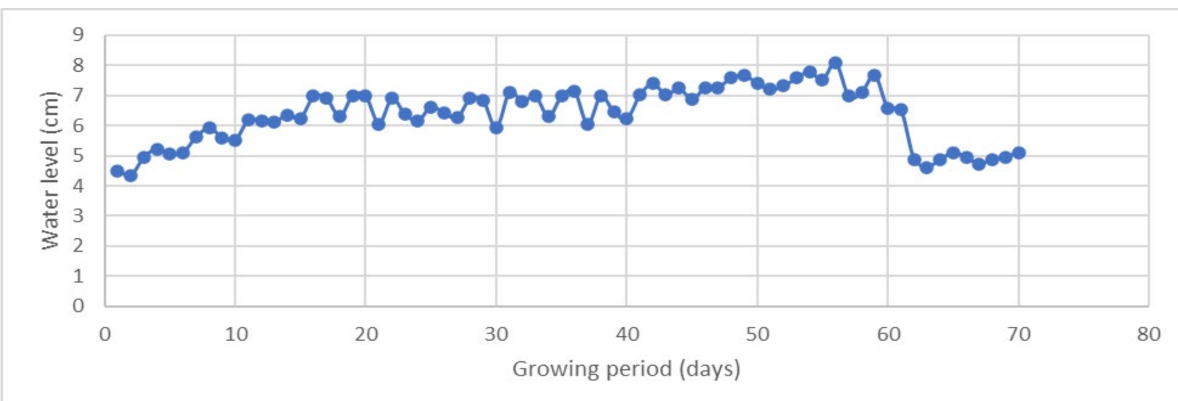

Fig. 3.1: Plot of daily water level in manometer tube against growing period

Daily Water use by Plant from Lysimeter with the conversion factor

The average weight of the five (5) lysimeters with dry soil sample was found to be 33kg and was 41kg when 4litres of water was added to each. This confirmed that the average weight of a litre of water used for this experiment is about 2kg. The internal and external areas of the lysimeter tank were obtained as 1017.88cm^2 and 1134.12cm^2 respectively. From the internal and external areas of lysimeter tanks, a factor of 1.114 was obtained in line with the submission of (Moorhead, 2018) which finally gave the actual amount of water use in mmday^{-1}. The average actual daily water use by the eggplants is as presented in Figure 3.2. From the graph, it could be seen that, though it follows a similar pattern to that of Figure 3.1, actual water use obtained at all the growing stages on day^{-1} is more than the rise of water in the manometer glass tube. Also, the amount of water used by the eggplants in the mid-growing stages from all the lysimeters is more than the water used at other stages of growth. At the development stage, the actual daily water use is seen to be almost 5 $mmday^{-1}$, this gradually rises to about 9 $mmday^{-1}$at the mid-season, and finally falls back to about 5.5 $mmday^{-1}$at the late growing period of the plant. This result followed actual plant water use trends as discussed in most literature, even though the values are slightly higher than the ones obtained using the Modified Penman-Monteith Equation as described in FAO (56) Manual (Allen *et al.,* 2006).

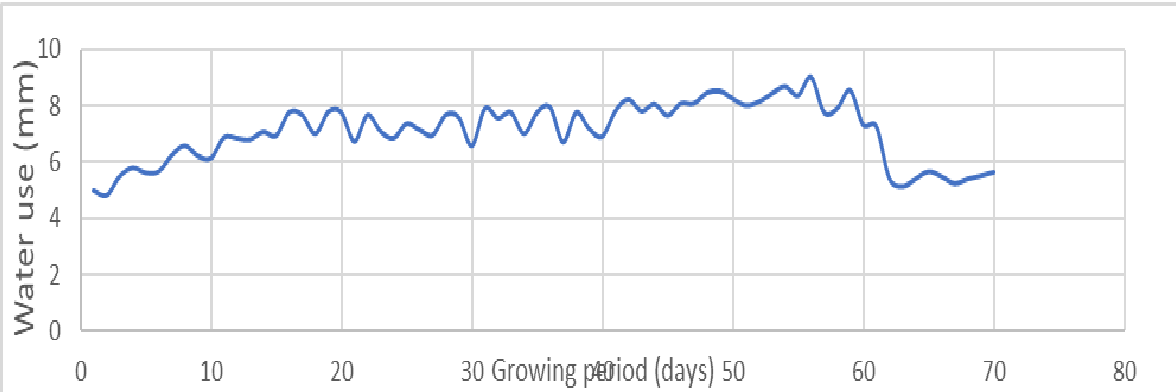

Fig. 3.2: Plot of daily water use ($mmday^{-1}$) for eggplant considering Lysimeter boundary factor

Daily Water use by Plant from Lysimeter considering the weight of lysimeters

The result of the crop water use obtained considering the daily differences in weights of lysimeters was presented in Figure 3.3. From the graph, it could be seen that crop water use of eggplant at its mid-growing stage is higher when compared with those of the development and late growing stages. The water use as seen from the graph was slightly above 4 $mmday^{-1}$ at the development stage and rises to slightly above 7 $mmday^{-1}$ before falling back to as low as 4.5 $mmday^{-1}$ during the late growing stage. This result gives a good representation of the actual behaviour of crop water use during its stages of growth but was however lower than the result obtained when the lysimeter conversion factor was used.

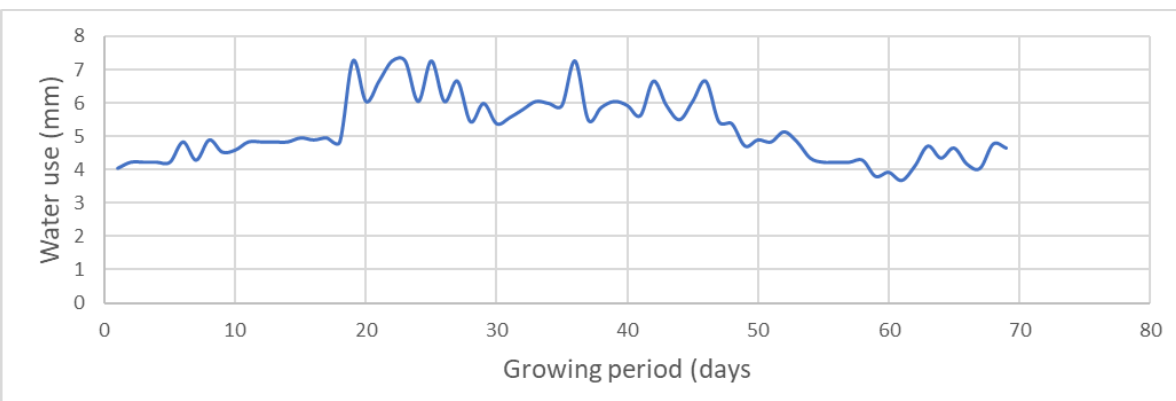

Fig. 3.3: Plot of daily water use ($mmday^{-1}$) for eggplant considering the weight of Lysimeter

Crop Coefficient Determined

The result of the crop coefficient or crop factor determined for November, December and January is presented in Table 3.1. From the table, it could be seen that the crop coefficient at the mid-stage of growth is higher compared to those at the development and late growing stages. This result conforms to the results documented in FAO book 54.

Tab. 3.1: Result of Crop Coefficient Determined

S/No	Months	Plant G/stage	ETc Determined	Theoretical ETo	Fc	Determined
1	November	Development	5.0 $mmday^{-1}$	5.17 $mmday^{-1}$	0.9	
2	December	Mid-stage	8.9 $mmday^{-1}$	4.96 $mmday^{-1}$	1.7	
3	January	Late stage	5.7 $mmday^{-1}$	4.50 $mmday^{-1}$	1.2	

Also, the water requirement in $mmday^{-1}$ of the crop as determined by the lysimeter experiment is slightly lower than the theoretical values obtained using weather information of the study area. The widest gap was that of the mid-growing stage with 8.9 $mmday^{-1}$ and 4.96 $mmday^{-1}$ for lysimeter and theoretical respectively. This wide gap was also responsible for the larger value (1.7) of the crop coefficient.

Result of Monthly Water use by Plant from Lysimeter at each growing stage

The monthly crop water use for eggplant at its development, mid-stage and late growing stages is presented in Table 3.2. From the Table, the highest crop water required throughout the crop growing months was that of its mid-growing stage, while the lowest was that of its development stage. This is true of the amount of water required by plants in their growth stages, the plants in most cases use more water in their mid-growing stages that in the other stages of growth. The seasonal crop water required was determined to be 588.0mm. This value is within the range of values documented in FAO book 54, which maintains that seasonal crop water required for eggplants is between 400 and 800mm.

Table. 3.2: Result of Crop Coefficient Determined

S/no	**Months**	**Fc Determined**	**Fc from Table**	**ETc**	**Growth Period**	**Monthly ETc**
01	November	0.9	0.8	5.0 $mmday^{-1}$	Development	150.0
02	December	1.7	1.15	8.9 $mmday^{-1}$	Mid-season	267
03	January	1.2	0.85	5.7 $mmday^{-1}$	Late season	171
TOTAL						**588.0mm**

Also, the crop coefficients obtained are slightly different from the already established values in litre. This could be due to either human errors or error due to imperfection of equipment used.

4. Conclusions and Recommendations

The research was a successful one, the five lysimeters were fabricated and utilized for the determination of crop water requirement as well as crop coefficients of eggplants at different stages of growth until maturity. The eggplant water required at its development, mid and late stages of growth are determined as 5.0 mmday^{-1}, 8.9 mmday^{-1} and 5.7 mmday^{-1} respectively. Also, the crop coefficients were determined as 0.9, 1.7 and 1.2 respectively. Seasonal water required for the crop was as well obtained as 588.0mm. In all, values obtained for both daily water requirement crop coefficients in all the stages of growth are not too far from the ones recorded in most literature. This research has been able to demonstrate that one can determine the crop water requirement of any plant using lysimeters fabricated with available local materials around us. Based on the above, it is recommended that the fabricated lysimeters be used to determine crop water requirements and crop factors of some other selected crops in the area.

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EFFECT OF IRRIGATION DEPTH SELECTED AGRONOMIC AND POST-HARVEST PARAMETERS ON TWO CASSAVA (TMS 0581 AND TME 419) VARIETIES

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Abstract

An attempt was made to ascertain the effects of irrigation depth, some selected agronomic and post-harvest parameters on two Cassava varieties, TMS 0581 and TME 419, and also perform comparative analysis under standard agronomic practices. The design was a Randomized Complete Block Design (RCBD) of four treatments and three replicates. Treatment A had fertigation, B used poultry manure, C employed NPK, 15-15-15 while D with no treatment was used as control. Some of the parameters measured include: the depth of irrigation water in each of the treatment plots, agronomic parameters such as plant height, stem girth, leaf area, number of branches and leaves and post-harvest parameters as in tuber yields (with and without biomass) and results obtained were subjected to statistical analysis. From the results, TMS 0581 performed better in terms of plant height, stem girth, number of branches, and leaf area, while TME 419 did well in terms of the number of leaves only. Treatments A of all the four treatments and in both varieties had the highest average yields (without biomass) with values of 44.32±0.01 Kg/plot (11.1 Tons ha^{-1}) in TME 419 and 34.45±0.07 Kg/plot (8.6 Tons ha^{-1}) in TMS 0581 respectively. Irrigation depth ranged between 1.70±0.01 (0.56 metres) and 1.76±0.01 feet (0.58 metres) indicating the presence of sufficient water supply within the root crop zone required for optimum crop growth and development. TME 419 is therefore recommended due to marginal higher yield and lower agronomic development with no visible negative effect on the yield.

Keywords: Cassava: agronomic: post-harvest: irrigation: varieties

1. Introduction

Cassava (*Manihot esculenta Crantz*) belongs to the family *Euphorbiaceae* with a well-developed fibrous root system and is grown mainly in the tropical region of Africa (including Nigeria), Brazil, Indonesia, Philippines and Thailand (Olukunle *et al.*, 2010). It is a root crop planted from stem cuttings and thrives in fairly bad weather and poor soils with or without fertilizer and grows well in areas with an annual rainfall of 500-5000mm (Eze and Ugwoke 2010). A very wide range of Cassava varieties are grown worldwide depending on the locality but they are broadly classified into the sweet and the bitter varieties based on the level of the poisonous hydrogen cyanide (HCN) present in the tuber. Similarly, they are also classified based on maturity period as most traditional varieties mature in eighteen months and beyond, however, some new improved Cassava varieties developed by the International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria mature as early as six months after planting (IITA, 2010). These varieties are high yielding, and resistant to pests and diseases with cyanide contents as low as 3.1mg/100g (Uchechi and Nwanchukwu 2010). Cassava is mostly processed traditionally into *gari, lafun, fufu, abacha, and akpu* in Nigeria, and, *kokonte and agbelima* in Ghana (Anju *et al.*, 2014; IFAD/FAO 2005). Nigeria is the largest producer of crops in the world with a production level estimated at 49 million tons per year (Uthman, 2011). This is a third more than the production in Brazil (World's second-largest producer) and almost double the production of Indonesia and Thailand. Cassava is presently the most important food crop in Nigeria for both the area under cultivation and the tonnage produced. This is the fact that it has transformed greatly into a high yielding cash crop, a foreign exchange earner, as well as a crop for world food security and industrialization, as a result of this, there has been an unprecedented rise in the demand for Cassava and its numerous products worldwide for both domestic and industrial applications (Ayoola and Makinde 2007). Considerable efforts have been put into increasing Cassava production to meet the burgeoning population demand globally. Anju *et al.*, 2014 and Odedina *et al.,* 2012 concluded that the production of drought-resistant varieties and an increase in land area under cultivation will improve its production while Akinbile *et al*., (2011) identified the efficient adoption of irrigation technology as another major way of ensuring increased Cassava production and therefore optimum water application management is required during Cassava cultivation to supplement water deficit. Apart from the soil constituents and profile, which largely determines the root configuration, responses of the agronomic parameters to optimum water and fertilizer applications are also factors responsible for the development of cassava tubers during cultivation. With the advent of new technologies that combine the operations of fertilizer application with irrigation (fertigation), the process of growth and development of crops generally has been simplified as ambiguities associated with poor irrigation and fertilizer application have been eliminated (Liang *et al*., 2014). Further investigation as to what extent the agronomic parameters in optimum water application have on the root and tuber development of Cassava is required hence this study. This became imperative because a similar study to determine the effects of some soil properties, moisture content, yield and consumptive water use of these same two varieties of Cassava has been conducted with outstanding results (Akinbile *et al.,* 2019).

Therefore, the objective of this study was to determine the effects of the depth of irrigation water and selected agronomic and post-harvest parameters on two Cassava varieties (TMS 0581 and TME 419) within the entire growing season.

2. Methodology

The research was conducted at the experimental farm of the Agricultural and Environmental Engineering Department, The Federal University of Technology, Akure, Ondo State between January and November 2016 which lies in the rainforest zone of the region. Akure has a mean annual rainfall of between 1,405 mm and 2,400 mm with two distinct wet/rainy seasons from April to October and a relatively dry season from November to March seasons (Akinbile *et al.,* 2011). Akure is located within the humid region of Nigeria on latitude 9˚ 17’N and longitude 5˚ 18’E with an average temperature of 27.5˚C, relative humidity ranging between 85% and 100% during the rainy season and less than 60% during the dry season. Soil texture at the experimental field is sandy loam, which is an alfisol classified as clayey skeletal oxic-paleustaif (USDA). (Akinbile and Yusoff 2011). The field experiment was laid out in a Randomized Complete Block Design (RCBD) consisting of four treatments and three replicates, making a total of 12 plots (Figure 1). (Treatment A = liquid fertilizer (Plantzyme Agricultural Soluble Fertilizer) administered at 2.0 t ha^{-1}; Treatment B = poultry manure; Treatment C = NPK fertilizer and Treatment D = control). Each plot was of dimensions 4 m x 4 m and the total field dimension was 22 m x 16 m with 2m alleyways along the length and width of the plots and between the plots and the fence at the four edges respectively. The field was planted with 96 pieces each of TMS 0581 and TME 419 Cassava cuttings, obtained from the IITA Ibadan, Nigeria in March 2016. Drip emitters were connected to main pipes and were subsequently connected to two reservoirs located 4 m away from the edge of the experimental field at the upper end (Figure 2). These emitters, in predetermined drip irrigation frequency, were used to convey the mixture into the respective blocks of treatments. All these followed the procedure and pattern adopted by Akinbile *et al.,* (2019) in their studies. Agronomic parameters were measured weekly which began three (3) Weeks after Planting (WAP) and ended at 32 WAP. Irrigation water was applied to the crops at three days’ intervals during the peak of the dry season and later reduced to once weekly when rainfall had begun to stabilize. Some of the parameters measured include depth of irrigation water in each of the treatment plots, agronomic parameters such as plant height, stem girth, leaf area, number of branches and leaves, and post-harvest parameters as in tuber yields (with and without biomass). The Meter rule was used for plant height and stem height while the number of leaves and branches was determined by counting manually. The stem girth was obtained by using a digital Vernier calliper. Results obtained were subjected to statistical analysis using SAS 9.1 version while one-way ANOVA and Least Square Difference (LSD) were performed on all data at a 95% significance level.

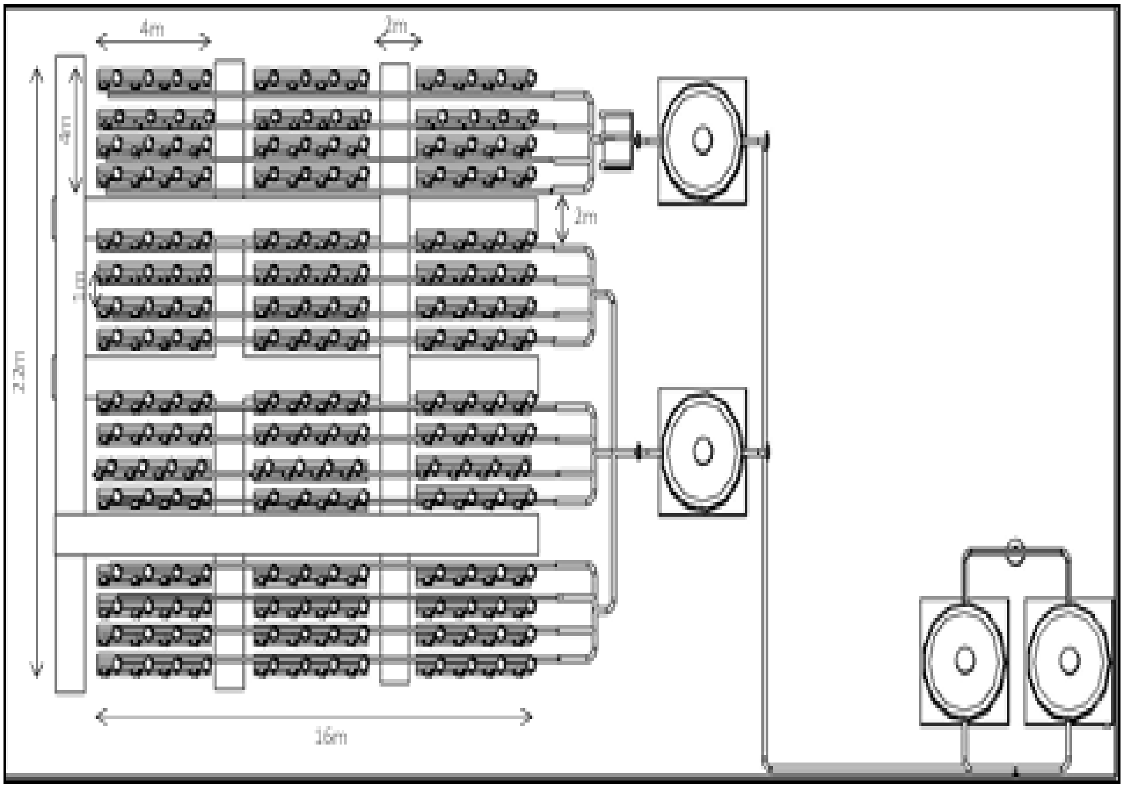

Figure 1: The 2-Dimensional experimental design layout of the field.

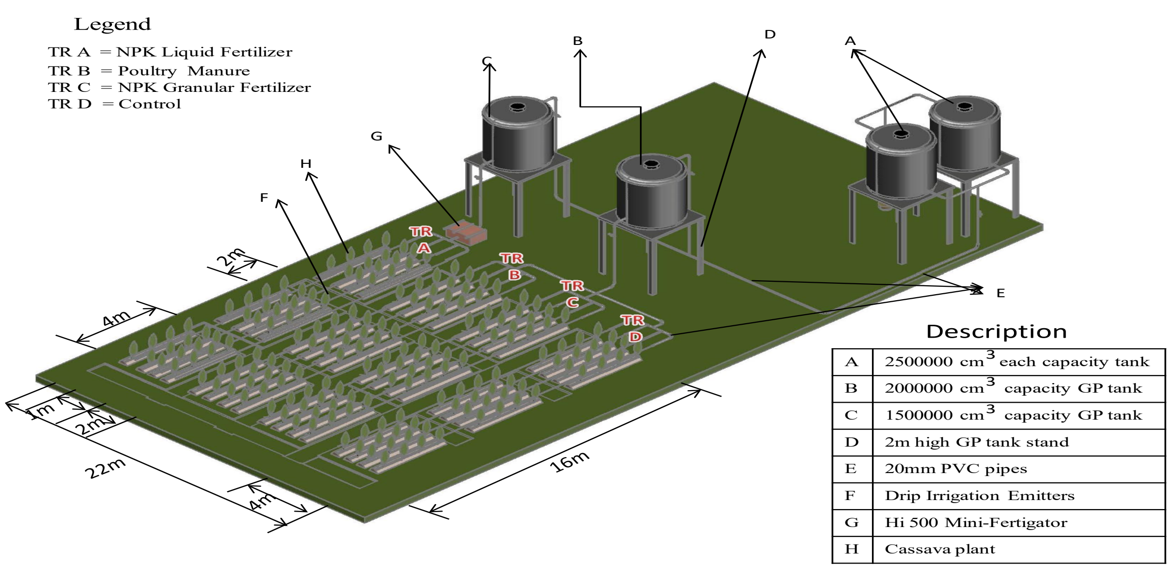

Figure 2: The 3-Dimension experimental design layout of the field

3. Results and Discussions

The results of the average depth of irrigation water in each of the four treatments are presented in Table 1. The highest depth of 1.76±0.01[a] feet (0.58 meters) was recorded in Treatment A, closely followed by 1.75±0.01[ab] (0.58 m) in treatment B, 1.70±0.01[c] (0.56 m) and 1.72±0.02[bc] (0.57 m) were reported in treatments C and D respectively. This result showed the significant effects of irrigation water applied to attain specific depths for proper tuber configuration and development otherwise known as *tuberization* even though the difference in the Treatments was not substantial along the rows. The Cassava development and performance at this stage were favourably influenced by the availability of regular water applied. This finding is in line with FAO (2013) which remarked that Cassava responds well to optimum irrigation while root decay is experienced when considerably higher quantities of water are supplied in an attempt to envisage much higher yields under standard farming conditions. At this stage, pore spaces were filled and the soil is supersaturated and the root tubers are enmeshed in moisture.

Table 1: Average depth of irrigation recorded in each of the four treatments

Treatments	Depth of irrigation
A	1.76±0.01[a]
B	1.75±0.01[ab]
C	1.70±0.01[c]
D	1.72±0.02[bc]

The results of some selected agronomic parameters analyzed in the two Cassava varieties were as presented in Tables 2 and 3. From Table 2, the results showed that all the treatments have a significant difference in the numbers of leaves, numbers of branches, plant height, stem girth, and leaf area in the TMS 0681 Cassava variety. The identical observation was recorded in the TME 419 variety in Table 3. There was a substantial agreement of the results with the findings of Eze and Ugwuoke (2010) who reported that the performance of Cassava is influenced by both the quality of planting material used and the agronomic practices employed, including the application of a combination of manure and inorganic fertilizers, or of inorganic fertilizers alone. Similarly, average plant heights recorded in TMS 0581 are similar to the ones recorded by Odedina *et al.,* (2012) in identical research using the same variety but slightly different results were obtained in TME 419 at the same locations and under the same circumstance. This may be a result of variation in the soil characteristics and weather as reported by Burns *et al.,* (2012) in their findings.

Table 2: Maximum Average Agronomic Parameters attained by TMS 0581 in each Treatment

Treatments	Numbers of leaves	Numbers of branches	Plant height cm	Stem girth cm	Leaf area cm^2
A	5.90±0.08[c]	6.78±0.14[b]	2.02±0.02[c]	8.70±0.34[a]	70.85±0.01[c]
B	8.80±0.02[a]	5.90±0.17[c]	2.56±0.21[a]	5.95±0.01[c]	74.65±0.35[b]
C	7.70±0.14[b]	12.90±0.07[a]	2.31±0.05[b]	7.66±0.04[b]	81.43±0.04[a]
D	5.48±1.13[d]	5.85±0.07[c]	2.29±0.19[b]	4.46±0.07[d]	72.15±0.20[d]

Data represent the Mean ± Standard error mean of triplicate readings. Values with different superscripts in the same column were significantly different (p<0.05). Except otherwise stated all the units are in cm and cm²

Table 3: Maximum Average Agronomic Parameters attained by TME 419 in each Treatment

Treatments	Numbers of leaves	Numbers of branches	Plant height cm	Stem girth cm	Leaf area cm²
A	3.70±1.48^{b}	6.60±0.14^{b}	2.62±0.92^{b}	8.70±0.14^{a}	69.65±0.21^{c}
B	1.80±0.14^{d}	3.60±0.57^{c}	2.78±0.21^{a}	5.95±0.21^{c}	75.55±0.35^{b}
C	5.50±0.14^{a}	9.90±0.57^{a}	2.41±0.85^{c}	8.20±0.14^{b}	82.40±0.14^{a}
D	2.88±1.13^{c}	4.25±0.07^{c}	2.09±0.49^{d}	6.35±0.07^{c}	22.25±0.21^{d}

Data represent the Mean ± Standard error mean of triplicate readings. Values with different superscripts in the same column were significantly different (p<0.05)

The results of Cassava yield performance of TME 419 and TMS 058 varieties in all the treatments are presented in Tables 4 and 5. From the findings, a significant difference in the yield with and without the biomass was observed across all the treatments. Similarly, the difference in fertilizers applied in addition to the quantity of water applied was responsible for variations observed in the yields in all the treatments and among the two varieties and aligned with the observations of Anthony and Mynie (2005) in their studies. For example, treatment A performed better than Treatment D with and without the biomass with the values of 55.30±0.14^{a} Kg ha^{-1} and 44.32±0.01^{a} Kg ha^{-1} respectively. The highest yields were observed in both varieties in Treatment A while the lowest yields were recorded in Treatment D. This result implies that for maximum yield, both varieties are good with fertigation technique but TME 419 variety is better. The yield results obtained from the study agreed with the findings of Odedina *et al.,* (2012) who reported that with good agronomic management practices, newly released Cassava varieties are capable of producing a yield range of 20 – 40 tons per hectare rather than 10 – 20 tons per hectare recorded using traditional tropical methods. The researchers, however, added that the yields depend on the region, the variety, the soil, and other factors.

Table 4: Average Yields in Kg/plot, Kg/ha and Tons/ha of TME 419 variety within the Four Treatments

Treatments	With biomass	Without biomass	Kg/ha	Tons/ha
A	55.30±0.14^{a}	44.32±0.01^{a}	1,108	11.1
B	27.26±0.01^{c}	20.50±0.71^{c}	512.5	5.1
C	40.13±0.01^{b}	30.32±0.02^{b}	758	7.6
D	27.72±0.01^{d}	24.92±4.23^{d}	623	6.2

Data represent the Mean ± Standard error mean of triplicate readings. Values with different superscripts in the same column were significantly different (p<0.05)

Table 5: Average Yields in Kg/plot, Kg/ha and Tons/ha of TMS 0581 variety within the Four Treatments

Treatments	With biomass	Without biomass	Kg/ha	Tons/ha
A	47.44±0.05[a]	34.45±0.07[a]	861.25	8.6
B	37.06±0.01[c]	24.92±0.01[c]	623	6.2
C	40.15±0.07[b]	28.65±0.21[b]	716.25	7.2
D	35.12±0.01[d]	23.26±0.01[d]	581.5	5.8

Data represent the Mean ± Standard error mean of triplicate readings. Values with different superscripts in the same column were significantly different (p<0.05)

4. Conclusions

A comparative analysis of the effects of irrigation depth selected agronomic and post-harvest (with and without biomass yield) between two cassava varieties (TMS 0581 and TME 419) was carried out. In the overall analysis, TMS 0581 performed better in terms of plant height, stem girth, number of branches, and leaf area, while TME 419 did well in terms of the number of leaves only. Treatments A of all the four treatments and in both varieties had the highest average yields (without biomass) with values of 44.32±0.01 Kg/plot (11.1 Tons ha^{-1}) in TME 419 and 34.45±0.07 Kg/plot (8.6 Tons ha^{-1}) in TMS 0581 respectively. Irrigation depth ranged between 1.70±0.01 (0.56 metres) and 1.76±0.01 feet (0.58 metres) indicating the presence of sufficient water supply within the root crop zone required for optimum crop growth and development. TME 419 is therefore recommended due to marginal higher yield and lower agronomic development that seems not to harm the yield.

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DYNAMIC PERFORMANCE OF CONSTRUCTED WETLAND TO TREAT AGRICULTURAL WASTEWATER

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Abstract

Constructed wetlands (CWs) have great potential for the treatment of wastewater. These systems consist of beds or channels which have been planted with helophytes (water-loving plants), which rely upon physical, chemical and biological processes to remove contaminants from wastewater. CWs are a treatment option for agricultural wastewater. Their ability to adequately function in tropical climates continues to be evaluated as they are biologically active systems that depend on microbial and plant activity. CWs are generally classified into two categories: surface flow and subsurface flow. Both systems are capable of removing 42% nitrogen, 76% phosphorus, 81% biochemical oxygen demand, 75% chemical oxygen demand, 83% total suspended solids, 76% metals and 64% pathogens from different types of domestic and industrial wastewaters. CW provides the mechanism of removal of contaminants from wastewaters in the root zone of constructed wetlands which includes both aerobic and anaerobic microbiological conversions, sedimentation, mineralization, chemical transformations, physicochemical adsorption, chemical precipitation and ion exchange. This technology act as a natural and low-cost treatment facility for wastewaters of different origin. The plant species selected is of great importance Typha. latifolia (broadleaf cattail), Arundo donax (giant reed) and Cyperus alternifolius (umbrella palm) were very effective in the removal efficiency of the pollutants in the water.

Keywords: Constructed wetlands, surface flow, subsurface-flow, wastewater, contaminants

1. Introduction

As CW systems gain increasing acceptance as wastewater treatment technologies, a need exists for information about their design, operation and performance. There are many applications for CWs ranging from the treatment of landfill leachate, and domestic sewage, to the management of agricultural wastewater (An, 2003). It is important to consolidate the knowledge and experience gained from the many CW studies that have been conducted and summarize the regional performance and wastewater source data. Runoff from crop fields, barnyards and feedlots and the discharge of contaminated process water can introduce significant amounts of unwanted nutrients and other pollutants into the environment if it is not captured and properly treated (Lotter, 2003). Applications include the treatment of milkhouse wash water and farmyard runoff, tile drainage outflow, aquaculture wastewater abattoir wastewater, and winery process water.

CWs are engineered to optimize naturally occurring biological, chemical, and physical processes to treat wastewaters (Donnison *et al.*, 2000). Reduction or removal of contaminants is accomplished by diverse treatment mechanisms including sedimentation, filtration, chemical precipitation, adsorption, microbial interactions and uptake or transformation by helophytes (Czarnecki, 2015). However, many of these processes can be affected by temperature and as a result, questions have been raised about CW's ability to function year-round in cold regions, unlike the tropics/subtropics where it is of great advantage (Hanson, 2002). The objectives of this review are to consolidate CW research and assess their performance for agricultural applications in the treatment of wastewater, demonstrate that, under predetermined hydraulic and design conditions, the choice of plant species and the management of the vegetation can significantly affect the pollutant removal performance of constructed wetlands, assess the performance of CW to treat agricultural wastewater.

2. Materials and Methods

2.1 Wetland Component Description/Design

The most common CW designs are surface flow (SF), horizontal subsurface flow (H-SSF) and vertical subsurface flow (V-SSF). According to Avrahami *et al*., (2003), many of the CWs considered were designed for the treatment of high solids wastewater from livestock or aquaculture operations. However, different designs can be better suited for the removal of different contaminants found in agricultural wastewater so it may be beneficial to incorporate hybrid designs to take advantage of the strengths of each design.

Figure 1: A free water surface constructed wetland (FWS CW) for stormwater runoff

2.1.1 Constructed Wetlands with Horizontal Subsurface Flow

HF CWs consist of gravel or rock beds sealed by an impermeable layer and planted with wetland vegetation. The wastewater is fed at the inlet and flows through the porous medium under the surface of the bed in a more or less horizontal path until it reaches the outlet zone, where it is collected and discharged. In the filtration beds, pollution is removed by microbial degradation and chemical and physical processes in a network of aerobic, anoxic, and anaerobic zones with aerobic zones being restricted to the areas adjacent to roots where oxygen leaks to the substrate (Zhang *et al.*, 2010).

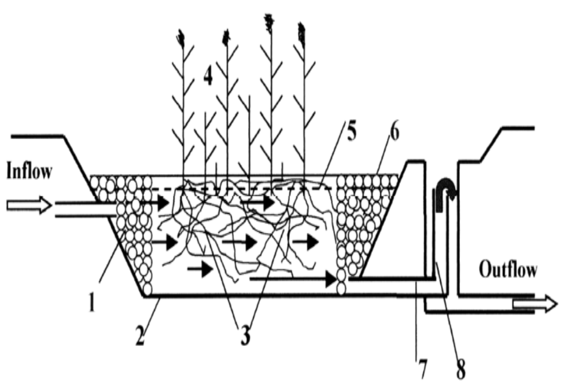

Figure 2: Horizontal flow (HF) CWs

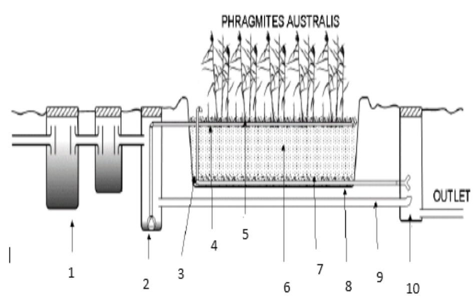

Figure 3: Vertical flow (VF) CWs

2.1.2 Constructed Wetlands with Vertical Subsurface Flow

Vertical flow constructed wetlands (VF CWs) were originally introduced by Seidel to oxygenate anaerobic septic tank effluents (De *et al.*, 2002). However, the VF CWs did not spread as quickly as HF CWs probably because of the higher operation and maintenance requirements due to the necessity to pump the wastewater intermittently on the wetland surface (Donnison *et al.*, 2000). The water is fed in large batches and then the water percolates down through the sand medium. The new batch is fed only after all the water percolates and the bed is free of water (Jones *et al.*, 2002).

2.1.3 Hybrid Constructed Wetlands

Constructed wetlands could be combined to achieve a higher treatment effect by using the advantages of individual systems (Luo *et al.*, 2009). Most hybrid constructed wetlands combine VF and HF stages. The VF-HF system was originally designed by Seidel as early as in the late 1950s and the early 1960s but the use of hybrid systems was then very limited (Almasri et al., 2004). In the 1980s VF-HF hybrid constructed wetlands were built in France and the United Kingdom (Donnison *et al.*, 2000). At present, hybrid constructed wetlands are in operation in many countries around the world and they are used especially when the removal of ammonia- N and total- N is required (Mader *et al.*, 2002). Besides sewage, hybrid constructed wetlands have been used to treat a variety of other wastewaters, for example, landfill leachate, compost leaching, slaughterhouse, shrimp and fish aquaculture or winery (Jenkins *et al.*, 2008).

2.2 *Pollutants Analysis*

2.2.1 Fertilizers and Contaminants

Global food security owes much to the widespread use of mineral fertilizers. However, the commercially available fertilizers are blended with a range of trace metals, which are introduced into the soil along with the application of fertilizers (Elouear *et al.*, 2016). A high and significant dependency on fertilizers for sustainable crop production heightens environmental concerns as the issues of agricultural soil contamination become very important (Marschner *et al.*, 2003).

2.2.2 Contaminants in Inorganic Fertilizers

Among inorganic fertilizers, phosphate fertilizers are the major source of contaminants as they may contain traces of cadmium (Cd), lead (Pb), arsenic (As), chromium (Cr), fluorine (F), strontium (Sr), thorium (Th), uranium (U) and zinc (Zn) (Jenkins *et al.*, 2008). Certain levels of heavy metals (HMs) are present naturally in soils which are contributed by weathering of parent materials (Jimoh *et al.*, 2003). The contaminants in phosphate fertilizers owe their existence to their origin as almost all of the world's phosphate fertilizers are derived from phosphate rocks (Marschner *et al.*, 2003).

2.3 *Vegetation*

Many studies have compared plant species for treatment performance. Although there are no conclusive species with unanimous acceptance, *Typha sp.* (cattails) tend to be the most commonly used in this region (Saudi Arabia) (Jiao *et al.*, 2015). However, it may be best to consider what wetland plants are found within the area of construction to allow natural succession to determine the species composition after establishment (Elouear *et al.*, 2016).

Plant height, stem density, and fresh and dry weight of the above-ground (leaves and stems) and below-ground (roots and rhizomes) plant parts were considered to analyze plant growth between 2011 and 2013 (Kim *et al.*, 2008). A representative sample of 10 plants, selected randomly from various sections of each experimental unit for both HSSFs CWs, was used to determine average plant height. Stem density was randomly determined on an area of 1 m^2 for each unit. Four main crop growth stages were identified.

In November of each year, the plants were cut back to a height of 50 cm above the gravel surface. The fresh above-ground and below-ground plant parts were determined on a sample of 10 plants selected from each unit. The biomass dry weight was calculated by drying the collected plant material in an oven at 62˚C for 72 hours. A carbon, hydrogen and nitrogen (CHN) analyzer were used to measure the nitrogen (N) levels in the above-ground and below-ground plant parts, following plant biomass basic analysis standards (Carpenter, 2005).

3. Results and Discussion

3.1 Performance of CW for Agricultural Wastewater Treatment

Constructed wetlands are sustainable technologies for the treatment of wastewater. These biological systems have been widely studied throughout the world for more than 30 years (Miao *et al.*, 2012); however, most studies have focused on the effects of design and engineering on pollutant removal from wastewater (Malhi *et al.*, 2000). Undoubtedly, agro-technical aspects have been given too little consideration by research. These systems have been of great interest to many countries for a long time, and the horizontal subsurface flow system (HSSFs) is one of the most commonly used systems around the world (Adriano, 2001). Plants, substrate and microorganisms are the main components of CWs and their interaction is fundamental for the optimal functioning of the system (Almasri *et al.*, 2004).

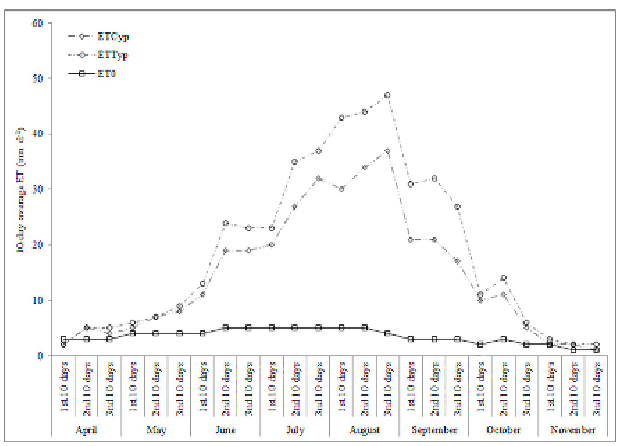

Figure 6: 10 day-average ET0, ETtyp and ETcyp in HSSFs CW(1)

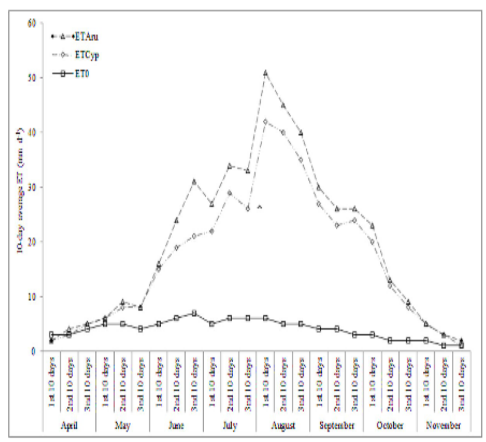

Figure 7: 10 day-average ET0, ETaru and ETcyp in HSSFs CW(2)

3.2 Effects of cropping system on pollutant removal efficiency

In HSSFs CW 1, when comparing only the planted units, TSS, BOD_5, COD, TKN, $N\text{-}NH_4$ and TP effluent concentration rates were lower in the *T. latifolia* than in the *C. alternifolius* planted unit (Table 1). An identical trend was observed in microbiological concentration levels. Both the planted units obtained pathogen levels which were lower than the unplanted unit at the outflow (Chen *et al.*, 2014). The two planted units had higher removal efficiency (RE) values than the unplanted control and the *T. latifolia*-planted unit had higher RE values than the *C. alternifolius*-planted unit for all the chemical and microbiological parameters in the study. Both planted units produced high RE values for all the chemical and microbiological parameters in the study (Al-Attar *et al.*, 2012).

In both of the HSSFs CWs, each planted unit was managed under the same operational parameters (e.g. inflow rate, hydraulic loading rate, hydraulic retention time) and the three macrophytes grew under the same climate conditions, using the same agronomic practices (e.g. planting date, plant density, harvesting time) and all plants received nutrients from the wastewater establishment times in CWs, diverse levels of tolerance to wastewater composition and competitive ability against weeds (figure 8). All these factors affected macrophyte growth rates and aboveground and below-ground biomass levels and contributed to the differing pollutant RE values obtained (An, 2003).

Pollutant reduction efficiency (RE) depends greatly on the contact time between wastewater and below-ground plant parts; therefore, the higher the hydraulic retention time (HRT), the greater the performance of a CW (Jarfanejadi *et al.*, 2013).

Table 2: Main operational parameters of the two pilot HSSFs CWs

Parameter	**Unit**	**HSSFs CW(1)**	**HSSFs CW(2)**
Inflow rate	$m^3\ d^{-1}$	3.0	6.0
Hydraulic loading rate (HLR)	$cm\ d^{-1}$	3.0	6.0
Hydraulic retention time (HRT)	D	16.5	8.3

Table 3: Chemical, physical and microbiological water parameters of the influent and effluent of HSSFs CW 1 from 2010 to 2016

Parameter	**Treatment Influent**	***T. latifolia*** **Effluent**	**Removal efficiency (%)**	***C. alternifolius*** **Effluent**	**Removal efficiency (%)**	**Unplanted Effluent**	**Removal efficiency (%)**
TSS ($mg\ L^{-1}$)	31.02 ± 4.96	11.13 ± 3.42	64	13.52 ± 3.85	57	23.51 ± 5.23	24
BOD_5 ($mg\ L^{-1}$)	25.32 ± 3.95	8.21 ± 1.83	68	9.25 ± 1.98	64	14.01 ± 3.19	43
COD ($mg\ L^{-1}$)	54.41 ± 4.70	12.93 ± 3.70	75	15.62 ± 3.96	70	30.91 ± 7.90	51

TKN (mg L^{-1})	18.42 ± 3.30	8.82 ± 1.34	51	10.3 ± 1.51	43	15.2 ± 2.77	17
NH_4-N (mg L^{-1})	13.42 ± 1.98	6.62 ± 1.05	52	7.74 ± 1.40	41	10.72 ± 1.39	19
TP (mg L^{-1})	7.82 ± 0.74	4.21 ± 0.71	47	4.91 ± 0.90	38	7.00 ± 0.80	10
TC (MPN 100 mL^{-1})	4.37 ± 0.08	3.39 ± 0.17	88	3.54 ± 0.11	85	4.13 ± 0.08	41
FC (MPN 100 mL^{-1})	4.24 ± 0.07	3.30 ± 0.16	88	3.45 ± 0.12	83	4.07 ± 0.10	32
FS (MPN 100 mL^{-1})	3.91 ± 0.07	3.11 ± 0.03	84	3.27 ± 0.11	77	3.66 ± 0.02	44
E. coli (CFU 100 mL^{-1})	3.11 ± 0.06	2.09 ± 0.09	90	2.15 ± 0.08	88	2.82 ± 0.08	48

Table 4: Chemical, physical and microbiological parameters of the influent and effluent of HSSFs CW 2 from 2009 to 2015.

Parameter	Treatments Influent	*A. donax* Effluent	Removal efficiency (%)	*C. alternifolius* Effluent	Removal efficiency (%)
TSS (mg L^{-1})	45.03 ± 10.01	11.45 ± 3.26	74	12.82 ± 3.71	71
BOD_5 (mg L^{-1})	31.14 ± 4.88	9.35± 4.23	70	10.98 ± 2.69	64
COD (mg L^{-1})	63.60 ± 8.98	18.03 ± 3.38	71	21.28 ± 3.81	66
TKN (mg L^{-1})	18.20 ± 3.89	9.16 ± 1.86	48	9.91 ± 2.52	45
TP (mg L^{-1})	3.62 ± 0.91	1.83 ± 0.37	48	2.05 ± 0.57	42
TC (MPN 100 mL^{-1})	4.49 ± 3.83	3.53 ± 3.05	89	3.65 ± 3.18	85
FC (MPN 100 mL^{-1})	4.24 ± 3.44	3.23 ± 3.57	90	3.29 ± 2.75	88

E. coli (CFU 100 mL^{-1})	3.05 ± 2.23	2.10 ± 1.54	88	2.22 ± 1.77	85

4. Conclusions

The information presented in this review indicates that fertilizers, in addition to boosting the agriculture sector, cause contamination of soils and waters. Fertilizers contain vital nutrients required for soil improvement and the proper growth of crop plants. Being extremely vital for agriculture, fertilizers are equally harmful to the environment, humans, and livestock. In addition to mineral nutrients, they also contain various contaminants including HMs and radionuclides. Along with inorganic fertilizers, organic fertilizers also add potentially harmful and toxic metals, organic pollutants, and pathogens to soils and waters. However, organic fertilizers are more conducive to soil health as they increase nutrient status, moisture content, aeration, soil microbial diversity, and organic matter. Organic fertilizers should be processed properly to make them free from undesirable metals, organic chemicals, and pathogens before application to soil. Repeated long-term applications of fertilizers cause an accumulation of nutrients in the soil which, through leaching and surface runoff, enter the groundwater and surface water resources and make water unpalatable and harmful for consumption.

For instance, P from agriculture fields enters surface water bodies and causes eutrophication which results in algal blooms and degraded water quality. Moreover, fertilizers also add HMs to the soil that is taken up by the plants and enter the food chain where they affect human and animal lives. Nitrogen from nitrogenous fertilizers gets converted to NO_3 and becomes a potentially fatal contaminant when leached into groundwater sources. Therefore, to cope with the adverse effects of fertilizers and their contaminants, it is necessary to develop crop varieties that utilize the available nutrients efficiently.

Future research should be directed to develop fertilizers with minimum contaminants and to explore the optimum dose of fertilizers for a particular crop with minimum losses to the environment. Fertilizer-induced contamination of soil and water can also be minimized by adopting various control measures such as phytoremediation, application of the lowest possible dose of fertilizers, wastewater treatment, nutrient monitoring, mathematical models, public awareness, and legislation.

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FARM STRUCTURES, ENVIRONMENT AND EMERGING TECHNOLOGIES

CASSAVA DISEASE DETECTION AND CLASSIFICATION USING EFFICIENTNET DEEP LEARNING MODEL

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Abstract

Plant diseases have drawn back the predicted and future value of food security in most countries due to the significant losses it causes in terms of production, economy, quality, and quantity of agricultural produce. Crop yield is a significant determinant of food supply for man's survival; this underscores the need to control losses incurred by plant diseases and the resulting instability in the food supply. Plants need to be monitored carefully from the initial stage of their life-cycle to develop an early treatment technology and reduce economic losses significantly. Cassava is one of the plants grown extensively in most sub-Saharan African countries due to its high usefulness and market demand. However, this plant is affected chiefly by unknown diseases during planting, which decreases the quality and quantity of the farm produce. The approach used in this research was Convolutional Neutral Network (CNN) that binds deep learning EfficientNet models and transfer learning approach to detect four diseases affecting cassava plants. Experimental results showed that our proposed approach could effectively recognize the four different types of diseases, with the ability to deal with complex scenarios from a plant's surrounding area.

Keywords: CNN, EfficientNet, Plant Disease Detection, Deep Learning, Transfer Learning

1. Introduction

Food insecurity has become a global issue due to the imbalance of food production resulting from the inadequate treatment of crop pests and diseases. In recent research, over one billion people are suffering from different malnutrition situations due to lack of quality food supply (Godfray *et al*., 2010). Apart from that, approximately twice that population does not have access to sufficient nutrients or vitamins to meet their daily nutrition needs in most African countries (Barrett, 2010). Early farmers competed against pathogen damage to their crops using supernatural or superstitious practices (Martinelli *et al*., 2015).

Cassava is the second-largest carbohydrate source in Africa and a main food security crop grown by smallholders, as it is capable of withstanding harsh conditions. This starchy root grows at least 80% of household farms in Sub-Saharan Africa, but viral disease is a major cause of low income (*Cassava Production Guidelines for Food Security and Adaptation to Climate Change in Asia and Africa*, 2018). To minimize the disease-induced damage in crops during growth, harvest, and postharvest processing, as well as to maximize productivity and ensure agricultural sustainability, advanced disease detection and prevention in crops are highly important. Currently available disease detecting methods require farmers recruiting the assistance of government-funded agricultural experts to visually examine and diagnose the plants. This is labour intensive, limited in quantity and expensive.

Detection of plant diseases has been a field that many researchers are working on using different techniques and technologies for securing foods throughout the year for human consumption. Specifically, several researches (Mohanty *et al*., 2016; Fuentes *et al*., 2017; Ramcharan *et al*., 2017) have been done to detect and identify plant disease among which is the use deep learning; an artificial intelligence (AI) function that mimics the human brain's interpretation of data and pattern creation in order to make decisions. Fuentes et al. (2017); Ramcharan et al. (2017) used a deep learning approach for plant disease diagnosis. Owomugisha *et al*. (2018) used spectroscopic analysis to study the way different materials interact with light to absorb or reflect wavelengths. The study argued that most early works used leaf images of already affected crops as the primary information input and that the moment a symptom is seen indicates that the disease has already progressed and that little can be done to safeguard the affected plant from a practical perspective. Fuentes *et al*. (2017) proposed a realistic approach for the class identification and location of tomato plant diseases. Ferentinos (2018) used a variety of model architectures, including AlexNet, AlexNetOWTBn, GoogleNet, Overfeat and Visual Geometric Group (*VGG)* (Solid State Drive) to train an open database on a range of 58 groups of combinations of plant diseases, including healthy plant. The most productive model was 99,53 % accurate, with 87,848 images from 25 different plants.

In this study, EfficientNet deep learning architecture is used to classify and detect cassava diseases, and the performance of the model is evaluated. The outcome of this research will help in the timely and accurate diagnosis and discovery of cassava disease before it damages plants; this will reduce the amount of plant and produce lost to disease and, as a result, improve food security and sustainability which follows the United Nations Sustainable Development Goals specifically, end hunger, achieve food security and improved nutrition and promote sustainable agriculture (SDG 2), and ensure sustainable consumption and production patterns (SDG 12).

2. Materials and Methods

2.1 System Overview

The work is aimed at identifying four (4) classes of cassava diseases, namely Cassava Mosaic Diseases (CMD), Cassava Bacterial Blight Disease (CBBD), Cassava Brown Streak Disease (CBSD), and Cassava Green Mottle Disease (CGMD), using deep learning EfficientNetB5 CNN model. A general overview of the system is shown in Figure 1.

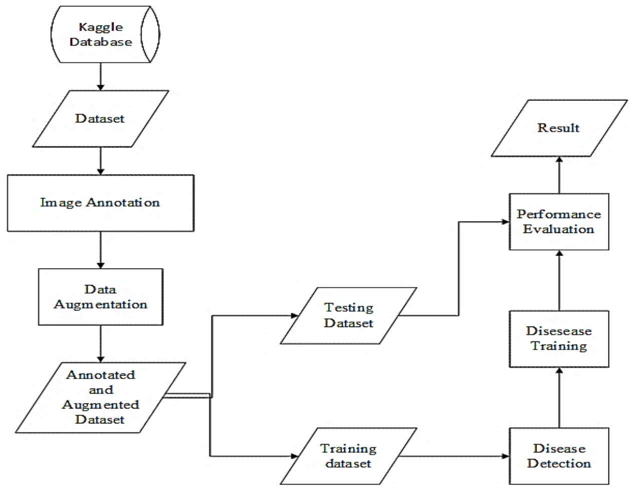


Figure 1: System overview of the proposed deep learning approach for cassava disease detection and classification (adapted from (Fuentes et al., 2017)).

2.2 Experimental Set-up

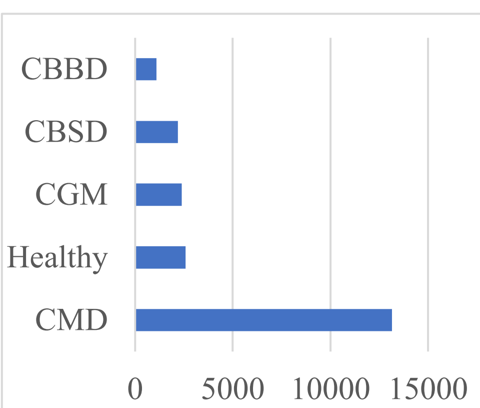
The model used in this study was compiled with Graphical Processing Unit (GPU) support. All experimental studies were conducted in Google cloud environment on a 64-bit Windows 10 operating system running on Intel (R) Core (TM) i3-3227U CPU @ 1.90GHz CPU and 6 GB RAM with NVIDIA Tesla K80 having 12GB memory. All codes were realized with Keras 2.3.1 framework, an open-source deep neural network library written in Python.

2.3 Dataset Description

Kaggle open dataset containing 21,397 images (Mwebaze *et al*., 2019) of leaves of healthy and infected cassava was used to train and test the CNN models. Exploratory Data Analysis (EDA) of the dataset shown that the heathy leaf class contains 2577 images, CMD class contains 13158 images, CGMD contains 2386 images, CBSD contains 2189 images, and 1087 images were in the CBBD as shown in Figures 3 and 4.

2.4 Data Pre-processing and Augmentation

The data augmentation was implemented using the Keras library in Python 3. To increase the data set's size and capacity, the data generator function in Keras was used to generate new images using simple transformations such as rotation, width shifts, height shifts, shearing, zooming, and horizontal and vertical flips.



2.5

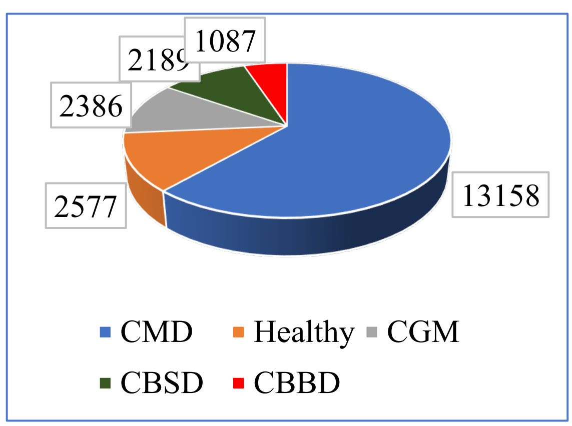


Figure 2: Bar chart showing the number of images per class.

Fgure 3: Pie Chart showing the number of images per class.

2.5 Model Architecture

The model's architecture, as shown in Figure 4, is the EfficientNet model.

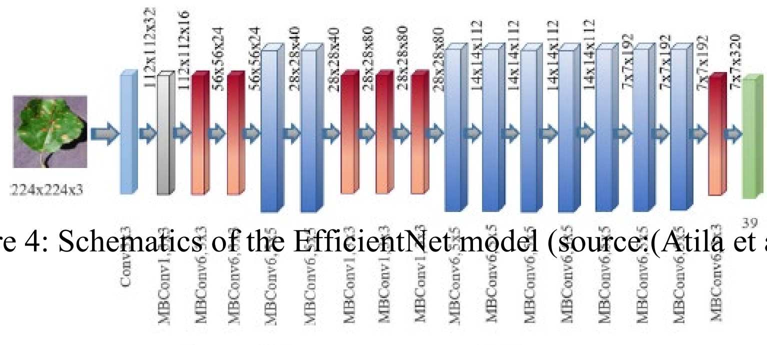


Figure 4: Schematics of the EfficientNet model (source:(Atila et al., 2021)

2.6 Training the model

In this study, the transfer learning approach was combined with EfficientNet CNN models. The CNN model was fine-tuned to define and classify all classes in the dataset, with pre-trained models on the ImageNet dataset, to speed up learning. There are approximately 1.2 million images and 1000 class groups in the ImageNet dataset. According to the problem, the last fully connected layers of all models with 1000 outputs were modified to 5 outputs. All pre-trained model layers were made trainable. In the final layer, Softmax was chosen as the activation function, and categorical cross-entropy was chosen as the loss function. The early stopping technique was used during the preparation, with patience set to 5 and the minimum change in loss set to 1e-3. The maximum epoch was not established in the training of models since an early stopping technique was used.

2.7 Performance Evaluation of the Model

The confusion matrix [normalized, non-normalized], accuracy, precision (Hossin and Sulaiman, 2015; Kaur and Sharma, 2019), sensitivity (recall), specificity, F1-score, Precision-Recall curve, and AUC-ROC (Area Under the Curve – Receiver Operating Characteristics curve) (Kaur and Sharma, 2019; Ullah *et al.*, 2019) are the most widely used performance measures of classification in Data Science. The Precision-Recall curve is used to evaluate an imbalanced data set model, while the AUC-ROC is used to evaluate the model performance of a balanced data set. Accuracy is often used to assess a model's performance; however, it suffers from an anomaly when classes are unbalanced. These performance evaluation metrics can be obtained from the equations (Sambasivam and Opiyo, 2020)

$$\text{Precision} = \frac{\text{True positive}}{\text{True positive} + \text{False positive}} \tag{1}$$

$$\text{Recall} = \frac{\text{True positive}}{\text{True positve} + \text{False negative}} \tag{2}$$

$$\text{f1} - \text{Score} = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \tag{3}$$

$$\text{Accuracy} = \frac{\text{True positive} + \text{True negative}}{\text{True positive} + \text{True Negative} + \text{False Positive} + \text{False Negative}} \quad (4)$$

3. Result and Discussion

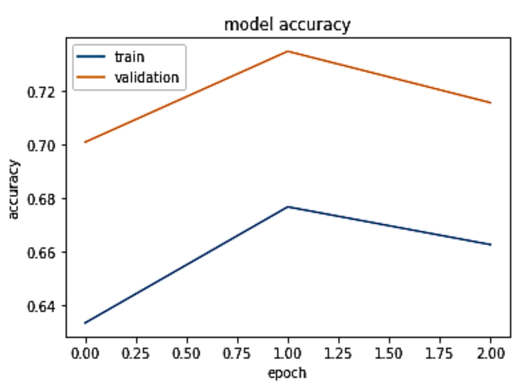
3.1 Performance Evaluation

The model used in this study was analysed based on five performance metrics, namely, accuracy, precision, recall, support, and F-measure. The detailed result of the performance metrics is shown in Table 1. On examining Table 1, it can be seen that the model is capable of accurately predicting CMD with a precision of 97%. However, with a precision of 48 %, 86%, 63%, and 72%, the model performed poorly in predicting CBBD, CBSD, CGM, and healthy classes, which may be due to misclassification resulting in the unbalanced data set.

Table 1: Performance Result of the experimental study on the dataset

Image Classes	Precision	Recall	F1-Score	Support
0	0.48	0.83	0.61	232
1	0.86	0.68	0.76	467
2	0.63	0.85	0.72	472
3	0.97	0.90	0.93	2597
4	0.72	0.64	0.68	512
Accuracy			0.83	4280

Figure 5 shows that the model's accuracy increases as the epoch increases and starts declining after the first epoch. It is also seen from the graph that the accuracy gotten during validation is greater than that of the training and the overall accuracy of plant disease identification is 83% which is lower than result obtained by Atila et al. (2021). A confusion matrix (Figure 6), an n-by-n table (where n is 5, which represents the number of classes) that measures the output of a machine learning algorithm, was computed to understand the results better.



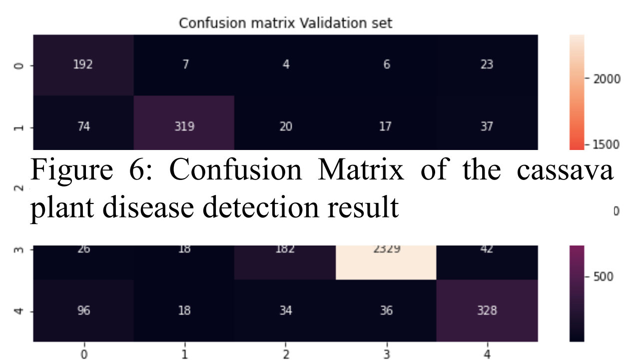


Figure 6: Confusion Matrix of the cassava plant disease detection result

It cannot be easy to equate the output of a machine-learning algorithm to that of others due to these indices' heterogeneity. The F1-score, which returns a value between 0 and 1, estimates how good a model is. This index is specified where 1 (or 0) indicates that the

a Figure 5: Train and validation Model's accuracy for CNN. ı test sample. Our model resulted in high values (Table I) for e and 0.93, thus demonstrating the algorithm's efficacy, but the model can be improved.

S! ges from test data (these images were used neither in the training nı redicting cassava disease categories.

Figure 5: Train and Validation Model

Accuracy for CNN

Figure 7: Randomly predicted images by the model from the test set.

4. Conclusion

This study has shown that the EfficientNet model can be used to develop plant disease detection and classification system. This system introduces a practical and applicable solution for detecting four (4) classes of cassava diseases, namely CMD, CBBD, CBSD, and CGMD and the location of these diseases in cassava. A limited amount of imbalanced dataset was used. The model performance showed a promising result but was limited by the dataset. Future works should focus on improving the current results by using a balanced dataset and fine tuning the model.

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DEVELOPMENT OF A PROTOTYPE AUTOMATIC GRAIN STORAGE MONITORING DEVICE

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Abstract

Grains are rich in carbohydrates, proteins, fibres and oil. These components form daily constituents of man and animal food. Nigeria is one of the largest producers of grain crops in Africa, though, more than 60% of this is lost to postharvest processing, another 45% perishes due to inadequate storage structures and inappropriate storage techniques. Grain storage in Nigeria is still done at traditional and intermediate scale with few modern structures poorly managed by the public sector. In order to curb storage postharvest losses, this study developed a prototype automatic grain storage monitoring device. The device monitors internal temperature and relative humidity of stored grains. Temperature sensors, humidity sensors, buck converters, Node MCU, Arduino IDE, H-bridge and fan were soldered and connected to perform the expected function. During testing, a 13 % grain moisture content was stored, the average storage temperature and relative humidity of the stored grains as recorded by the device were 32 ^{o}C and 62.5% respectively, while the final moisture content after the experiment was 12.7%. When the designed threshold was attained as programmed, signals received from the DHT22 sensor were sent to the H-bridge and the fan rotated to discharge the excessive respiration inside the storage house. More so, this device can be used with a mobile phone interface for monitoring of the storage activities. It was found that this monitoring *device is simple to use, easy to install and relatively economical compared to economic value of the quantity of grains loss usually experienced in Nigeria at the storage phase.*

Keywords: Grain, storage, temperature, moisture content, automatic device

1. Introduction

Production of grain crops has been on the increase over the years due to technology advancements like better seeds, fertilizers, pesticides, and irrigation. However, an associated grain loss has as well been on the rise resulting from heat production and moisture content generated from grain respiration (Olorunfemi *et al.,* 2016; Ashok and Shakunthala, 2018). Adesina (2019) estimated that Nigeria produces 2.85% of world legumes, out of which about 60 - 70% are stored traditionally in Nigeria for immediate need (Kartikeyan *et al.,* 2009), some later transferred to structures for food and other socio-economic needs within the year (Iliyasu *et al.,* 2013) and others are sold as the need arises (Adejumo and Raji, 2007). During grain storage, grain postharvest losses are incurred due to environmental factors like type of storage structure, temperature, pH, moisture and others. These losses are grossly associated to inadequate processing facilities, inefficient storage facilities (Iliyasu *et al.,* 2013).

Postharvest losses of grains has been a great concern to farmers that they are often discouraged to invest in large scale production (Olorunfemi *et al.,* 2016). Reports shows that about 2.4 billion tonnes of foods, estimated at ₦ 48 billion annually are lost to inappropriate and inefficient harvest and storage facilities (Adejumo and Raji, 2007). In order to minimize these huge postharvest losses, modern storage that implores the use of scientific, technological, skilled and logistical systems are required. Such storage caters for good management practices of moisture and temperature monitoring (Bayode *et al.,* 2018). As a result, this study developed a prototype automatic grain storage monitoring device capable of regulating the temperature and relative humidity within the storage structures, ensure appropriate gaseous exchange and enhanced digital monitoring at any location.

Bayode *et al.* (2018) developed a computer-aided management system that minimizes post-harvest grain losses at the storage level in Nigeria. The software designed has a user interface using Dreamweaver 8, coded with Pre-processor Hypertext Programme (PHP) code, and Database retrieved using MySQL was developed to handle all activities of grain storage and validated at a case study silo complex. Daily temperature and Moisture content of the stored grains were obtained and computed for monitoring. Application of the software saves time by 66 % of manual operation, more accurate and energy saving. It aids management of administrative and technical issues and can communicate with all storage users at every point of grain management due to its web-based capability.

Also, Olorunfemi *et al.* (2016) monitored the temperature of grain stock using computer aided grain aeration management. Materials used were temperature sensors, silo bins, probes, and fans. Temperature sensors were installed inside the silo bins at different sections. Temperatures were taken in the morning and evening and aeration systems work every 5 hours. The maximum grain temperature during their experiment was 45ºC and cools down with the aeration system to 25ºC which was held between 25 – 41ºC for the duration of the experiment. A comparative was done between computer aided silo monitored and the manual silo, results revealed that postharvest grain loss during silo storage was reduced to $< 1\%$ as against 5% allowable level, the power requirement increases as air flow rate and grain depth increased and aeration can be better monitored economically with the use of a computer system.

2 Materials and Method

The conceptual design of the grain monitoring device was sketched and the circuit diagram developed using Fritzing 2016 software, Version 0.9.3 as shown in Figure 1. A schematic diagram of integrated circuits, buck converter, breadboard, grain moisture content probe and module, Node micro control unit (MCU) DHT22, H bridge, and Fan were collectively soldered, arranged on a circuit board as presented in Figure 2.

The jack plug receives the 12V from the power source, stepped down to 5V using the buck converter; the required voltage for effective performance of Node MCU. The Node MCU positioned on the breadboard controls and coordinates all other components by receiving and sending signals within the hardware and software when connected to the internet. Arduino IDE was used to program (sketch) the microcontroller. Signals received from the grain moisture content probe are sent to the grain moisture content module which passes through the Node MCU and processed. The Digital Humidity Temperature sensor DHT22 outputs received in terms of relative humidity and temperature inside the storage structure are sent to the H-bridge which determines if the fan has to come up and in which direction it has to rotate.

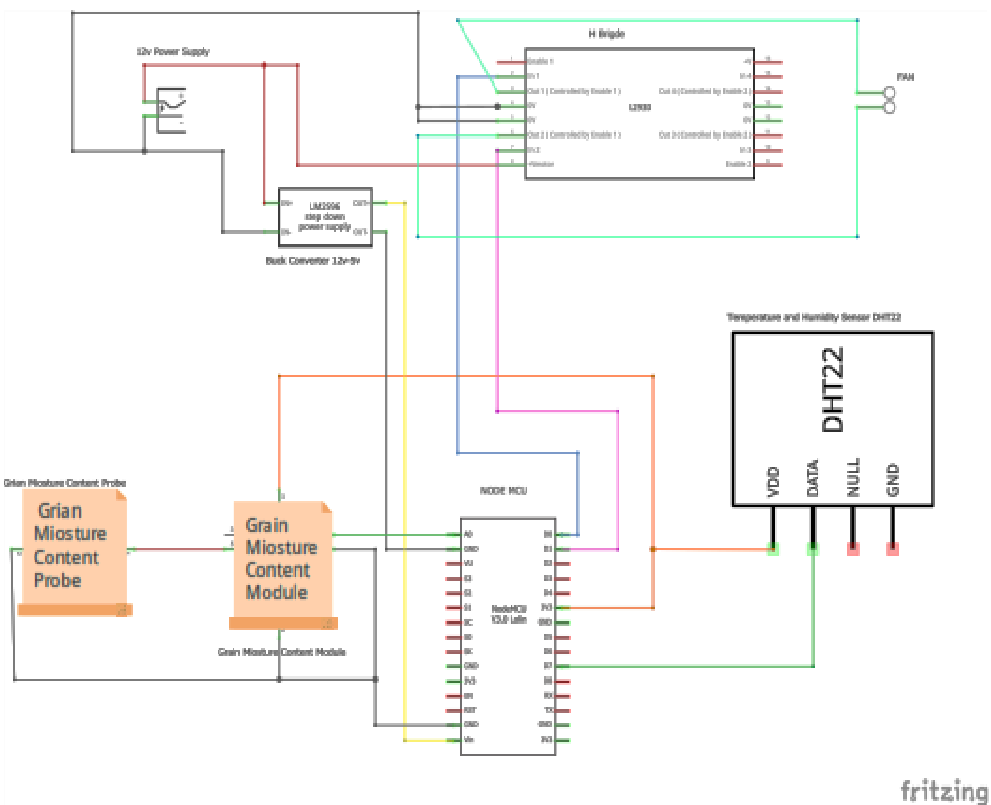

Figure 1. Circuit diagram of the grain storage monitoring device.

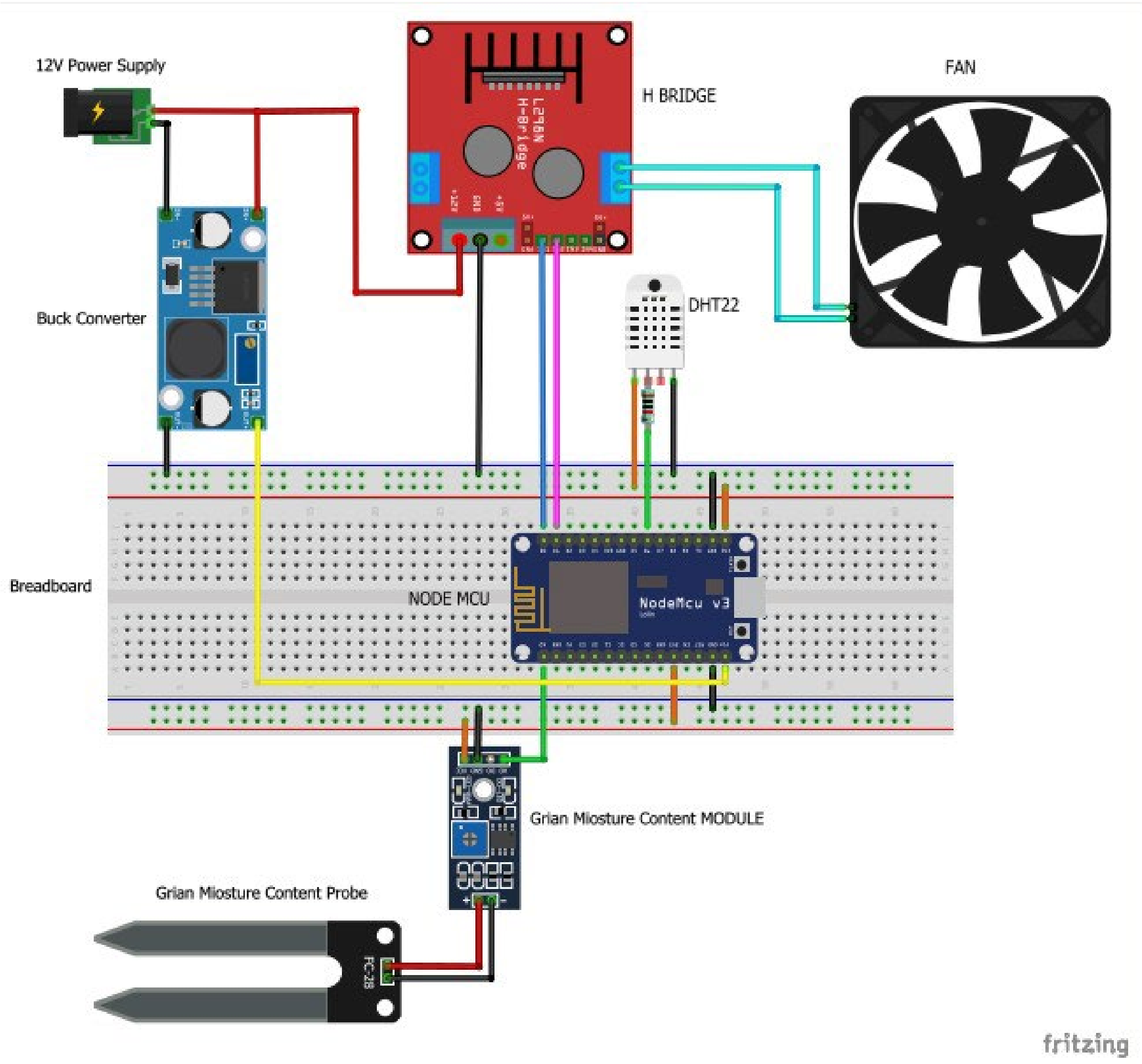

Fig. 2: Schematic diagram of the grain storage monitoring device

2.1 Principle of Operation

The automatic grain storage monitoring device measures the internal storage temperature and relative humidity of the stored grains. The device was calibrated to set the maximum and minimum storage temperatures and relative humidity at 37°C and 75% respectively. The temperature and moisture probes were inserted into the stored grains through a perforation created on the storage structure. The probes were then covered with the stored grains and the perforation properly sealed to ensure hermetic environment as required during storage. The device was carefully placed on the storage structure where readings can be monitored and taken. When a variation from the minimum or maximum temperature and humidity is experienced, the standby fan comes up automatically to serve as an impeller or expeller respectively. The device is powered by a 12 Volt battery or switch mode power supply (SMPS). Grains temperatures and relative humidity is monitored on mobile phone through an custom application called Bylink, which is configured with the hardware. This application is activated when the Node MCU is connected to the internet.

2.2 Performance Evaluation

The performance of the grain storage monitoring device was evaluated using Cowpea, been a common grain produced and consumed in Zaria, Kaduna State. A 25 litres jerican filled with 28 kg) of cowpea was stored in a room a month during the month of July, 2019. The grains were manually and subjectively sorted, initial moisture contents measured using a grain moisture meter, then weighed using a weighing scale and poured inside the jerican. The cowpea was poured into the jerican half way and the probes inserted before the remaining half was poured to fill the jerican. Temperature and relative humidity were measured weekly for one month. The weight was taken again after a month, sorted and reweighed.

3. Results and Discussion

The developed device was tested using cowpea stored at domestic level and the results obtained is presented in Table 1.

Table 1. Average values of temperature and relative humidity of stored cowpea

Temperature (°C)					Relative Humidity (%)				
Week 1	Week 2	Week 3	Week 4	Ave	Week 1	Week 2	Week 3	Week 4	Ave
33	32	32	31	32	60	62	63	65	62.5

Results presented in Table 1 shows that the average storage temperature and relative humidity as recorded by the instrument were 32 °C and 62.5% respectively. The initial moisture content of grain stored was 13% and when measured after experiment was found to be 12.7%. This implies that the storage monitoring device was able to read the changes in temperature and relative humidity inside the storage structure as it varies during the duration of storage.

4. Conclusions

The grain storage monitoring device was developed using local materials, bought out micro-chips that were assembled and calibrated after development. The device was found to be effective in monitoring the temperature and relative humidity inside the storage structure. It senses the slightest variations in parameters measured, indicating the sensitivity and efficiency of the device. The trial test carried out shows that it can perform satisfactorily on larger storage structures like silos and eliminate destructive methods of grain monitoring as experienced in some grain storage management. The device is simple, easy to install, require less technical know-how to use and relatively economical when compared to storage losses experienced in grain management in Nigeria.

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EVALUATION OF THE INDOOR AIR VELOCITY OF A SIDEWALL INLET AND ROOF EXHAUST VENTILATED BROILER SHED USING COMPUTATIONAL FLUID DYNAMICS

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Abstract
Fast growing broiler chickens, bred for meat, find it difficult to adapt to warm condition during hot weather periods in an enclosed environment. They tend to change their behavioural and physiological mechanisms in order to survive. This study was carried out to evaluate the air velocity distributions within a sidewall inlet and roof exhaust ventilated broiler shed using the computational fluid dynamics (CFD). The simulation was conducted using three turbulence models (standard $k-\varepsilon$, realisable $k-\varepsilon$, and SST $k-\omega$) to determine the best predictive model for the hot weather ventilation of the broiler shed under consideration. Before the simulation was carried out, some assumptions in the literature were verified with CFD to ensure that they were applicable in this study. The verification indicated that the structural details and the boundary conditions of the shed to be simulated are crucial factors that the ventilation engineers need to consider when carrying out the simulation of livestock shed in order to improve the accuracy of CFD predictions. The results predicted by the turbulence models were validated with the field experimental results. It was discovered that standard $k-\varepsilon$ turbulence model predicted air velocity distributions, close to that of the air velocity distributions obtained during the experimental study except at the centre of the broiler shed where the CFD predicted higher air velocity. This shows that CFD could be adopted by Agricultural Engineers to create appropriate environments for animals and plants before the structures are physically erected.

Keywords: Airflow distribution; hot weather condition; simulation; inlet opening size; Climate control.

1. Introduction

To provide a healthy animal environment, it is crucial that air flow reaches the animal occupied zones (Bustamante *et al*., 2013; Li *et al*., 2017;). The sustainability of suitable climatic condition in the animal shed depends on the performances of the ventilation system (Norton *et al,* 2007). It is a difficult task to accurately quantify the indoor environmental conditions within the animal shed because of the complexity of the indoor conditions (Norton *et al,* 2007). However, significant progress has been achieved as to how computational fluid dynamics (CFD) could be used to quantify and analyse the indoor and outdoor environmental parameters.

CFD has been used for simulating fluid flow in the agricultural facilities such as greenhouses (Benni et al., 2016), broiler sheds (Bustamante *et al*., 2013), cattle sheds (Norton *et al*., 2010) and pig houses (Li *et al*., 2017). Notwithstanding, the information on its application in the sidewall inlets and roof exhaust ventilated broiler shed, during hot weather periods, is hardly available. As indicated by Albright (1990) poultry keepers generally open the sidewall inlets 100 % to increase the air movement into the broiler shed with the aim of ensuring higher air movement at the animal occupied zones during hot summer times. For proper understanding of the effect of the 100 % opening of inlets on air velocity distribution in the animal occupied zones, it is vital to numerically simulate the indoor conditions using CFD. This would enable the ventilation engineers to provide appropriate hot weather ventilation system for sidewall inlet and roof exhaust ventilated broiler sheds.

Therefore, this study was carried out to evaluate the effect of opening the sidewall inlets 100 % on the indoor air velocity in the animal occupied zones using CFD. The objectives of this study were (1) to simulate air velocity in the animal occupied zones inside the sidewall inlet and roof exhaust ventilated broiler shed; (2) to determine suitable turbulence model for evaluating the indoor conditions of the broiler shed and; (3) to validate the CFD simulation against field experiments conducted in the broiler shed at Harper Adams University, UK.

2.0 **Materials and Methods**

2.1 Experimental shed and measurements

The experimental work was carried out in a broiler shed located at Harper Adams University, United Kingdom with latitude and longitude 52. 7795 ^{o} N and 2.4271 ^{o} W. The shed is 21.75 m long, 18.30 m wide, 2.36 m eave height and the inlets are 1.60 m above the floor. There are 24 bottom-hinged sidewall inlets (12 inlets on each sidewall) in the shed with dimension 0.52 m by 0.21 m and five roof fans of diameter 0.63 m which are all mechanically controlled by a CLIMATEC environmental control system.

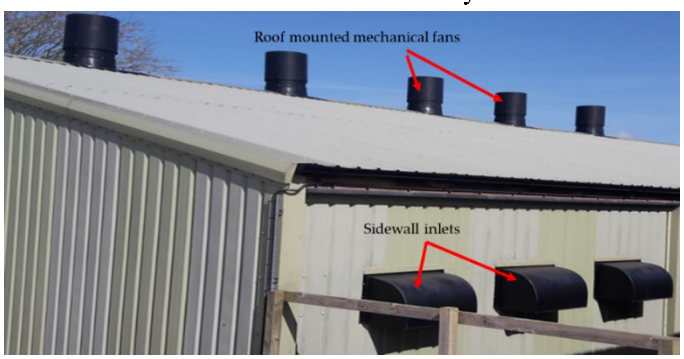

Figure 1: A sidewall inlet and roof exhaust ventilated broiler shed.

2.1 CFD Modelling

2.1.1 Empty broiler shed

Figure 2 shows the geometries of broiler sheds with different inlet configurations and indoor obstacles. The geometries were developed with SolidWorks 2016. Figure 2a shows a typical broiler shed with twenty-four 0.52 m by 0.21 m sidewall inlets. Figure 2b shows a broiler shed with feeder and drinker lines raised to the height of 0.3 m above the floor with their locations from the sidewall as they are in the experimental broiler shed. These geometries were used in the CFD simulations to verify the assumptions earlier discussed and for simulating the indoor air velocities of the empty broiler shed.

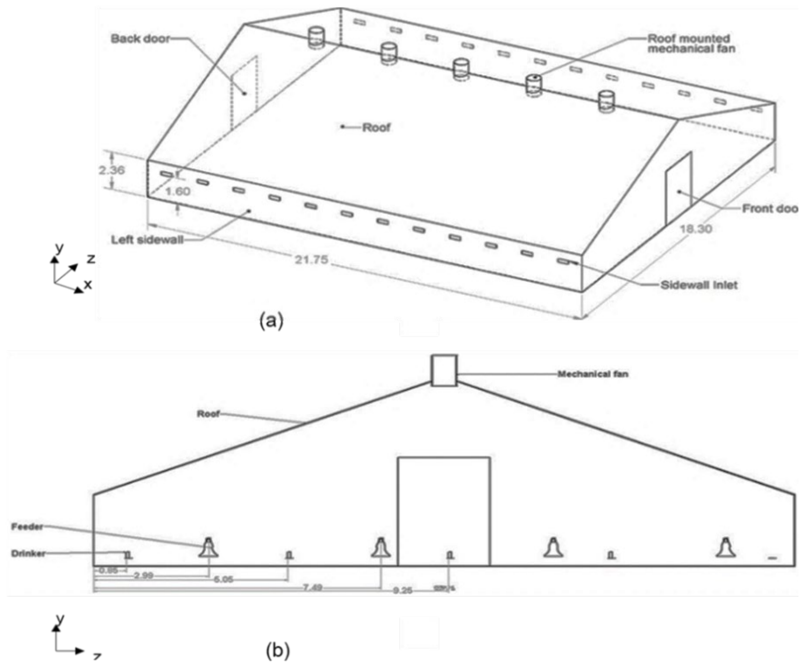

Figure 2: Broiler shed with (a) twenty-four sidewall inlets and (b) drinker and feeder. All dimensions are in metres.

2.1.2 Mesh generation

The broiler shed (Figure 2) were imported into the CFD software package (Star CCM+ 12) for simulations. The internal parts of the geometry, which represents the computational domain, were extracted for surface and volume discretisation.

For each of the shed geometries, three unstructured coarse mesh densities were generated to discretise the computational domain (Table 1). As shown in Table 1, Mesh 3 has the highest mesh densities in all the shed geometries tested compared to Meshes 1 and 2. Therefore, in order to ensure that CFD predictions were precise and accurate for all the turbulence models, Mesh 3 was selected and used in all the CFD simulations.

Table 1: Mesh densities used for model verification

Cases	Multiple inlets	Long inlets	Internal obstacles
Mesh 1	656,983	605,335	656,724
Mesh 2	791,754	738,144	853,522
Mesh 3	925,448	870,795	1,050,996

Figure 3 shows the meshes of the broiler shed with different inlet configurations and internal obstructions. During volume meshing, unstructured polyhedral grids were used to improve and optimise the overall quality of the cell surfaces and the volume mesh model. A prism layer mesh was used to generate prismatic cells near wall surfaces to improve the accuracy of the flow solution closer to all wall surfaces.

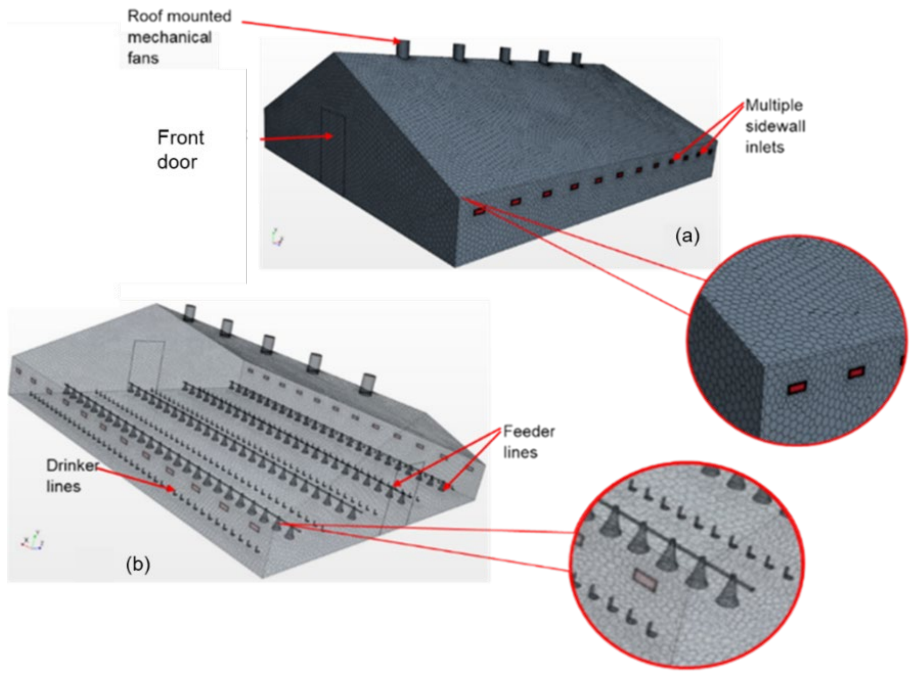

Figure 3: Polyhedral meshes of the broiler shed with; (a) twenty-four bottom-hinged inlets and (b) internal obstacles.

2.1.3 Turbulence models, measurement planes and convergence criteria

To verify the conditions under which indoor conditions of broiler shed were simulated, three (standard (Std) $k-\varepsilon$, realisable (Re) $k-\varepsilon$, and shear stress transport (SST) $k-\omega$ turbulence models), widely adopted were selected (Li et al., 2016; Rong et al., 2016). They were selected to determine the most appropriate turbulence model for the indoor environment of a sidewall inlet and roof exhaust ventilated broiler shed.

For the purpose of solution monitoring and convergence criteria, a global residual of 0.001 (0.1 %), for all fundamental equations was defined. The computations were not terminated until the residuals were lesser than 0.001 and the air velocity magnitudes in the broiler occupied zones were also stabilised. The air velocity magnitudes in the broiler occupied zones, where broiler chickens experience heat stress during hot weather periods, were only considered in this study.

2.1.4 Boundary conditions

The boundary conditions specified in this study are shown in Table 2. These include the air velocity at the inlet, pressure at the outlet and shed wall surfaces. Air turbulence intensity of 0.10 was imposed at the inlet. The same turbulence intensity was obtained during the field experimentation at the inlet of the sidewall inlet and roof exhaust ventilated broiler shed.

Table 2: Boundary conditions specifications

Shed surfaces	Boundary conditions
Inlet	Velocity inlet
	Air velocity of 4.91 m s^{-1} at the inlet
	Inlet turbulence intensity of 0.10 (10 %)
Outlet	Pressure outlet
	Pressure (0 Pa)

Shed walls, floor and roof	No-slip and smooth wall

2.2 Occupied Broiler Shed

The experimental broiler shed, occupied with broiler models, was developed with SolidWorks 2016 (Figure 4) and imported into the Star CCM+ for turbulence modelling. For CFD simulation purpose, the shed was filled with broiler models of a characteristic dimension of 0.18 m, similar to the size of the broiler models used during the field experiment (Jongbo et al., 2020). The fluid domain (internal part of the shed) was extracted and the surface and volume meshing were performed (Figure 5).

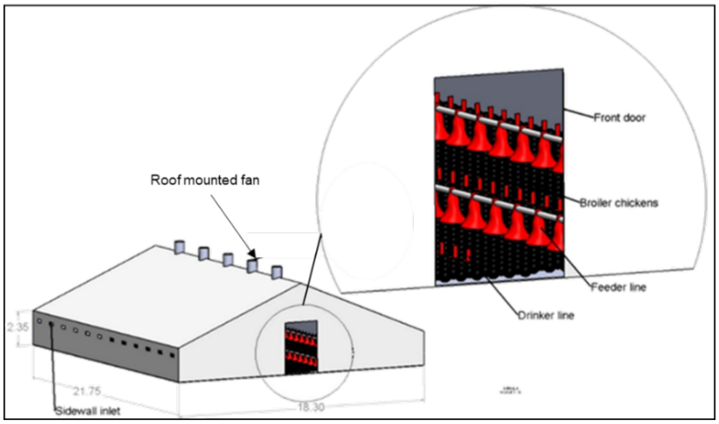

Figure 4: Experimental broiler shed occupied with broiler models. All measurements are in metres.

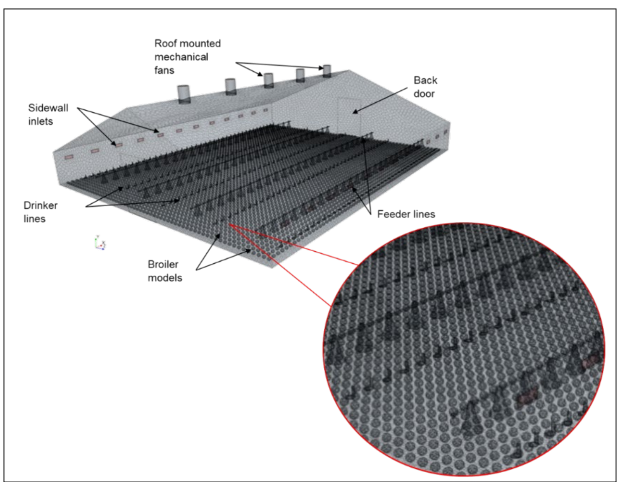

Figure 5: Surface and volume meshes of the broiler shed

The mesh densities (Meshes 1, 2 and 3) refinements were performed based on the number of cells in the prism layers (Table 3).

Table 3: Mesh density refinement of the occupied broiler shed

Cases	**Mesh densities (cells)**
Mesh 1	808,805
Mesh 2	976,541
Mesh 3	1,095,753

The mesh densities were used for the simulations and were validated with the field experimental results in order to determine the appropriate volume mesh that would predict the airflow distributions in the broiler occupied zones using standard $k - \varepsilon$ turbulence model. Only standard $k - \varepsilon$ turbulence model was used for the occupied broiler shed due to its predictive capability in the simulated empty broiler shed. Air velocity magnitudes in the broiler occupied zones were obtained on the Plane B situated at 7.3 m from the front door.

2.3 Field Experimentation Set up

The field experiment comprised of two studies. The first study was carried out in an empty experimental broiler shed while the second study was carried out with the experimental broiler shed occupied with broiler models to represent live broiler chickens. The details of the field experiments have been reported by Jongbo et al. (2020).

3. Results And Discussion

3.1 Validation of Air Velocity in the Empty Broiler Shed

The air velocity predictions of the CFD simulation conducted with the broiler shed, having indoor obstacles such as feeding and drinking lines were validated using the field experiment results. Figure 6 shows the results of the validation of the turbulence models with the field experimental results.

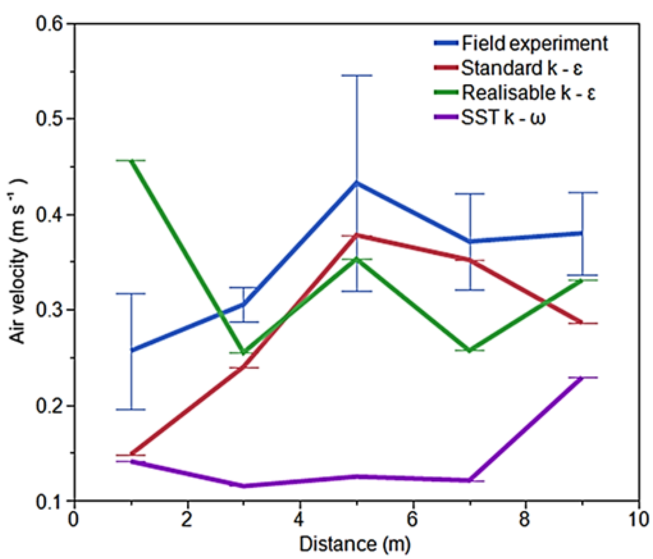

Figure 6: The validation of turbulence models [Std $k - \varepsilon$ (red line); Re $k - \varepsilon$ (green line); SST $k - \omega$ (purple line)] predictions with field experiment (blue line).

As shown in Figure 6, the best CFD turbulence model that predicted close air velocity in the broiler occupied zones was Standard $k - \varepsilon$ (red line). Standard $k - \varepsilon$ turbulence model has been indicated as a good predictive turbulence model in some studies (Bustamante et al., 2013; Norton *et al.*, 2013). In the study conducted by Blanes-

Vidal *et al.* (2008), it was reported that there were higher discrepancies between the CFD predictions and field experiment. In this study, the discrepancies between the Standard $k-\varepsilon$ (red line) and the field experiment were ±0.10 m s^{-1} at all measurement locations. The CFD predictions of Standard $k-\varepsilon$ could therefore be considered very good based on its predictions in this study. In the study carried out by Norton (2010, p.53) in the naturally ventilated calf shed, he indicated that standard $k-\varepsilon$ and realisable $k-\varepsilon$ were good turbulence models for predicting indoor environment of livestock. However, in this study, realisable $k-\varepsilon$ has not shown to be a good turbulence model for simulating sidewall inlet and roof exhaust ventilated broiler shed because realisable $k-\varepsilon$ turbulence model predicted that air velocity at the sidewall (1 m from the inlet) was 0.46 m s^{-1}, higher than that at 5 m away from the sidewall (0.36 m s^{-1}).

A t-test was conducted with SAS JMP 14 to analyse the differences between the predictions of the standard $k-\varepsilon$ turbulence model and the field experiment at the distance 1 and 5 m from the sidewall. The result of the analysis indicates that at 1 m from the sidewall, there was a significant difference (p = 0.045) between the standard $k-\varepsilon$ turbulence model prediction and the field experiment. However, at distance 5 m, there is no significant difference (p = 0.245) between the standard $k-\varepsilon$ turbulence model prediction and the field experiment. Previous studies (Blanes-Vidal *et al*., 2008; Mostafa *et al.*, 2012) have also shown that turbulence model may not predict the exact results as they were obtained during the field experiment. However, the prediction of CFD, though not exactly as field experiment, could roughly follow similar pattern of field experiment.

3.2 Validation of Air Velocity in the Broiler Shed Occupied with Broiler Models

For better understanding, Mesh 1 (Table 3), was considered to be appropriate for further simulation processes (Figure 7). As shown in Figure 7, there is no significant difference ($p < 0.05$) between the prediction of standard $k-\varepsilon$ and the field experiment at all locations except at the centre of the shed (9 m from the sidewall) where the standard $k-\varepsilon$ turbulence model predicted higher air velocity in the broiler occupied zone. Similar to the previous study (Blanes-Vidal et al., 2008), this study has shown that CFD could be used as an engineering tool to give an estimation of indoor conditions of sidewall inlet and roof exhaust ventilated broiler shed which could direct further field experiments.

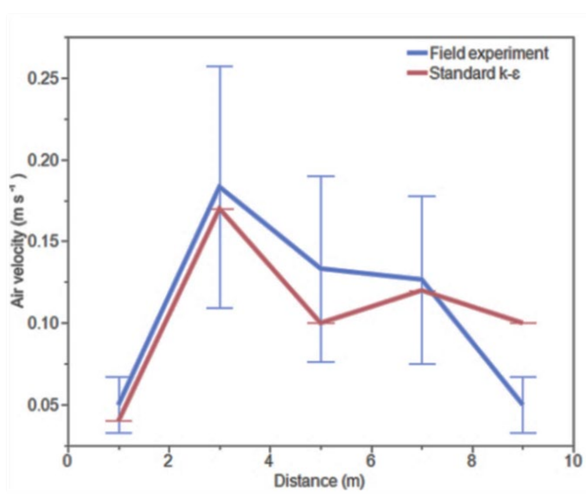

Figure 7: Validation of air velocity predictions of standard $k-\varepsilon$ turbulence model (red line) with the field experiment (blue line).

4. Conclusion

Airflow in the broiler occupied zones, within an empty broiler shed, was validated with the field experiment. The results of this study have shown that an estimation of the indoor air velocity of the sidewall inlet and roof exhaust ventilated broiler shed could be predicted by using CFD simulation and that standard $k - \varepsilon$ turbulence model showed better results compared to other turbulence models (realisable $k - \varepsilon$ and SST $k - \omega$) considered in this study. However, in order to simulate airflow in an empty broiler shed, it is advisable to increase the mesh density during the surface and volume discretisation so as to improve the prediction capacity of the CFD modelling.

Further study with an occupied broiler shed was conducted to evaluate the impact of current inlet opening technique used during the hot weather conditions by the commercial poultry farmers. The standard $k - \varepsilon$ turbulence model performed well in predicting the airflow distributions in the occupied zones of broiler chickens when validated with the results of field experiment. However, comparing the mesh densities of occupied broiler shed with that of the empty broiler shed, this study has shown that the higher number of cells in the prism layer may be avoided due to the design complexity and longer computation time. With lesser design details of broiler shed occupied with broilers, the CFD could accurately predict the airflow distributions in the broiler occupied zones.

This study, in conjunction with the report findings of Albright (1990), has shown that the current method used in the sidewall inlet and roof exhaust ventilated broiler shed needs to be re-evaluated. It has clearly shown that the method may not provide a better airflow in the broiler occupied zones where higher air movement is needed during hot weather periods. Therefore, this study suggests that the ventilation engineers need to investigate other appropriate hot weather ventilation system for broiler production so as to alleviate the heat stress challenges faced by broiler chickens during hot weather periods.

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ERGONOMIC DEVELOPMENT AND PERFORMANCE EVALUATION OF FISH KILN IN NORTH EASTERN NIGERIA.

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Abstract

Fish processing through agro- business using appropriate technology for poverty reduction among fish processors are paramount. Despite conventional and local fish kilns reviewed, the one under study is an intermediate appropriate technology based on participatory design approach. Twenty traditional fish smoking processors were randomly sampled, studied and structured questionnaires was administered. 10 kg of catfish and tilapia fishes each was processed to packaging by the local fish smoking method. Within which, time, duration spent was recorded. Thereafter, development and performance evaluation of kiln oven for fish preservation was carried out based on physico-mechanical properties of 10 kg each of catfish and tilapia fishes. Construction was done based on the detailed design calculations, embodiment drawings, assembly of parts, free testing and full load performance evaluation. Sensory evaluation was carried out using train and untrained panelist to evaluate color, texture and flavour. The total width and height of the oven was ergonomically considered. One of the major *component of developed kiln was the switch, attached to the battery cage which controls the temperature via speed of the fan to the charcoal tray. The average results of physico- mechanical properties for Length, width, thickness, curled diameter (cm) weight (g), Volume (cm^3) and Density (g / cm^3) of Cat and Tilapia fishes are: (36, 13), (5, 5), (12, 0), (5, 3), (158, 50), (189, 60) and (0.8, 0.8) respectively. The average weight (g), volume (cm^3) and density (gcm^{-3}) of charcoal used for both the traditional and developed kiln are: (500, 1200, 0.419) respectively. 10 kg of cat / tilapia fish each processed to packaging by traditional smoking and developed oven kiln took average of 500 min (8 hrs.) for three days with temperature range 30 – 70 ºC and 210 min (3.5 hrs) for developed oven kiln within a day with temperature of 50 – 78 ºC, respectively. The mean throughput capacity, efficiency and moisture content for cat / tilapia fish proceed by the developed oven kiln are (2.9 kg/hr; 92.38%) ; (1.92kg/hr; 100%) and (10.91% ; 10.14%), respectively. It was concluded that increase in capacity and reduction in processing time has been achieved. ANOVA was used for analysis of mean average, differences between values of the level of significant were considered at ($p \leq 0.05$) test. In terms of texture the calculated p – value of (0.05451) indicated that there was no significant difference ($p \leq 0.05$) between the two samples. Total production cost of the developed kiln as at 2020 is N 41,180. 00 (Forty-one thousand one hundred and eighty thousand Naira only). While some local and conventional kiln costs ranges from N 78, 000. 00 – N 350, 000.00 depending on sophistication and capacity. Issues of aquaculture / fish farming are discussed.*

Keywords: Fish, kiln, appropriate, technology, aquaculture, design, embodiment, capacity, efficiency.

1. Introduction

Globally, technological intervention recognizes and embodies the needs, resources, environment and lifestyles of the people using the technology (Carr, 1985). There are several general principles for designing a task, so that work postured is not inflict pain (Ifem and Asota, 2003). Therefore, ergonomics and anthropometry are the investigation of human physical and mental abilities and the application of this knowledge which help designers' and engineers in products and can result in products that are safer or easier to use (Bridger, 1995). The procedure involves finding out what people are doing and help them do it better especially related to food processing specifically fish preservation. Due to the outbreak of Ebola and bird flu, people now prefer eating fish than bush meat (FAO, 2012). People have also recognized that fish is a healthy, low in cholesterol level. A decline in fish availability will have a detrimental effect on the nutritional status of the citizenry particularly in place where fish contributes significantly to the protein intake of the people. Fish is one of the most important animal protein foods available in the tropics. Developed countries capture 50% of the world fish harvest and a large proportion of the catch is consumed internally (FAO, 1996).

According to Eyo (2001), due to poor handling, preservation and processing practices adopted by the artisanal fishermen, fish farmers and fisheries entrepreneurs. These losses are therefore significant when considered on national scale. In most developed countries, canning or freezing methods are used for fish preservation to improve fish quality, quantity and extend the shelf life of fish. However, in less developed countries, traditional fish smoking is still being practiced especially in the tropics. This is because the equipment developed for postharvest processing and handling fish are too sophisticated for the farmers to operate and are not affordable. Some of this equipment **requires** electricity or fuel such as gas for their operation. In Nigeria electricity supply in the rural areas is unstable and cost of fuel continues to rise. These are many attempts on fish kiln examples (Ikenweiwe, *et, al*. 2010, Olayemi, *et,al*. 20013; Omodara, *et, al.* 2016), etc, but non used ergonomic and Intermediate participatory design approach**.** Hence the attempt to ergonomically developed and evaluate performance evaluation of fish kiln from grass root need of farmers cannot be overemphasized.

2. Materials and Methods

The research was conducted at Modibbo Adama University of Technology, Yola, and Adamawa State Nigeria. The research commenced with design consideration to justify economically, affordable, durable, reliable, maintainable and material selection for the construction to prevent corrosion and ergonomic incorporated (Goodlove**,** 2005**).** Basis for Selection of Participating Subjects: Previous knowledge (i.e level of experience) in fish smoking operation was considered as a major factor in the selection of subjects. These factors enabled them to perform the various operations knowledgeably and with minimum interference and / or uncertainty while performing required task. The subjects selected have age range of 30- 45 years. This range was cited as the most representative of (Maunde, 2005 and Maunde, 2010). Spouse permission of some of the married subjects was obtained. Some of the subjects were rejected based on health status. Twenty traditional fish smoking processors were randomly sampled, studied and structured questionnaires was administered**.** Ten kg of each varieties of tilapia and cat fishers of average weight of 50g were purchased from Jimeta main market of Adamawa state for the processors. Each of the processors processed processed to packaging by the local fish smoking method. Within which, time, duration spent was recorded**.** Estimated total amount of rest (scheduled or not scheduled) required for any given work activity, depending on its average capacity was provided.

2.1 Physic Mechanical Properties of Cat and Tilapia fishers

Parameters considered were: Length, width, weight, moisture Content, mass, curled diameter, volume Shape and Sizes, Bulk densities of fished and charcoal these were adopted (Adamu, 2015).

2.2 Design Calculation Ergonomic Incorporated

The capacity (volume) of the oven was calculated by L x b x h. … … …. … (2)

Where;

L = length of the fish tray (mm)
b = width (mm)
h = height (mm)
Therefore volume = l x b x h
The average weight of one fish is 158g and volume was measured to be 189cm^3, the length, width and height was calculated according to Smith and Hole (2006).

2.2.1 The capacity of charcoal tray

The density of the charcoal tray is given as

$$\rho = \frac{M}{V} \ \ (\mathrm{g/cm^3}) \tag{3}$$

where, *M* = mass of the charcoal (g)
V = volume of charcoal (cm^3)

If one mudu of charcoal weighed 500g which is the mass of the charcoal and the volume of one mudu of charcoal was measured to be 1200 cm^3.

Fan air density was calculated (Yahaya,1983).

$$P = \frac{1.325B}{T} \ (\mathrm{kg/m^3}) \tag{4}$$

where;

B = atmospheric pressure which is equal to 760mmHg

T = absolute temperature of air at room temperature which is equal to 35 + 273 = 308

The volume of the air to be supplied by the fan is given as fan air density per mass of dry air

$$V = \frac{p}{m} \tag{5}$$

where;

V = volume of air to be supplied (m^3)
P = fan air density (kg/m^3)
m = mass of dry air at standard temperature and pressure which is equal to 1.29 kg.

2.2.2 The determination of heat transfer by conduction:

The rate of heat transfer by conduction is obtained by using the following expressed (Bala,. and Mandol,2001)

$$q = K.A\left(\frac{T_1 - T_2}{L}\right)\ (\mathrm{J/m^2}) \tag{6}$$

where;

K = thermal conductivity of stainless steel = $30 Wmk^{-1}$
A = area of the fish tray
A = l x b = 520mm x 310mm
L = distance between the fish tray
T_1 = temperature inside the oven and is measured to be 100^0C
T_2 = temperature of the outside oven which is the ambient temperature and is equal to 35^0C.

$$q = K.A\left(\frac{T_1 - T_2}{L}\right)(\mathrm{J/m^2}) \tag{7}$$

Quantity of heat can be calculated using (Omodara *et, al.*2016).

$$Q = mC_p\Delta T \tag{8}$$

where,
Q = quantity of heat (j)
m = mass (kg)
ΔT = change in temperature(°C)
Cp = specific heat J/kg. °C.

3 Material Selection and Construction Method of the Smoking Oven

Steel metal was chosen because of corrosion free and low carbon content ranging from (0-0.3%) for mild steels up to (1.5%) for higher carbon steel (of up to 1.5%) (Khurmi and Gupta, 2003).The metal sheet was used for the construction of charcoal tray and fish tray. The angle iron was used for the construction of the frame and resting support of charcoal tray and fish tray. The method of construction refers to the process by which the component of the smoking kiln were formed before assembling into a complete functional unit. The smoking oven consists of chimney of length and width (250 mm x 100 mm) located at the top of the smoking oven to allow effective exit of smoke and excess heat from the oven.

Construction was done based on the detailed design calculations, embodiment drawings, assembly of parts, free testing and full load performance evaluation. Sensory evaluation was carried out using train and untrained panelist to evaluate color, texture and flavor. The total width and height of the oven was ergonomically considered. One of the major component of developed kiln was the switch, attached to the battery cage which controls the temperature via speed of the fan to the charcoal tray. Machine assembly**:** The smoking oven consist of metal frame, the fish tray, the charcoal tray and the motorize fan. A particular advantage of this machine is that it has a charcoal tray and can be easily removed for cleaning and control of heat to the fish. Appropriate bolts and nuts were used for tight construction.

3.1 Operational Techniques:

The smoking oven operates in such a way that when the charcoal as a source of heat in the charcoal tray is lit and starts burning, it is placed beneath the fish tray. Fish to be smoke are fed into the fish tray and allowed it to smoke. The switch controls the speed of the fan which provides air for the lighted charcoal. The heat from the fire dries the fish while the smoke envelopes the fish which serves as a preservative. The smoked fish is offloaded by pulling out the fish tray to rest on a support. The weight of the fish is usually taken after every one hour of smoking until the final weight is obtained.

3.2 Care and Maintenance:

The machine is made up of metallic materials, corrosion is apparent therefore subsequent repainting with oil paint is necessary. The fish tray should be removed, cleaned and oil after using. Charcoal tray should be removed and cleaned after using. For long time of non-usage the smoking oven should be keep under dry shed or inside store for storing.

3.3 Performance Evaluation:

Two set of fish samples catfish and tilapia were procure from Jimeta main Market. The samples were thoroughly washed and spread salt on the fish, then allow the water to drip and dried for 30 minutes in the sun. Then the charcoal in the developed smoking oven and the traditional smoking kiln were ignited using kerosene and marches. The ignited charcoal was allowed to burn for 10 to 15 minutes to allow kerosene ordour to be exhausted, then more charcoal was added to the burning charcoal. The catfish after drip was weighed (initial weight) as well as the weight of tilapia. The fish samples were arranged on both the fish tray of developed smoking oven and the traditional smoking kiln (oil drum types). As the charcoal was burning the fan is fanning the charcoal to supply a constant heat. While the traditional smoking kiln is expose to natural air blow to maintain it heat which is not constant. During the smoking process the side of the fish facing the burning charcoal was change routinely by turning the fish upside down. The time taken for the smoking was the total time taken. After smoking the fish were allow to cool and kept in a polythene bag to determine the shelf and storage life.

Design drawings based on data obtained from design calculations**:**

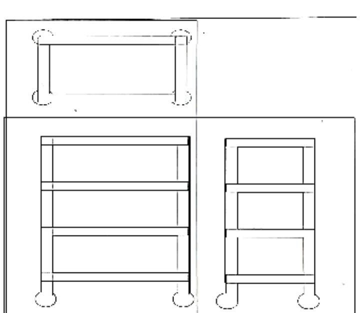

Figure 4: Orthographic Drawing the Frame of the Developed Fish Smoking Oven

(a)

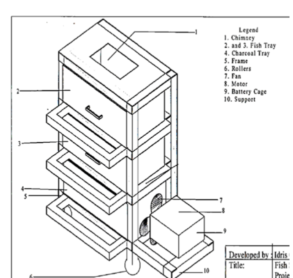

Figure 3: Isometric Drawing of Developed Fish Smoking Oven

(b)

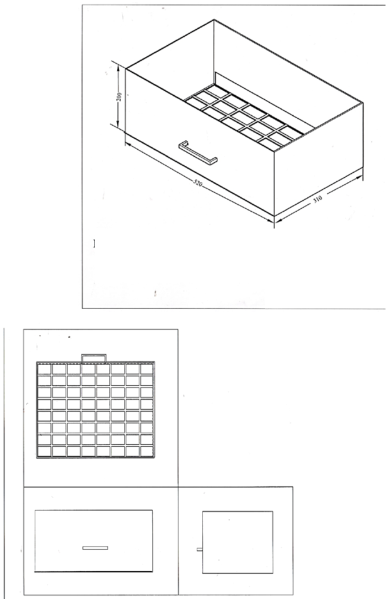

Figure 6: Orthograhic Drawing of a Fish Tray

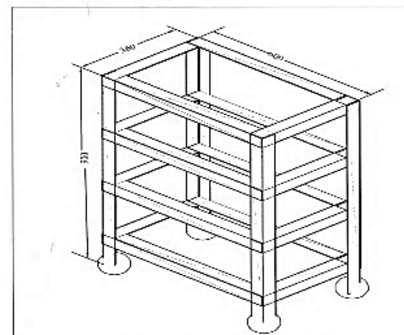

Figure 4: Isometric Drawing the Frame of the Devceloped Fish Smoking Oven

(c) (d)

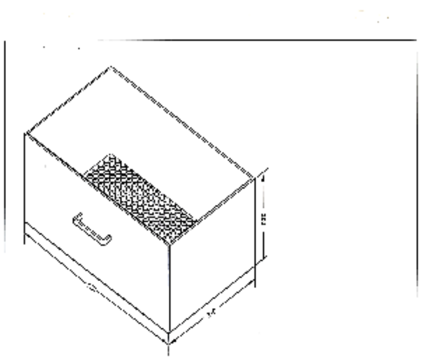

Figure 6: Isometric Drawing of a Charcoal Tray

(e)

(f)

Fig: 1 Isometric and Orthographic drawings of the Developed fish kin (a,b,c,d,e,f).

(a) (b)

(c)

(a) Traditional method cat fish (b) Tradional method tilapia (c) Improved fish kin

Plate (1): Displays of fish varieties locally and improved fish kin (a,b,c).

(a) Fish kiln without ergonomic (b) fish kiln without shelves (c) fish kiln with shelve and ergonomic

Plate (2): Some locally developed fish kilns (a & b) while the new developed fish kin (c)

Analysis:

Data generated was subjected to statistical analysis using computer software SPSS version 16, 2016 the result were presented as a mean average, differences between mean values were analysis using one way ANOVA and the level of significant were considered at ($p \leq 0.05$) test (Uzukwe, 2010).

Sensory Evaluation: The sensory evaluation of the two fish samples was carried out using 10 man panelist through a 5 point hedonic scale as suggested by poste *et al.,* (1991) grading sheet to evaluate colour, texture and flavor. The panel of 10 members familiar with scoring fish were given the products scores at weekly basis. After cooking, the two fish sample were serve in dishes to the panelist, the panelist were asked to taste the two fish sample and score on the score sheet. The products were scored on a scale of 5 – Like very much, 4 – Like slightly, 3 – Neither like nor dislike, 2 – Dislike slightly and 1 – Dislike very much.

4.0 Results and Discussion

Table 1 shows adopted physic mechanical properties of the fish varieties (Adamu, 2015).

Table 1: Summary result of relevant Physico-mechanical properties of Catfish and Tilapia

	Length (cm)	Width (cm)	Thickness (cm)	Curled diameter (cm)	Weight(g)	Volume (cm^3)	Density (g/cm^3)	Moisture Content (%)
Catfish	36.33	5.13	4.86	11.66	158.00	189.00	0.83	10.91
Tilapia	12.66	5.00	2.50	-	50.00	60.00	0.83	10.14

Source: Adamu, 2015.

Results of design parameters is presented in Table 2. One of the major component of developed kiln was the temperature via the fan to the charcoal tray as presented in Table 2. This agrees with Ikenweiwe, et, al. (2010).

Table 2: Design parameters of the developed kiln

S/N	DESIGN PARAMETERS	CALCULATED VALUES
1	Quantity of heat (Q) J	39000
2	Fan air density ($\boldsymbol{\rho}$) (kg/m^3)	3.30
3	Density of charcoal (ρ) (g/cm^3)	0.419g
4	Mass of charcoal (g)	0.0134
5	Volume of charcoal (m^3)	0.032
6	T1 (C^o)	50
7	T2 (C^o)	78
8	Volume of air to supply by fan (m^3)	2.558
9	The number of fish in a tray 26.8/0.158 =	169
0	Throughput Capacity (kg /hr)	3.9

Figure (1) shows Isometric and Orthographic drawings of the developed fish kiln which show the total height, width and length incorporated with ergonomic according to Good love **(**2005). While Plate (2) constructed developed kiln based on Figure (1) and design calculated parameters, the developed fish kiln (c) unlike the others (a & b). This agrees with Yahaya (1983) and Khurmi and Gubta (2003). Plate (1) shows result of Sensory evaluation by train and untrained panelist shows the color, texture and flavor of both Cat and Tilapia process by developed fish kiln has higher taste and quality than the one processed by the traditional fish smoking. This agrees with Olayemi, et. al,(2013) and Poste, et. al, (1991). Results of traditional fish smoking and developed fish kiln is presented in Tables 3 and 4 respectively. Little disparity is seen in smoking efficiency for both the traditional method and the ergonomically developed fish kiln. During the process task activities it was observed there is back pain subjected on the subject. This agrees with Carr (1985) and Ifem,, and Asota (2003). There is high disparity in efficiencies of smoking time of traditional method and developed fish kiln.

Table 3 : Summary Result of the performance evaluation of catfish and tilapia smoked using traditional smoking kiln

S/N	Initial Weight (kg)	Final Weight (kg)	Time (Min)	Moisture Content (%)	Smoking rate (kg/h)	Smoking Efficiency (%)	Efficiency of smoking time (min
Catfish	5.50	2.10	5.00	69.12	0.42	30.88	62
Tilapia	2.00	0.70	3.00	35.00	0.23	35.00	59

Table 4 : Result of performance evaluation of catfish and Tilapia using develop smoking oven

Fish Varieties	Initial Weight (kg)	Final Weight (kg)	Time (Min)	Moisture Content (%)	Smoking rate (kg/h)	Smoking Efficiency (%)	Efficiency of smoking time (min
Catfish	X5	X5	X5	X5	X5	X5	
Total	35.00	10.66	17.75	344.00	3.22	152.84	457
AV	7.00	2.13	3.55	68.00	0.64	30.56	91.4
Tilapia	X5	X5	X5	X5	X5	X5	X5
Total	10	2.99	12.28	350.00	1.33	150	481
AV	2	0.59	2.56	70.00	0.27	30.00	96.2

Table 6: ANOVA for developed traditional smoking and developed kiln for Cat and Tilapia fishes.

Fish Varieties	Source of Variation	SS	DF	MS	F	P-value	Fcrit
Cat	Between groups	1.03	4	0.2575	7.573529	0.023763	5.192168
	Within groups	0.17	5	0.034			
Total		1.2	9				
Tilapia	Between groups	0.476	4	0.119	4.958333	0.05451	5.192168
	Within Groups	0.12	5	0.024			
Total		0.596	9				

Results of ANOVA shows mean average, differences between values of the level of significant were considered at ($p \leq 0.05$) test. In terms of texture the calculated p – value of (0.05451) indicated that there is no significant difference ($p \leq 0.05$) between the two samples calculated according to Uzukwe (2010). Total production cost of the developed kiln as at 2020 is N 41,180. 00 (Forty-one thousand one hundred and eighty thousand Naira only). While some local and conventional kiln costs ranges from N 78, 000. 00 – N 350, 000.00 depending on sophistication and capacity. Figures (2 &3) shows graphs of weight loss in series 2 for Cat fish and series 3 for

Tilapia for developed kiln as compared with graph of weight loss in fish process with traditional Smoking Kiln. Results shows higher smoking time in traditional method.

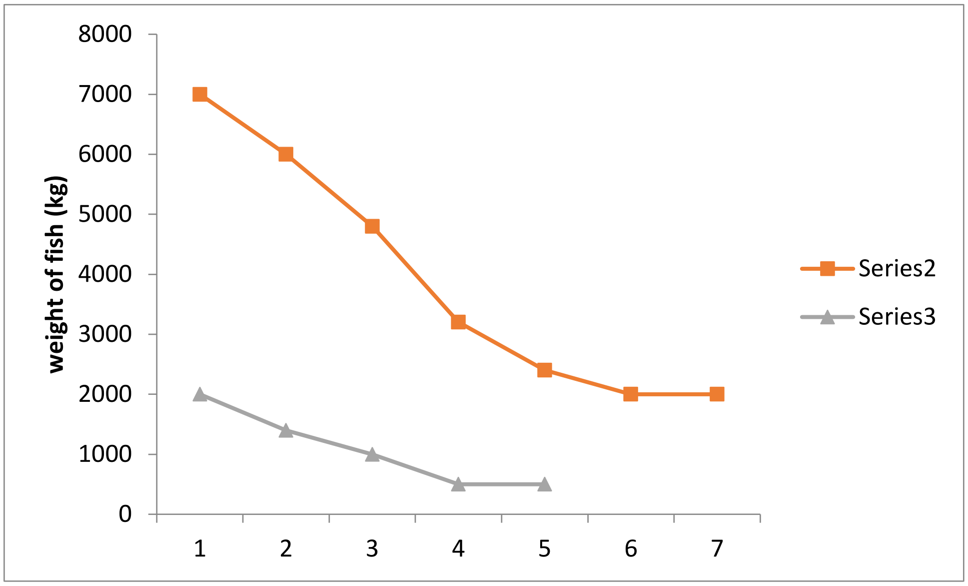

Figure 2: Graph of Weight Loss in Fish Drying Process with Developed Smoking Oven.

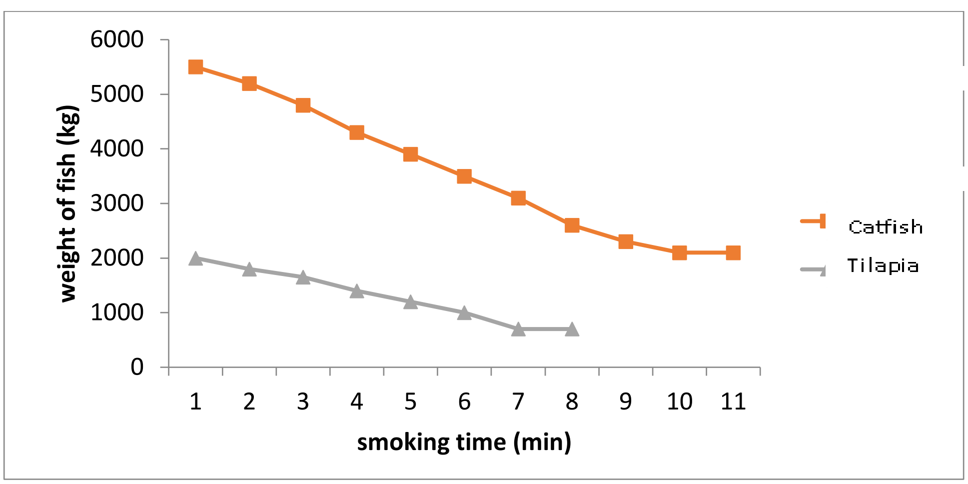

Figure 3: Graph of Weight Loss in Fish Drying Process with Traditional Smoking Kiln.

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DEVELOPMENT AND TESTING OF PORTABLE CAPACITIVE DIGITAL WOOD MOISTURE METER

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Abstract

Portable digital wood moisture meter is a vital tool used by timber processing industries and wood workers for determining the moisture contents of wood for its optimum utilization. Wood moisture content is one of the most relevant parameters considered when deciding the quality and durability of wood during seasoning, storage, processing and application in designs as the conventional oven-dry method is time consuming and destructive. However, digital wood moisture meters are not readily available in Nigerian local markets, and the few imported ones are very expensive and they have look-up tables which constitute inconveniences while carrying out measurements. Thus, in this study, a portable and easy-to-use capacitive moisture meter, which eliminates these problems owing to its novel design, and provides accurate wood moisture measurements in percentage directly on an LCD display was designed, developed and calibrated for Mahogany, Afara, Obeche, Iroko, and Apa wood species; and was also tested for other commercial wood species available at Nsukka, Southeastern Nigeria after re-calibration. The novelty of this instrument is that the user can re-calibrate the meter for other wood species at any point in time, and it is easy-to-use, portable and does not require look-up tables. The developed digital moisture meter works satisfactorily for all practical purposes in the range of 0-100% of wood moisture with an accuracy of ± 0.1%.

Keywords: Development, testing, capacitive digital meter, wood moisture measurement.

1. Introduction

Wood moisture meter is a very important handy tool that has the ability to measure accurately the moisture content of any wood material provided that the meter is calibrated based on the electrical properties of the wood species(Blaker, *et al.,* 2000; Straube, *et al.,2002;* Carfrae, *et al.,* 2011; De Wilde, *et al.,* 2011; Desch and Dinwoodie, 2016). This vital instrument is not readily available in Nigerian local markets while the few imported ones are with look-up tables which cause inconvenience when carrying out measurements and are very expensive. Wood moisture meters have a great deal of advantage over other methods for the determination of moisture contents of woods or wood-based materials because of their convenience and speed. They are therefore used for sorting lumber, and veneers on the basis of moisture contents (Dunlap, 1944). Generally, the methods for determining moisture contents of woods can be divided into direct and indirect methods. Conventional methods of moisture measurements in woods like oven-dry method, distillation, drying with desiccants, etc., are direct methods and time-consuming with greater chances of errors occurring during measurements if the measurements are not done carefully, whereas those based on electrical resistance, dielectric (capacitance), chemical, microwave spectroscopy, etc., are indirect methods (Theraja, 1980; Feynmam, *et al.,*1988). Oven-dry method is a standard technique(ASTM-Standard,2003; McFarlane, 2006)and widely recognized method (Hall, 1970; Young, 1983) against which other indirect method-based moisture meters are calibrated, but it is destructive and time consuming with the rigours of weighing, drying and re-weighing the representative samples (Dinwoodie and Desch, 1996; Fuchs, *et al.,* 2009; Desch and J. M. Dinwoodie, 2016).This makes wood moisture meters extremely important. Indirect methods involve the measurement of certain property of the material, which depends upon the moisture content.

Wood is a heterogeneous, hygroscopic, cellular, anisotropic, porous and fibrous structural tissue found in the stems and roots of treesor woody plants, consisting of cells which are composed of micro-fibrils of cellulose (40% – 50%) and hemicellulose (15% – 25%) impregnated with lignin (15% – 30%) (Simpson, 1993; F.P.L., 1999; Keey, *et al.,* 2012). Its moisture-related dimensional changes vary in its three principal anatomical axes – longitudinal or parallel to grain, radial and tangential; with the most pronounced moisture response is in the tangential direction (Langrish and Walker, 1993; Bratasz and Kozłowski, 2005).Woods are generally classified as either softwoods (i.e. evergreen and cone bearing trees which consist of tracheid elements e.g. pine, yew, cedar, larches, baldcy press, fir species, etc.) or hardwoods (i.e. deciduous and leaf bearing trees that contain vessel elements e.g. oak, mahogany, walnut, maple, ash, obeche, apa, iroko, cherry, agba, afara, rosewood, teak, wenge, birch, poplar species, etc.) (Sperry *et al.,* 1994; ASTM Standard, 1999; FPL, 1999). These names are a bit confusing, as hardwoods are not necessarily hard, and softwoods are not necessarily soft. The well-known balsa (a hardwood) is actually softer than any commercial softwood. Conversely, some softwoods (e.g. yew) are harder than many hardwoods (FPL, 1999; Briffa, 2008).The unique characteristics and comparative abundance of wood have made it a natural material for homes and other structures, furniture, tools, vehicles, and decorative objects with multitude of uses (Maher, 2006). Moisture content affects most of the important properties of wood, and it can vary widely depending on the environment or climate and history of the wood. Therefore, having good and reliable moisture meters for the determination of moisture content in wood materials is of great importance for many fields of applications within and outside the industry (James, 1988; Fuchs, *et al.,* 2009; Stacheder *et al.,* 2009).Wood is susceptible to decay by rot fungi if it is exposed to high moisture contents for a long period of time (M. W. Healy, 2003; Wengert, 2007). Dimensional change is perhaps the most important consequence of moisture sorption by wood. Wood shrinks as it loses moisture and swells when it gains moisture (James 1988).The quality of wood is influenced by its moisture content, which is one of the most important parameters always considered when deciding the quality of wood at the stage of seasoning, storage, processing and application in designs. Therefore, to give the best service, wood should be installed at moisture content close to the midpoint between the highest and lowest values it will usually attain in use (i.e., the equilibrium moisture content) (Chudnoff, 1984; ASTM-Standard, 1999; F.P.L., 1999). Portable and easy-to-use wood moisture meter is a therefore necessity for the benefit of wood workers and furniture industries.

In this study, a capacitive-type digital wood moisture meter was designed, developed, calibrated and tested against the oven-dry method using commonly available commercial wood species in Nsukka, Southeast Nigeria. Capacitive sensing has gained increasing importance in the last decades and is successfully employed in various applications in industrial and automotive technologies (Moser, *et al.,* 2008). Due to the high relative permittivity of water (about 80), capacitive techniques are typically well-suited for moisture measurement in bulk solids (Wobschall and Lakshmanan, 2005; Fuchs, *et al.,* 2009). Capacitive wood moisture meters are subject to less error that arises from non-uniform distribution of moisture and physical contact with the material under test (Hall, 1970; Young, 1983). This method permits moisture measurement over a wider range than the conductance method, and properly calibrated capacitive-type wood moisture meters work satisfactorily.

2.0 Materials and Methods

2.1 The Working Principle of The Capacitance Wood Moisture Meter

The functional block diagram of the system is shown in Figure 1.The device is a microcontroller based system with insertion capacitive sensor probe to measure the moisture contents of different wood species. Capacitance-based wood moisture meters use the relationship between moisture content and the dielectric constant of the wood (Rai, *et al.*, 2014). When the electrode of the meter is in contact with the wood, the electric field associated with the capacitance of the frequency-determining circuit of an oscillator penetrates the wood. This frequency of the oscillator changes due to the dielectric constant of the wood. Using the relation between the dielectric constant and the wood moisture, the meter was calibrated to read moisture contents in percentage (%). All capacitance type moisture meters are based on the same operating principle (Wobschall and Lakshmanan, 2005). When the capacitive sensor probe is inserted in the wood sample, the change in moisture content causes a change in capacitance of the wood. Since the oscillator circuit (555 timers) depends on timing resistor and capacitance, keeping the resistor at fixed value, the capacitance becomes a factor that changes the output frequency. This frequency can be measured either directly at the analog to digital converter (A/C) of the PIC microcontroller (pic16f877a) or converted to voltage output (mV) using a signal conditioner circuit. The result of the frequency or voltage measurement is converted to the corresponding moisture content in percentage (%) using the meter's calibration data in the re-programmable micro controller and then it is displayed at the LCD (liquid crystal display)display of the system. The basic equation relating the measured capacitance, C, (which is dependent on moisture content of the wood) and the frequency, F is given by equation (1).

$$F = \frac{1}{\{C\ (R_1 + 2R_2)\ In2\}}\ \text{(Hertz)} \quad (1)$$

$$\text{where } C = \frac{\epsilon_0 \epsilon_r\ A}{d}\ \text{(Farad/m)} \quad (2)$$

ϵ_0=8.8419 x 10^{-12}

Farad/meter is known as the absolute permittivity of free space;ϵ_r is the relative permittivity of the dielectric or the dielectric constant of the material, *A* is the area of the electrode probe (m^2), and *d* is the distance between the electrode probes (m);R_1 = the discharging resistor and R_2 = charging resistor(Ω). The wood whose moisture content is to be measured acts as the dielectric medium of the capacitor as the parable sensor probes are inserted into the wood.

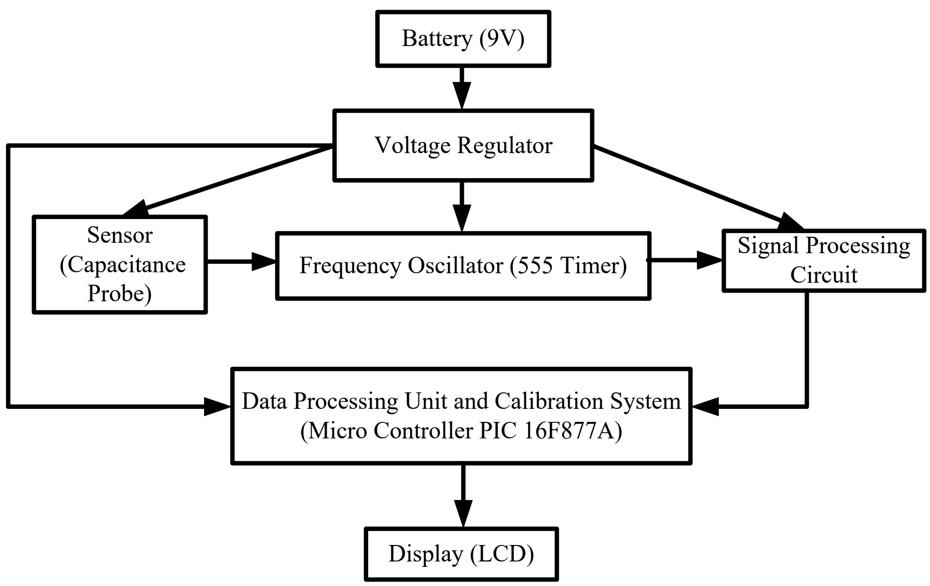

Figure 1: Functional block diagram of the capacitance-based digital wood moisture meter

2.2 Development of the Capacitance-Based Wood Moisture Meter

The electronic circuit of the system is depicted in Figure 2. The most common approach in developing capacitive meters is simply to use an analog timer circuit to generate a frequency, F, that is inversely proportional to the capacitance, C, and then utilize a microcontroller to count the pulses within a given period to estimate the frequency. A stable timer,(the classic 555 timer),which operates by charging and discharging thecapacitor, was employed in this design. The capacitor's voltage triggers the charge and discharge cycles as it transits across the lower and upper thresholds. Thus in this design, the microcontroller counts the pulses and displays the corresponding moisture content values in percentage (%) on the LCD as a digital output.The accurate functionality of the design components, power consumption, electrical voltage and current requirements were also considered for a wholesome development as well as the availability and cost of production. Figure 3 presents the picture of the developed digital wood moisture meter

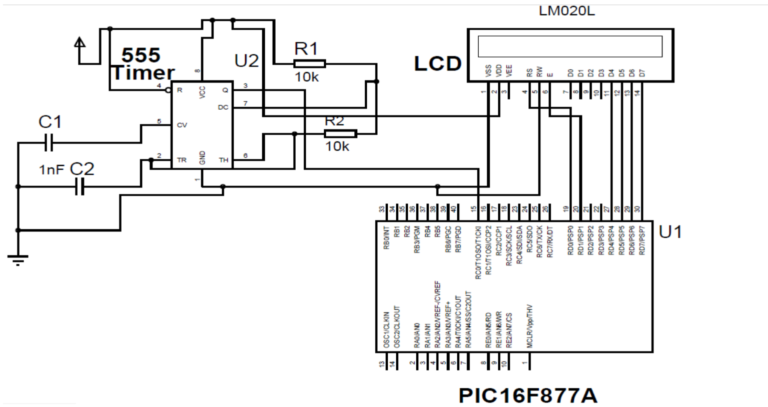

Figure 2: The electronic circuit of the system

Figure 3:The picture of the developed digital wood moisture meter

2.3 *Calibration of the Digital Wood Moisture Meter*

Themeter has been calibrated for Mahogany, Afara, Obeche, Apa, and Iroko respectively. To perform this, a set of freshly cut wood samples of the above mentioned wood species with varying moisture were conditioned to nearly constant relative humidity at a temperature of 80° F, after being first cleansed of foreign materials, using either water acid or saturated aqueous salt solution in an air-tight plastic container. The moisture meter's sensor probe was then inserted into each of the wood samples and the electrical capacitance of the wood (C_2) was used as the reference value to determine the moisture contents of each sample at green state (wet condition). These wood samples were,at the same time, periodically oven-dried at about 5 hours time intervalsfor a minimum of 48 hours at 103°C according to ASTM standards (1999);and their moisture contents determined by gravimetric method at each stage of the drying process with digital moisture prediction. This oven-drying result was used as a standard for the meter's calibration.As the capacitive sensorprobe is inserted into the conditioned wood samples, a pulse is generated using a 555 timer (oscillation circuit) which is based on the dielectric constant of the moisture content of the wood. This frequency (Hertz) ismeasured either directly at the analog to digital converter (A/C) of the PIC microcontroller (pic16f877a) or converted to voltage output (mV)using a signal conditioner circuit. A separate push switch was provided for each wood species that the moisture content was measured by pressing the corresponding push switch. The push switch connects the corresponding Y-axis intercept value adjustment circuit, which determines the intercept value of the appropriate curve. The voltage variation against moisture content (%) of wood was approximated to a straight line using linear regression analysis, and the instrument calibrated by adjusting slope, *'m'* and Y-axis intercept value *'c'* of the calibration curve in the programmable microcontroller.

In this method of calibration, the initial digital meter's reading of the moisture content of the wet wood sample, before oven-drying to varying moisture values, corresponds to the maximum moisture content percentage value while the final meter's reading, after the wood sample has been completely dried to a constant weight at 103^{0}C (Figure 5), represents the minimum moisture content percentage value. These moisture content values obtained with the digital meter and by oven-drying method were appropriated to a straight line and used in re-programming the microcontroller. At present, the developed system is calibrated for five wood species as mentioned above, but can be calibrated for any number of wood species using separate push switches for each wood provided the obtained calibration curves can be approximated as straight lines in the re-programmable microcontroller which enables direct display of moisture content in percentage (%) on the LCD display of the system. Table 1 and Figure 4 present the digital wood moisture meter's calibration results and curve respectively. While Figure 6 shows the experimental set up for moisture content determination using the developed meter.

Table 1: The digital wood moisture meter's calibration results

Number of Replication	**Mahogany**		**Obeche**		**Afara**		**Apa**		**Agba**	
	MC (%)	**V (mV)**	***MC (%)***	**V (mV)**	***MC (%)***	**V (mV)**	***MC (%)***	**V (mV)**	***MC (%)***	**V (mV)**
1	7.61	7.43	5.57	5.35	8.12	8.10	6.12	6.38	6.57	6.23
2	8.53	8.25	6.30	6.00	8.79	8.84	6.63	6.70	7.83	7.28
3	9.78	9.64	6.50	6.42	9.00	9.23	7.00	7.00	8.68	8.60
4	11.50	10.89	7.00	7.28	9.64	8.85	7.67	7.51	9.40	9.05
5	12.10	11.94	7.80	7.28	10.43	10.40	8.00	8.00	10.10	10.04
6	13.40	12.88	8.38	8.12	11.00	11.00	9.25	9.39	12.00	11.88
7	13.54	13.47	8.96	8.68	11.57	11.53	10.95	10.00	13.53	13.50
8	14.00	14.00	9.35	9.00	12.94	12.97	11.62	11.83	14.00	14.00
9	14.48	14.65	10.00	10.00	13.50	13.55	12.50	12.00	14.18	14.15
10	15.00	14.79	11.31	11.50	14.17	14.20	12.64	12.59	14.50	14.46

Note: *MC (%) = Moisture content (%)*, V (mV) = *Voltage output (mV) of the system*

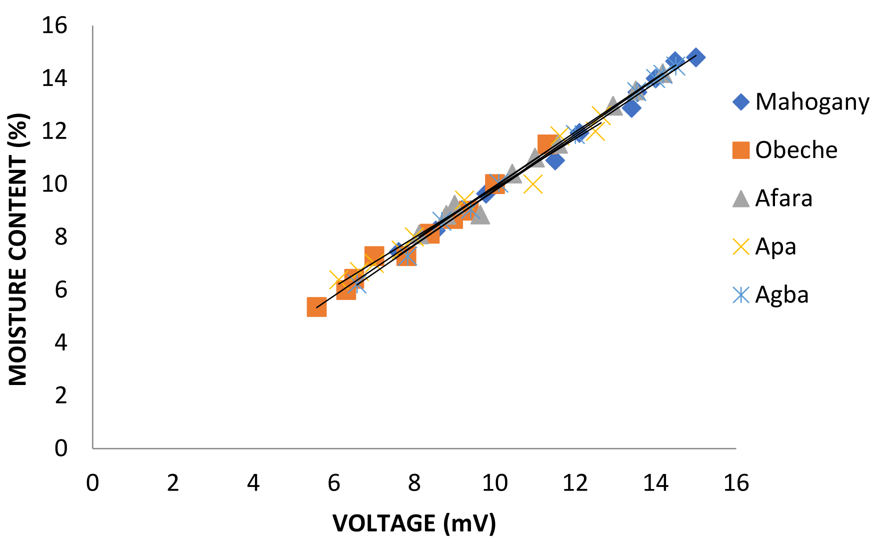

Figure 4: The digital wood moisture meter's calibration curve

Figure 5: Experimental set up for moisture content determination by oven-dry method

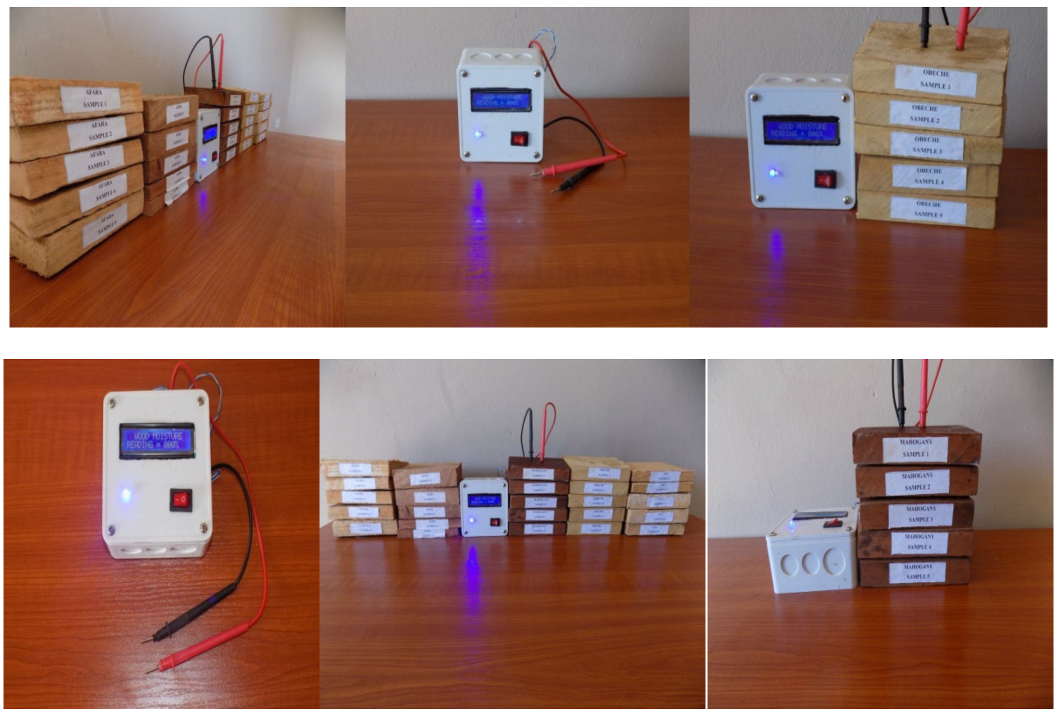

Figure 6: Experimental set up for moisture content determination using the developed meter.

3. Results and Validation

A field test was conducted to determine the accuracy or sensitivity of the digital meter using ten different wood species locally available in Nsukka, Southeast Nigeria. The results of the field test were validated, statistically, using the observed moisture content results obtained by oven-dry method. In this test, five clear straight-grained samples of each of the selected freshly sawn wood species, whose moisture contents were determined using the developed moisture meter, were collected from the timber shed and oven-dried to a constant weight at 103^0C for 48 hours according to ASTM standards (1999). Their moisture contents (MC) were then estimated using Equation 3.

$$MC\ (\%) = \frac{M_w - M_d}{M_d} \times 100 \quad (3)$$

where M_w=mass of wet wood sample, (Kg);M_d= mass of oven-dry wood sample, (Kg).

During the field test, the moisture meter's probe was driven about 1/4" (6mm) into the wood for each meter's reading. The moisture readings in percentage were measured parallel to the wood grain. Four readings were taken from each sample, two from each face, and averaged. This average meter reading represents the measured moisture content of each of the tested wood species. The observed moisture contents (oven-dry moisture contents) of each of the selected wood species were then compared statistically with the predicted moisture contents (moisture meter's readings) to determine the level of accuracy or sensitivity of the wood moisture meter. It was observed from the test results that the developed instrument works satisfactorily for all practical purposes in the range of 0-100% of wood moisture with an accuracy of ± 0.1% and negligible percentage error. Table 2 presents the results of moisture content determination of the selected ten different wood species that were tested using the developed digital meter and by oven-drying method after re-calibration. Regression analysis conducted on the two sets of the test results showed a strong correlation (R^2 ranges from 0.98 to 0.99) between the predicted and the observed values for the tested wood species. The analysis of variance tests conducted on the two sets of results proved that the relationship between the measured and observed moisture contents is statistically significant ($P < 0.05$). This indicates the effectiveness of the meter's calibration. This shows that the developed digital moisture meter is reliable for both in situ and laboratory measurements of moisture contents of wood species.

Table 2: Results of wood moisture content determination of the selected ten different wood species

S/No	Wood Species	MR (%)	OR (%)	Error (%)
1	Mahogany(*Khaya spp)*	14.1	13.9	0.2
2	African Walnut (*Lovoa trichilioides)*	13.5	13.2	0.3
3	Obeche (*Triplochiton scleroxylon)*	9	8.8	0.2
4	Apa (*Afzeliaspp*)	12.3	12.2	0.1
5	Teak (*Tectona grandis)*	11.6	11.3	0.3
6	Iroko (*Melicia excels)*	15	14.8	0.2
7	Agba (*Gossweilerodendronbalsamiferum)*	13	12.9	0.1
8	Omo (*Cordia millenii)*	14	13.8	0.2
9	Black Ebony (*Diospyros spp)*	16	15.7	0.3
10	Afara (*Terminalia superb)*	13	12.90	0.1

***Note**: MR (%)* = Meter's reading; OR*(%)* = Oven dry result; Error (%) = Error in the measured values

5. Conclusion

This study has demonstrated the design and development of a capacitance-type digital wood moisture meter that is cheap and simple to operate. In this study, a capacitance-based wood moisture meter, which eliminates the problem associated with the look-up tables due to its novel design, and displays moisture contents in percentage directly on a LCD display was designed, developed and calibrated for Mahogany, Afara, Obeche, Iroko, and Apa wood; and was tested for commercial wood species available at Nsukka, Southeast Nigeria. The novelty of this instrument is that it is compact, easy-to-use, portable, and field usable. However, the user can also calibrate the digital meter at his level for other wood species. The developed digital moisture meter works satisfactorily for all practical purposes in the range of 0-100% of wood moisture with an accuracy of ±1%.Regression analysis conducted on the two sets of the field test results showed a strong correlation (R^2 ranges from 0.98 to 0.99) between the predicted and the observed values for the tested wood species. The analysis of variance tests conducted on the two sets of results proved that the relationship between the measured and observed moisture contents is statistically significant ($P < 0.05$). This indicates the effectiveness of the meter's calibration. This shows that the developed digital moisture meter is reliable for both in situ and laboratory measurements of moisture contents of wood species.

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DEVELOPMENT AND PERFORMANCE EVALUATION OF A PORTABLE AUTOMATED EGG INCUBATOR

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Abstract

An incubator with a capacity of 30 eggs was developed and evaluated to determine its efficiency. The incubator comprised of an incubating chamber constructed with wood, an egg tray turning at an angle of 45 ° using a servo motor, a 60-watt bulb, a 12-volt 75 Amps batteryDC fan for ventilation and a water bowl for regulating the relative humidity within the incubator. The incubator was powered with two 12 volts 75 Amps battery and a 300 Watts inverter. The batteries were constantly charged using the battery charger connected to the main power supply. The whole system was controlled automatically using a programmable integrated circuit (a microcontroller). The performance evaluation of the incubator was carried out to determine the efficiency of the machine. The temperature varied from 36 °C to 38 °C and the average relative humidity was 56.5% inside the incubator which was considered safe for egg incubation. The incubation was tested with 16 eggs. The eggs were candled with which 10 were fertile while remaining (6) infertile. The working efficiency of the incubator based on the number of fertile eggs was estimated to be 63 %. This equipment is user friendly and also affordable.

Keywords: Temperature, relative humidity, local fowl eggs, candling and solar energy.

1. Introduction

The incubator is an equipment utilised for the logical hatching process in which temperature, relative humidity and ventilation could be controlled (Adichie *et al.,* 1985). With this equipment, a considerable amount of eggs could be hatched at a time while the laying birds continue to lay eggs, resulting in high poultry production. This could improve the economic situation of the farmer and the advancement of food production and food security in Nigeria. Egg incubation provides an environment which could keep the fertile egg warm to permit legitimate development of the embryos into chicks. In natural incubation, the birds give the expected conditions to the relatively few eggs she lays by sitting on the eggs continuously until they are hatched after about 21 days (Adegbulugbe *et al.,* 2013). Compared to the artificial incubator, a relatively large number of eggs from different laying birds could be handled at once (Adegbulugbe *et al.,* 2013).

Over the years, incubators were powered by electricity with the electric bulb as the heating element, have automatic egg turning devices and are equipped with automatic controls to keep up the best possible degree of temperature, relative humidity and air exchange (Umar *et al.,* 2016). Environmental conditions such as temperature, relative humidity and ventilation, sanitation and periodical record-keeping could affect the success of incubating and hatching of eggs. Embryos begin to prematurely develop at temperatures above 22 °C (Sani *et al.,* 2000). Eggshells contain thousands of pores which could allow water evaporation to enable the developing embryo to breathe (Umar *et al.,* 2016). Eggs maintained at about 58 % relative humidity and about 39 °C temperature could start hatching at eighteen days of incubation (Adegbulugbe *et al.,* 2013).

Many innovative egg incubators have been developed but they are too expensive. This has made them non-affordable by the small-scale farmers with just a few numbers of laying birds. Therefore, this work was carried out with the objectives of (1) developing a portable automated egg incubator and (2) evaluating the performance of the incubator.

2. Materials and Methods

2.1. Description of the Incubator

The incubator was constructed from locally available materials which are relatively cheap and could be afforded by peasant farmers. **The incubator is a force draft incubator, consisting of a 15 mm thick wooden frame with dimensions 600 × 400× 400 mm. The components include; blower, heat source(60 watts bulb), metallic servo motor, egg tray, egg guide, vent plugs, water tray, temperature and humidity sensor (DHT11), power supply unit (PSU), LCD, relay, RTC module, a microprocessor (ATMega 328), two** 12 volt battery, 300 watts power inverter and a battery charger(Figure 1)**. The required temperature range within the system was produced by the heating bulb, the blower uniformly distributed the warm air, and the relative humidity was generated by moisture from the water tray.**

Figure 1**. Egg incubator**

2.2 Testing of the Incubator

The temperature range and relative humidity of 36 to 38 °C and 55 to 65 % respectively were maintained within the incubator with the aid of a control system consisting of a relay, programmable integrated circuit, input sensor, water tray and heater. As the temperature reached 38 °C,

the sensor sensed the impulse and fed the microcontroller to stop the heating system of the incubator. The heater automatically turned on as the temperature dropped below 36 °C. These conditions were constantly maintained by the power produced from the 12-volt battery and inverter when there was power outage. The inverter converted the direct current (DC) from the battery to alternating current (AC). As soon as there was power supply, the source of power for the incubator automatically changed and the charging of the battery through the battery charger began.

The incubator was properly cleaned and test run for about two days without loading before setting the eggs on the tray. This was necessary to avoid infections which could contaminate or affect the hatchability of the eggs. **The incubator was tested with 16 local fowl eggs purchased from a local farmer. The test was necessary to determine the efficiency of the incubator.** The eggs were carefully arranged on the egg tray (Figure 2) and gently turned with the aid of servo motor connected to the tilting tray to ensure that the embryos were not stuck to the egg shells, completely formed and in the right positions during incubation process. The eggs were turned at an interval of 6 hours and at an oscillation angle of 45^0. For the candling of the eggs, a torchlight was used to examine the embryonic development in the eggs so as to be able to separate the fertile eggs from the infertile ones.

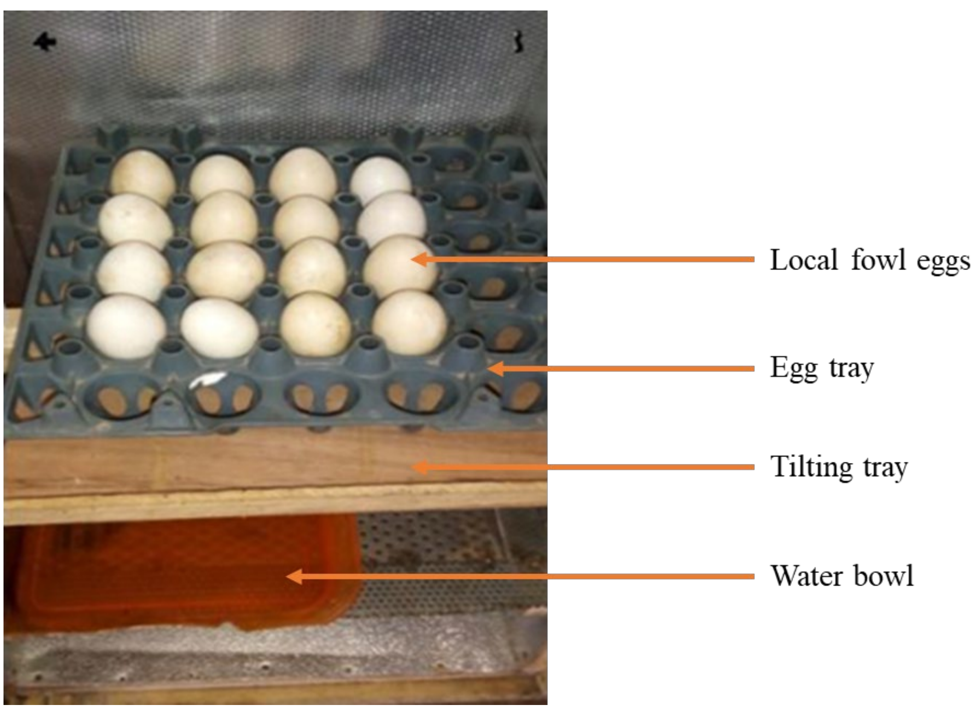


Figure 2. Arrangement of eggs in the incubator

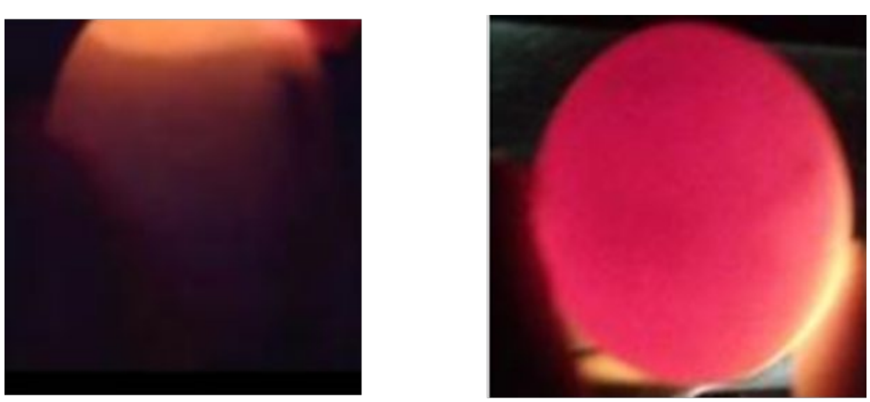
The Percent fertility of the eggs was estimated based on the number of fertile and infertile eggs using the expression in Equation 1(Umar *et al.,* 2016)**.**

$$Precent\ fertility = \frac{number\ of\ fertile\ eggs}{total\ number\ of\ eggs\ set\ into\ the\ incubator} \times 100 \qquad (1)$$

3. **Result and Discussions**

Throughout the period of incubation, the temperature was maintained within the recommended range of 36 °C to 38 °C which was achieved with the aid of the temperature and humidity sensor. The conditions were achieved by setting the control of the incubator to cut off power supply to the heating bulb when the pre-set temperature of 38 °C was reached and actuate the heating bulb when the temperature dropped below the temperature 36 °C. The average temperature achieved within the incubator was 37.5 °C (Lourens *et al.*, 2006)which was considered save for the incubation of the eggs. The relative humidity within the incubator ranged between 55 to 65 %.

The testing of the incubator lasted for 21 days and the candling of the eggs was conducted. After seven days of incubation, the eggs were candled to find out the fertilised eggs and to check the embryonic development in the egg. After candling the development inside the incubator was not that glaring but a slight change could be noticed (Figure 3)**. The egg candling process using a torchlight in the dark, indicated that fertile eggs contained shrimp, while infertile ones had no trace of any shrimp. It was discovered that 10 eggs were fertile and 6 eggs were infertile and they were removed from the incubator. The efficiency of the incubator was estimated as 63 % based on the number of fertile eggs compared to infertile eggs**



(a) (b)

Figure 3. Egg candling (a) fertile egg and (b) infertile egg.

On the 14th day of incubation, the eggs were candled in order to examine the embryonic development. After candling, it was found that the development of the embryo was glaring. After candling on the 14th day of incubation, it was noticed that five (5) out of the ten (10) that were fertile had started developing a noticeable embryo (Figure 4).

Figure 4. Developed embryo.

On the 18th day of incubation, the eggs were also candled for further observation of the embryonic development. After candling, some of the embryos had started developing. It was discovered that two (2) of the five eggs with noticeable embryo development during the fourteenth day candling, had developed some features (Figure 5) like yolk outside the embryo (Lourens *et al.*, 2006).

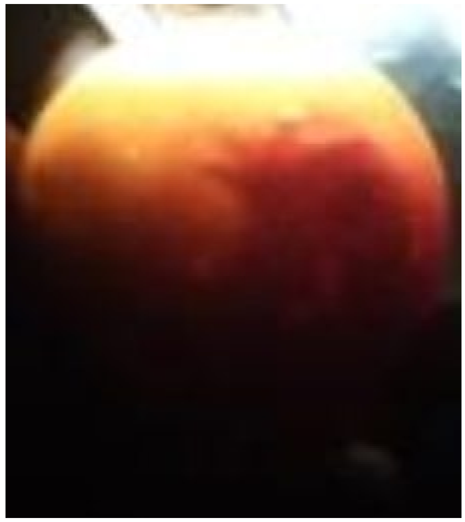


Figure 5. Developed embryo with some features.

On the 21st day which was expected to be the day of hatching, nothing was hatched because the incubator developed a fault during the 18th day of incubation due to a power surge in the control unit. The temperature and humidity sensors that were supposed to regulate the cutting off of the heating element could no longer perform their functions. So, the temperature exceeded the pre-set maximum temperature, which was 38 °C. This affected the development of the embryo. The incubation process was terminated and one of the eggs was cracked to examine the embryo development. The developing embryo had already died when the incubator malfunctioning took place (Figure 6).

Figure 6. Developed embryo removed from the shell.

4. Conclusion

A portable automated incubator was developed and tested. There was a power surge which affected the incubator, resulting in poor hatchability on the 21 day of incubation. However, based on the performance of the incubator up to the 14th day of incubation, the efficiency of the system could be estimated as 63 % based on the numbers of fertile eggs (10) compared to the infertile eggs (6). For further studies, the incubator needs to be worked upon to ensure that power surge is subsequently prevented so as to make the incubator available to the small-scale farmers. In addition, the system could also be powered using solar energy instead of electrical energy.

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PROPERTIES OF INTERLOCK BLOCKS PRODUCED FROM RECYCLED PLASTIC- SAWDUST MATRIX FOR PAVEMENT APPLICATIONS

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Abstract

This research investigated the possibility of integrating sawdust with waste plastic sachet in the production of interlock pavement blocks, - thereby recycling this problematic waste stream which is normally indiscriminately disposed. Polyethylene water sachet (PWS) was the main waste item used. A sawdust – plastic matrix was designed and cast successfully with percentage sawdust incorporations of 0, 5, 10, 15, 20 and 25% using two sieve sizes of 0.15mm and 0.6mm of sawdust with a constant waste plastic of 2.5Kg by weight, and specimen mix design of 10:1. For block testing, 99 rectangular blocks (205 x 100 x 50mm); and 33 cylindrical specimens (90mm diameter and 140mm long) were cast for tests of water absorption, compressive strength, flexural strength, split tensile and impact. 5 and 10% of 0.15mm; and 5, 10 and 15% of 0.6mm sieve sizes of sawdust content satisfied the required standard for compressive strength for interlock pavement blocks for non-traffic areas. There was a drop in strength at further increase of sawdust content. Water absorption characteristics of the sawdust-plastic matrix at 5% for 0.15mm size and 5% for 0.6mm sieve sizes increases with increase in sawdust content. Optimum water absorption was observed at 25% sawdust content. The sawdust-plastic matrix at 5% for 0.15mm sieve and 5% for 0.6mm sieve size showed the suitability for potential use of the composite in outdoor flooring. The maximum values for compressive strength and water absorption of these two sieve sizes were 27.03Mpa and 1.40% for 0.15mm sieve size and 32.16Mpa and 2.99% for 0.6mm sieve size respectively which met the requirement for compressive strength and water absorption in accordance with ASTM D1037-93 and ASTM D 5229. The flexural strength characteristics of 0.15mm and 0.6mm sieve sizes at 5-25% met the IS 15658:2006 standard which suggests that the minimum strength of a single paving block should not be less than 4.5Mpa. While 0-5% of 0.15mm sieve size met the standard for tensile strength in accordance to IS 15658:2006 which suggests that the minimum strength should not be less than 2.9Mp.

Keywords: waste plastic, sawdust, recycling, pavement blocks.

1.0 Introduction

The use of plastic materials has increased from 5 million tonnes in the 1950s to 100 million tonnes in the 2000s (Owusu-Sekyere, 2013). In order to reduce these wastes, reuse or recycling of waste plastics into useful products is necessary. Many Government agencies, private organizations and individuals have carried out researches concerning the feasibility, environmental suitability and performance of using waste plastics in the construction field (Mohammed and Afangide, 2018). Reuse or recycle of plastics have its economic importance that can save our world from environmental pollution (Madam et al, 2012). Construction materials from plastics are less susceptible to rotting, have minimum fatigue or thermal cracking and offer great durability (Ashori and Nourbakhsh, 2009). Wood plastic composite is therefore a combination of wood and plastic with the plastic as the matrix and the wood as the reinforcement.

Globally, sawdust waste production is approximately 24.15m^3 million per year and is either burnt or landfilled causing environmental problems such as air pollution, emission of green-house gases (GHG), and occupation of useful land (Dasong and Fan, 2015). Mostly, in rural areas, sawdust wastes are disposed onsite, along banks of streams, rivers, along roadsides or incinerated. The indiscriminate disposal constitute nuisance and breeding spaces for germs and worms, releasing obnoxious, pungent and foul odours and gases such as carbon dioxide (CO_2) and carbon monoxide (CO). This poor disposal constitutes environmental and occupational health hazards to the workers, their customers and the environment (Lasode *et al*, 2011). Plastics are non-biodegradable and can stay as long as 4500 years and they make up 5% of municipal solid waste that are toxic in nature (Chavan, 2013). Waste polyethylene sachet can be seen easily littered everywhere, they are indiscriminately dumped in drainages, gutters, canals and the streets which end up blocking flow of water in drainages thereby causing flooding. It reduces water infiltration into the soil, causes land degradation and makes landfill site to fill up quickly. It is observed that 45-50% of original wood (timber) taken for mechanical processing ended in waste (sawdust wood). This can present a hazard in manufacturing industries, especially in terms of its flammability (AL-Obaidi *et al,* 2015).

In Nigeria concrete mix has been the major material for production of interlock pavement blocks for decades. In a world with a rapidly growing population and declining resources it is necessary to use other alternatives in order to reduce the rate of exploitation of these resources in production of interlock pavements blocks. Economically, recycling of plastic waste is a value addition that is of great urgency due to the increasing amount of plastic generated daily. Composite formation is one of the many ways by which plastic waste can be recycled. Producing composite materials from plastics, water sachet and sawdust via recycling would help Nigeria in contributing to the solving of the plastic waste problem. Therefore, the study aims to explore an alternative material to conventional concrete for the production of interlock pavement blocks by recycling via a plastic-sawdust matrix. It is hoped that this alternative would supplement the conventional material.

2. Materials and Methods

2.1 Materials

The waste plastic used was polyethylene water sachet (PWS) obtained from "U. I. Water Enterprise" a packaged water producing organisation of the University of Ibadan, Ibadan. The PWS **is a waste water sachet plastic made from low density polyethylene (LDPE). The waste plastic is littered everywhere, disposed indiscriminately and combusted openly in the environment both in the University campus and Ibadan metropolis.**

The sawdust used in the research was from mahogany (hardwood), obtained from Sango Sawmill, Ibadan. It was sun-dried for 12hour to remove the moisture, untreated and sieved into two sizes of 0.15mm and 0.6mm before being used in the research.

The equipment used were a furnace (for melting of the plastic at 200ºC to 300ºC); an open-tong (for holding the crucible from the furnace and for easy pouring of the melted waste into a mould); a stirrer (for stirring of the composite); a compressive strength testing machine; and a small quantity of spent-engine oil (used as a lubricant for easy demoulding and to avoid the melted polymer from sticking to the surface of the mould).

2.2 Sieve Analysis of Sawdust

The procedure adopted for sieving was from ASTM C 136. The sawdust was oven dried at 105°C for 12hrs. The dried sawdust was sieved using Standard Sieves of apertures 19, 13.2, 9.5, 2.36, 0.6 and 0.15mm. At the base was a receiver. 500g of sawdust was placed on the top sieve and was manually shaken continuously for 10mins. The material on each sieve was weighed and then divided by the total weight to get the percentage retained on each sieve. The following equation was used:

$$\% \, retained = \frac{M2 - M1}{Total\ weight} \times 100 \quad (1)$$

where M_2 = weight of sieve + sample; and M_1 = weight of sieve.

2.2 Mix Design

After melting the polyethylene waste sachet (PWS) at temperatures between 200ºC to 300ºC, several trial mixes were carried out and tested for both physical and mechanical properties. In accordance with the ASTM D-1037: 1999, all specimens were carefully prepared and tested to evaluate a suitable mix ratio for the physical and mechanical properties of each type of WPCs. Six treatments of two different sieve sizes of 0.15mm and 0.6mm were carried out on the basis of percentage addition of untreated sawdust content (at 0%, 5%, 10%, 15%, 20% and 25%). A constant (2.5kg) polyethylene waste sachet was maintained for the mixing in all treatments. The total weight of plastic used was 300kg, while that of sawdust is 30kg. A total of 132 block samples were produced.

2.3 Preparation of the Composite Material Sample

A total of 99 rectangular block samples and 33 cylindrical wood-plastic composite (WPC) were cast for investigations. The rectangular samples were of dimensions 205mm x 100mm x 50mm while the cylinders were 90mm in diameter and 140mm long. The melting process was done using a local furnace and manual mixing was employed. The plastic was added continuously and stirred in the furnace. After full melting of the plastic, required percentage of untreated sawdust content was added to the melted plastic and stirred thoroughly for five minutes to achieve homogeneity. After the thorough mixing, the composite was poured into the mould and compacted manually. The internal surface of the mould was earlier lubricated with spent engine oil for easy removal of the moulded specimens. A steel hand trowel and scrapper were used to level the top surface. The cast specimens were demoulded after one hour.

2.4 Testing of Specimens

2.4.1 Compressive strength test

A total of 33 WPC rectangular interlock pavement block specimens were cast for the test. The dimension of the specimen was 205mm × 100mm × 50mm. A universal testing machine in accordance to ASTM D 1037–93 was used for determining the compressive. The compressive strength is reported to the nearest one decimal place.

2.4.2 Flexural strength test

A total of 33 WPC rectangular interlock pavement block specimens were cast for the test. The flexural strength was performed according to ASTM D790-03 procedure. A two-point set up was used to determine the flexural strength using a universal testing machine to perform this test. The jig used was a single loading type, and a plate with two rollers was placed under the single loading point to create a two-point loading. Three tests were carried out for each specimen and an average result was recorded. The dimensions of each test specimen were 205mm × 100mm × 50mm. The length of support span was 13mm and the loading nose had a radius of 6.5mm. The Flexural yield was estimated by the following equation.

$$F_{cf} = \frac{Fl}{bd^2} \quad (2)$$

where F is the breaking load (N); l is the distance between the supporting rollers (mm); b is the breath of the lateral cross section (mm); and d^2 is the thickness (mm).

2.4.3 Splitting tensile strength test

Splitting tensile strength test on the WPC cylinder is a method to determine the tensile strength of WPC. The procedure is based on the ASTM C496 (Standard Test Method of Cylindrical Concrete Specimen) which is similar to other codes like IS 5816: 1999. The specimens were loaded centrally along their length until failure was recorded. Loading was applied in constant rate in the Universal Testing Machine. The splitting tensile strength of each specimen was determined using:

$$F_{ct} = \frac{2F}{\pi LD} \tag{3}$$

where F_{ct} is the splitting tensile strength, (N/mm^2); F is the maximum load (N); L is the length of the specimen (mm); and D is the diameter of the specimen (mm).

2.4.4 Impact strength test

A total of 22 specimen blocks of 205mm x 100mm x 50mm were cast for the test. The weight of hammer used was 4.5kg. The specimen was placed centrally on the impact tester and the hammer was attached to the impact tester. The process uses a drop weight test, with specimens subjected to a progressive distance and single impact load from a guided free falling weight or striker dropped in a vertical direction. The drop weight determines the maximum distance at which the specimen breaks. Impact strength of each specimen was determined using:

$$Impact = \frac{F \times D}{B \times W} \tag{4}$$

where $F =$ Ma; M is the mass (Kg); a is the acceleration due to free fall (m/s;) D is the distance of the hammer (mm); B is the breadth (mm); and W is the thickness (mm).

2.4.5 Water absorption test

Eleven specimens (205mm x 100mm x 50mm) from each mix were used for this test. The moisture absorption of the composite specimen was carried out in accordance with ASTM D 5229 standard by dipping the specimen in a tank of water and determining the water uptake as a function of time at room temperature of 25^{o}C until the moisture equilibrium content was reached. A digital weighing balance was used for the measurement. The initial weight of each specimen was measured and recorded. The specimens were immersed in water at room temperature for 24hrs. The specimens were removed from the water and a clean cloth was used to wipe the excess water on the specimen-surface and the weight measured. The specimens were measured at 30mins interval in the 24hrs of soaking. The increase in weight of the specimens were calculated using the formula:

$$W = \frac{\text{Final weight} - \text{Original weight}}{\text{Original weight}} \times 100 \tag{5}$$

3.0 Results and Discussion

3.1 Material Analysis

The particle size analysis is shown in grain size distribution, Figure 1, indicating poorly graded particle. The result show that 0.6mm sieve size had the highest retained sawdust particle followed by 0.15mm sieve size. This sieve brought out substantial particles that were smooth enough to form the composite. The particles with a sieve size of 0.15mm had a very smooth feel. From literature, particle sizes affect the adhesion between the matrix and the filler as reported by Azad and Tajvidi, 2009.

3.2 Water Absorption

The water absorption values for 0.15mm and 0.6mm sieve sizes of sawdust had maximum values of 5.5% and 6.41% at 25% sawdust content of the WPC respectively. Figures. 2 and 3 illustrates the water absorption (WA) of the Sawdust-PWS composites based on various sawdust content after 30mins and 24hrs of immersion in water. The WA of the composites increased with an increase in sawdust content. These results are mainly attributed to the hydrophilic nature of wood. Wood is a hydrophilic porous composite which consists of cellulose, lignin and hemicellulose. For this reason, the WPCs have the potentiality to uptake water under humid condition (Adhikary *et al*, 2008). These results align with IS: 15658:2006 which state that water absorption of individual concrete paving block should be less than 7%. Similar results for increasing patterns of WA were reported by Chen et al, 2006 for WPCs made from HDPE and recycled wood particles. Water can be absorbed by WPC due to the hygroscopic nature of natural fillers and also through the gaps and flaws at the interface between sawdust and plastic (Mosadeghzad *et al*, 2009).

3.3 Compressive Strength Test

The results of the compressive strength tests for wood plastic composite (WPC) treatments are shown in Figures 4 and 5. The specimens with 5% of both 0.15mm and 0.6mm sieve sizes of sawdust content have the highest strength of 27.03Mpa and 32.16Mpa respectively followed by 10% which had strength of 25.36Mpa and 28.48Mpa respectively while 20% and 25% of sawdust content showed the lowest strength of 15.32Mpa and 16.14Mpa respectively. The compressive strength decreases significantly with increasing sawdust content of 5% to 25%. The corresponding increments were 5, 10, 15, 20 and 25% respectively. The reduction in strength aligns with the study of Ashori and Nourbakhsh (2009) which reported that as the percentage loading of sawdust increases, the weak interfacial area between the filler and the matrix increased which consequently decreased the strength of the composite. Therefore, there is decreasing trend with increasing filler content in the composite.

The WPCs containing 5 and 10% of 0.15 mm and 5, 10 and 15% of 0.6mm sawdust content gave strength values above 25Mpa which falls within the BS 6717:1986 for non-traffic weight areas for interlock pavement blocks. This suggests that increase in sawdust content has an effect on the compressive strength of WPCs for interlock pavement blocks.

3.4 Flexural Strength Test

The results of the flexural strength test on the specimens are shown in Figs. 7- 9. For specimen with 0% sawdust, F_{cf} was 7.035N/m^2. The flexural strength showed a slightly deceasing value with increase in sawdust content. There was a rise in strength at 5% for 0.15mm sieve size sawdust content with the highest value of 7.24N/mm^2 while 5% for 0.6mm sieve size sawdust content was 6.71Mpa. The flexural strength for 0.15mm sieve size was higher than the 0.6mm sieve size at 5% combination and above. According to Klyosov, 2007 the International Code Council can pass a material for construction if it has a flexural strength of 0.012Mpa. The flexural strength of the WPC aligns with IS 15658:2006, which suggest that the minimum flexural strength of a single paving block should not be less than 4.5Mpa.

3.5 Splitting Tensile Strength

The results of the splitting tensile strength test of the cylindrical specimens are shown in Figures. 10 - 12. The splitting tensile strength for WPC with 0% sawdust content was 3.056N/mm^2. The results shows WPC of 0% with the highest splitting tensile strength of 3.056Mpa within the bounds of these experimental considerations. The splitting tensile strength at 0% and 5% with 0.15 mm sieve size of sawdust aligns with the tensile strength of paving blocks as stipulated in IS 15658:2006 which reports that the tensile strength of interlock paving blocks should not be less than 2.9Mpa.

3.6 Impact Strength

The results of the Impact strength specimens are shown in Figures 13- 15. The impact strength for WPC with 0% sawdust content is 10.17N/mm^2. The results show that WPCs containing 5% of 0.15mm sieve size of sawdust had the highest impact strength of 10.40Mpa while there was a slight decrease in strength as the percentage of sawdust content increased in 0.15mm and 0.6mm sieve sizes from 5% to 25%. This study aligns with Khalil et al, 2006 which reported that the voids and micro cracks in the WPC also contribute to the decrease of impact strength.

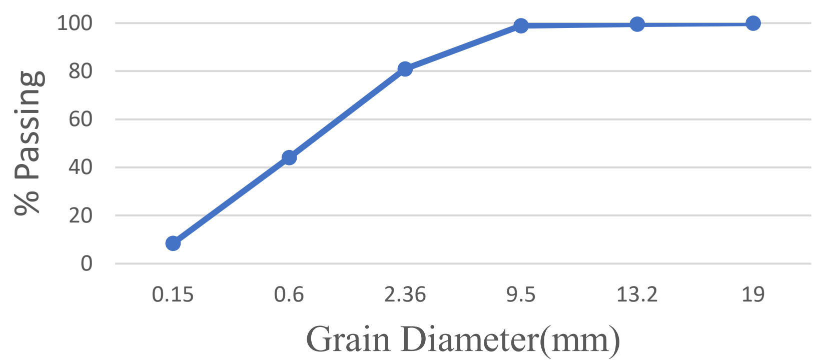

Fig 1: Grain size analysis of untreated sawdust

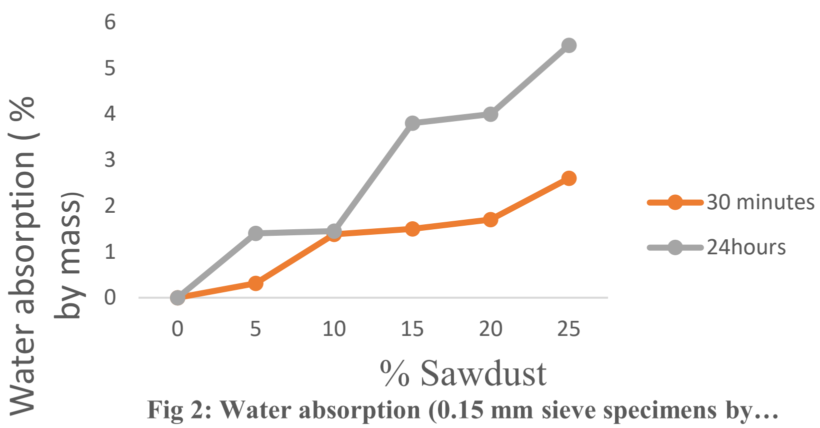

Fig 2: Water absorption (0.15 mm sieve specimens by…

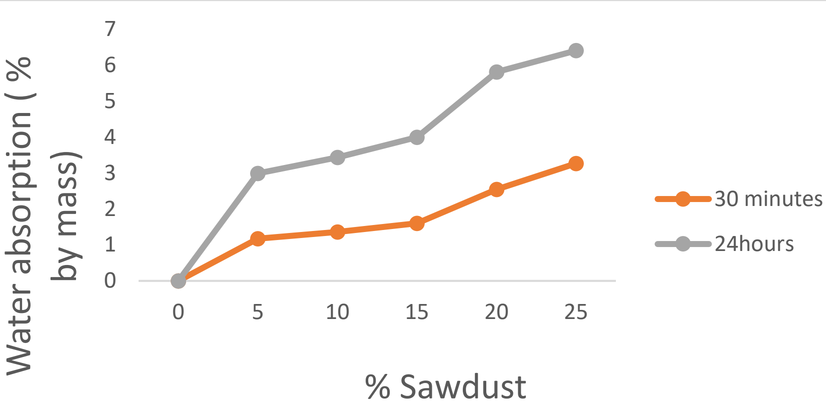

Fig 3: Water absorption (0.6 mm sieve specimens by…

Fig 4: Average Compressive Strength of 0.15 mm sieve size.

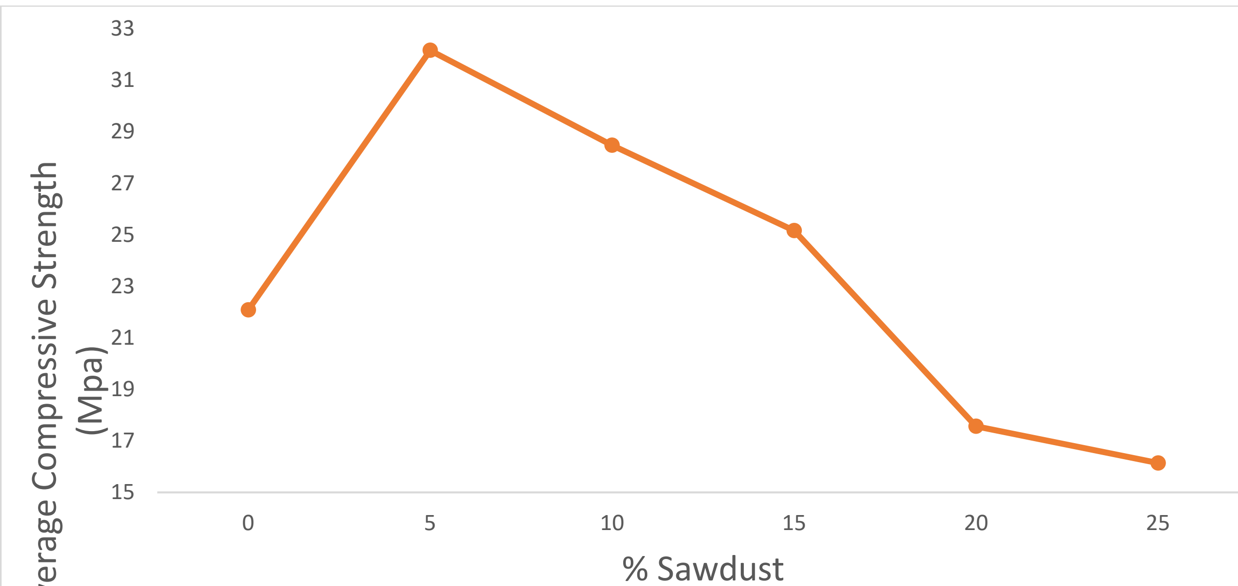

Fig. 5: Average Compressive Strength of 0.6 mm sieve size.

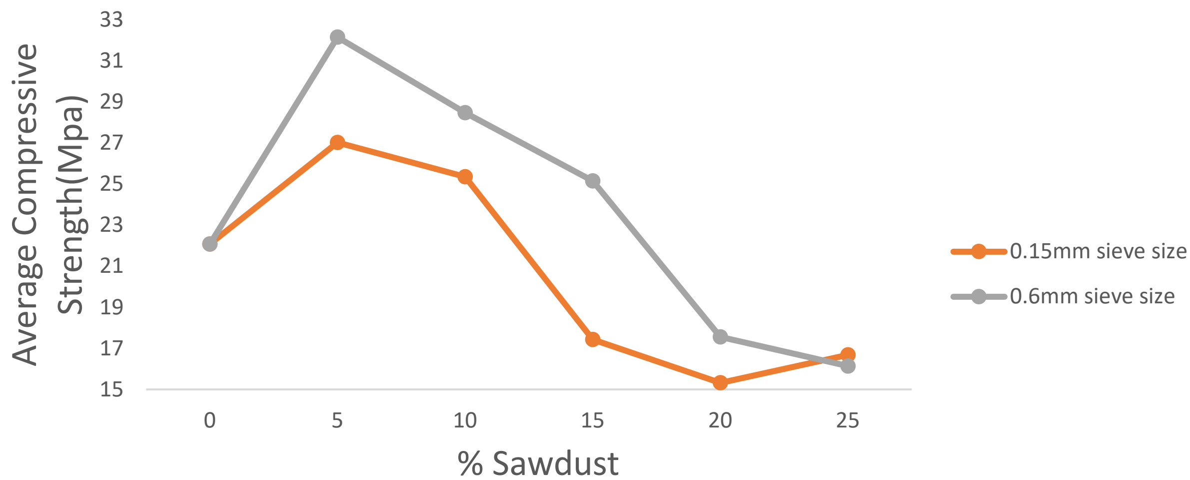

Fig. 6: Average Compressive Strength of 0.15mm and 0.6mm sieve sizes.

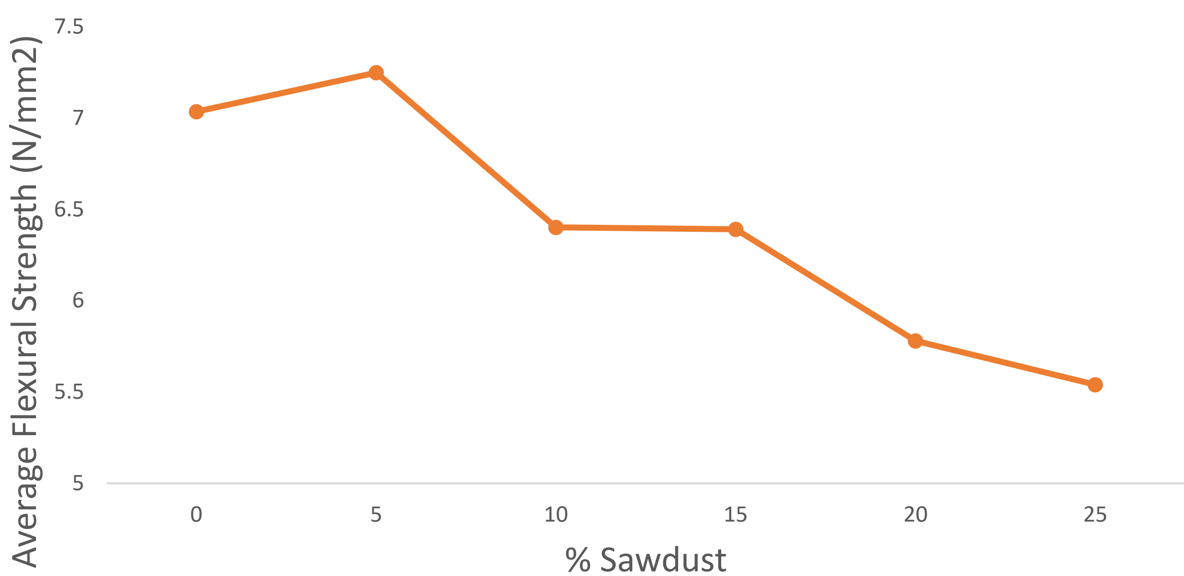

Fig. 7: Average Flexural Strength of 0.15 mm sieve size

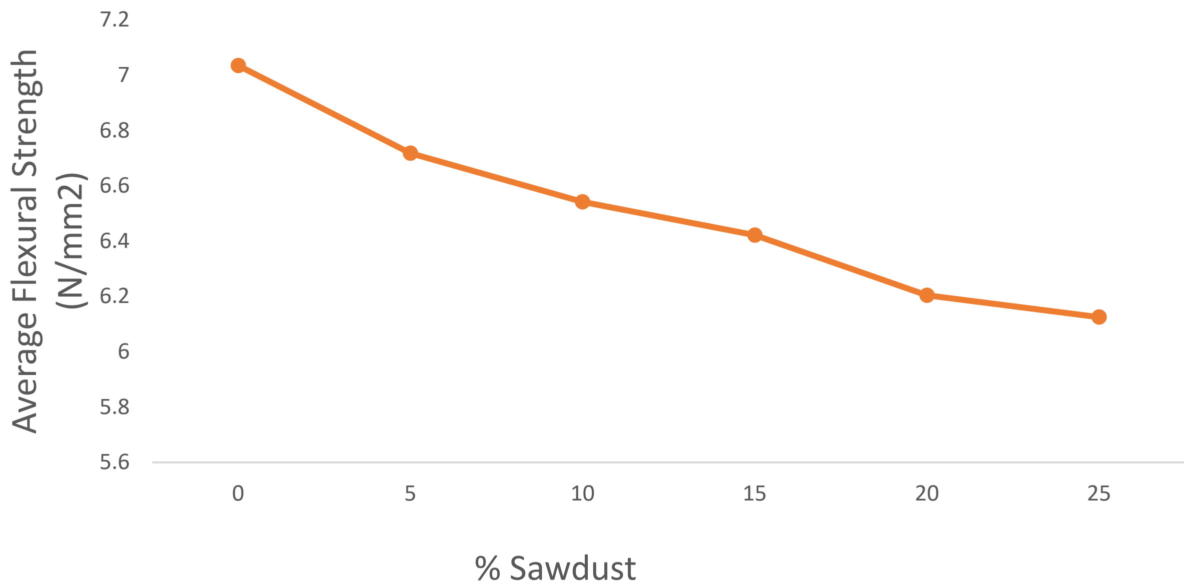

Fig 8: Average Flexural Strength of 0.6 mm sieve size

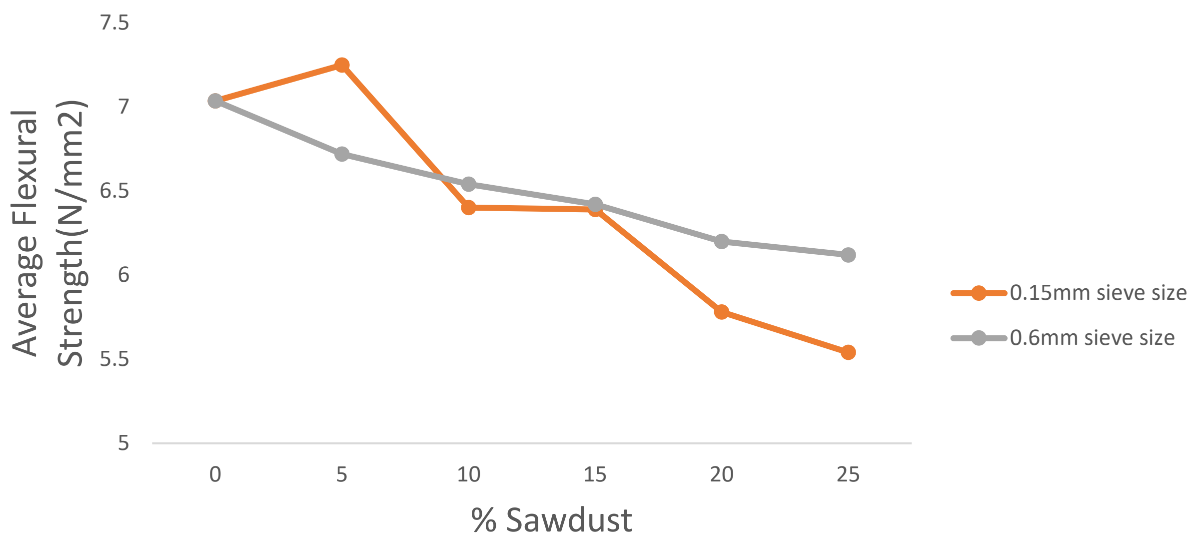

Fig. 9: Average Flexural Strength of 0.15 mm and 0.6 mm sieve sizes.

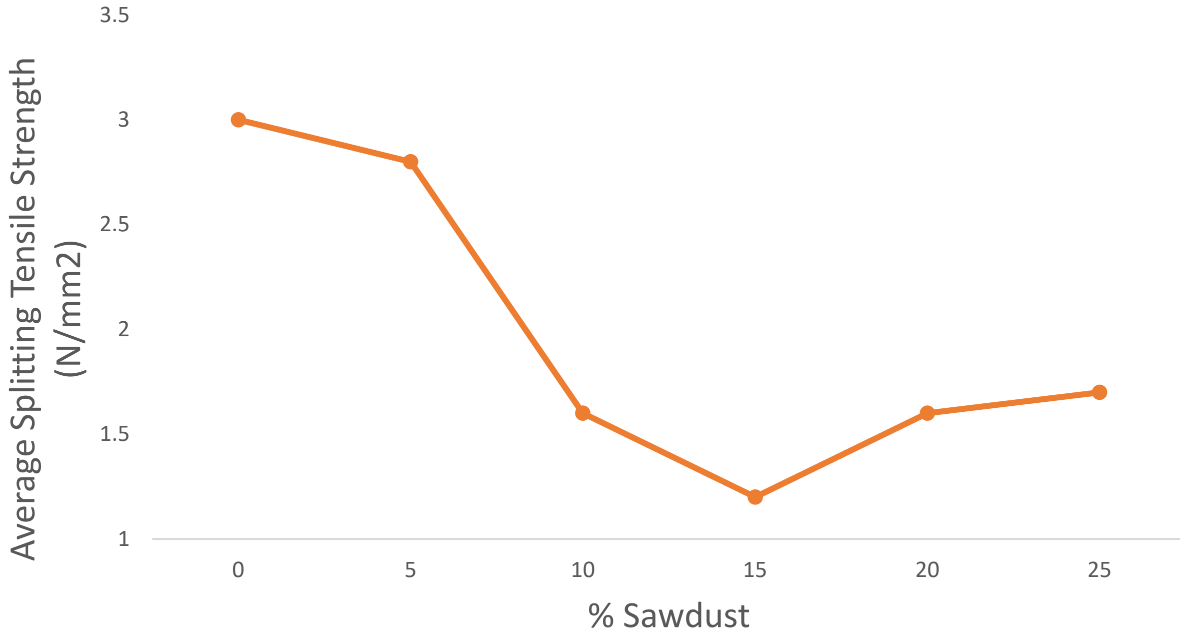

Fig. 10: Average Splitting Tensile Strength of 0.15 mm sieve size.

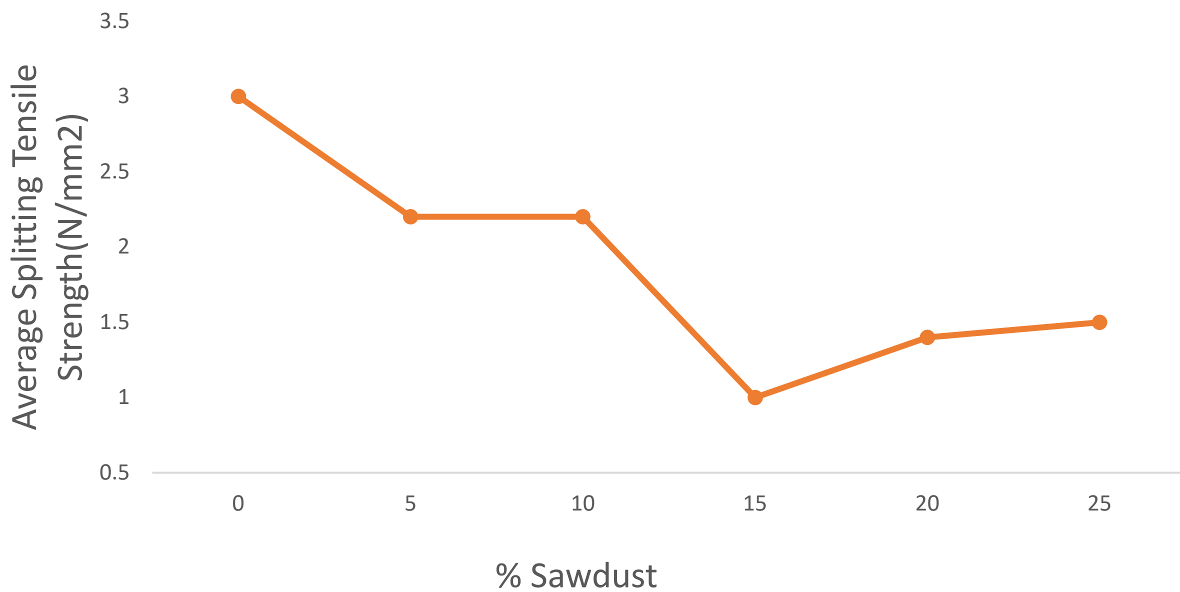

Fig. 11: Average Splitting Tensile Strength of 0.6 mm sieve size.

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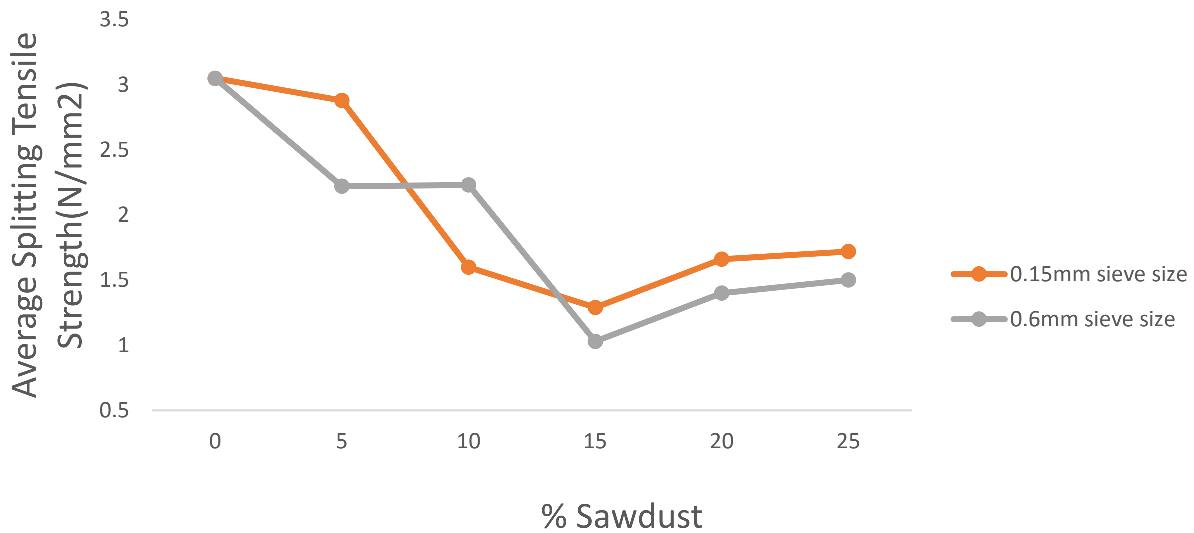

Fig. 12: Average Splitting Tensile Strength of 0.15 mm and 0.6 mm sieve sizes.

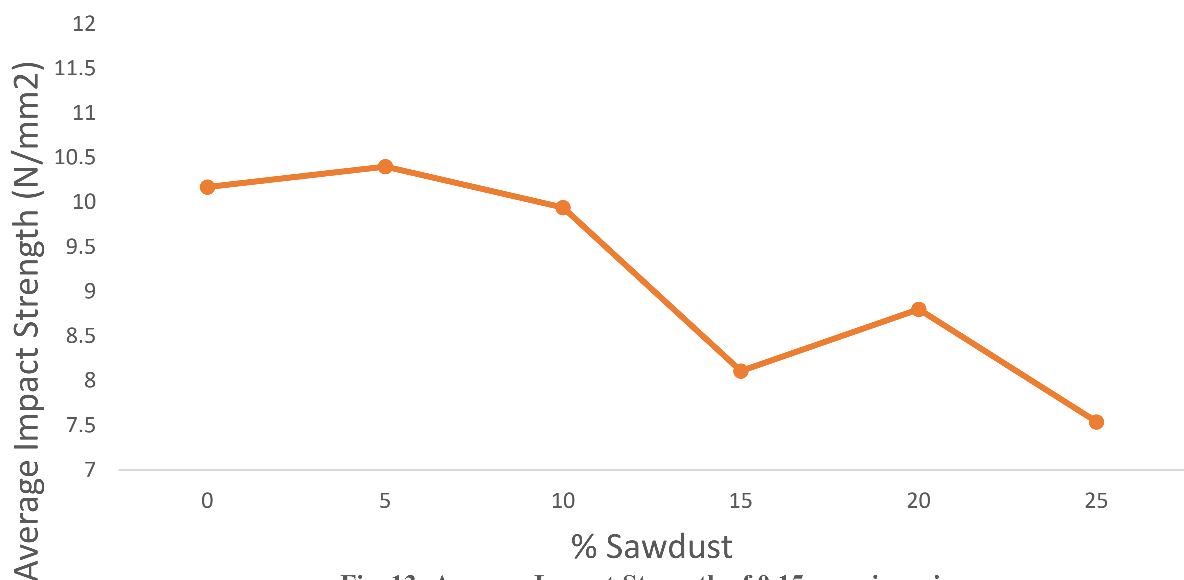

Fig. 13: Average Impact Strength of 0.15 mm sieve size

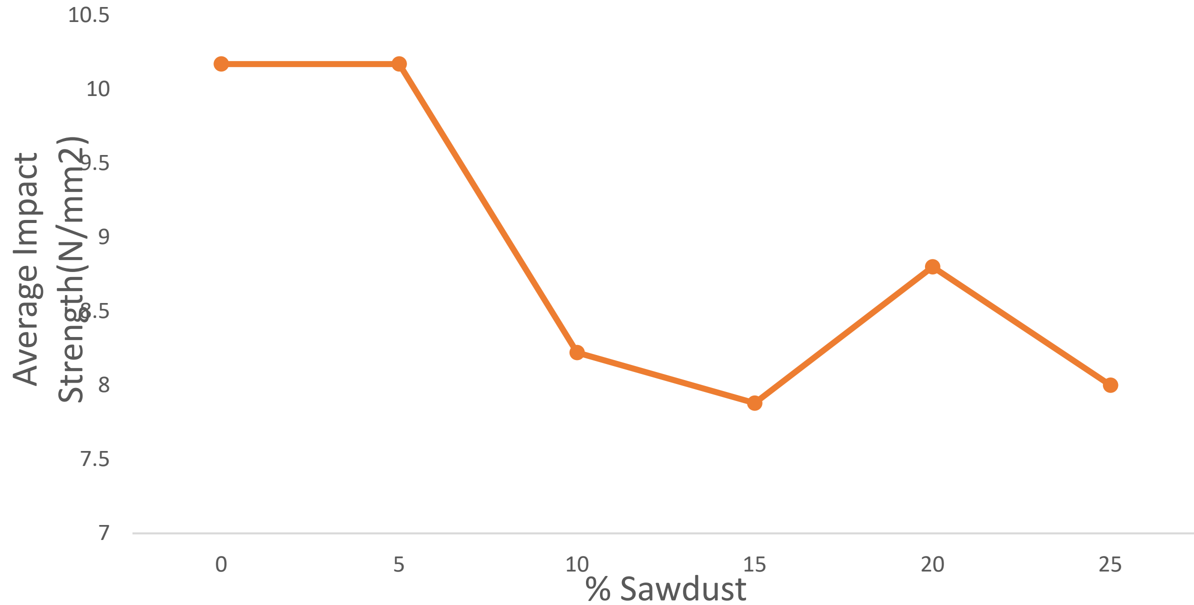

Fig. 14: Average Impact Strength of 0.6 mm sieve size

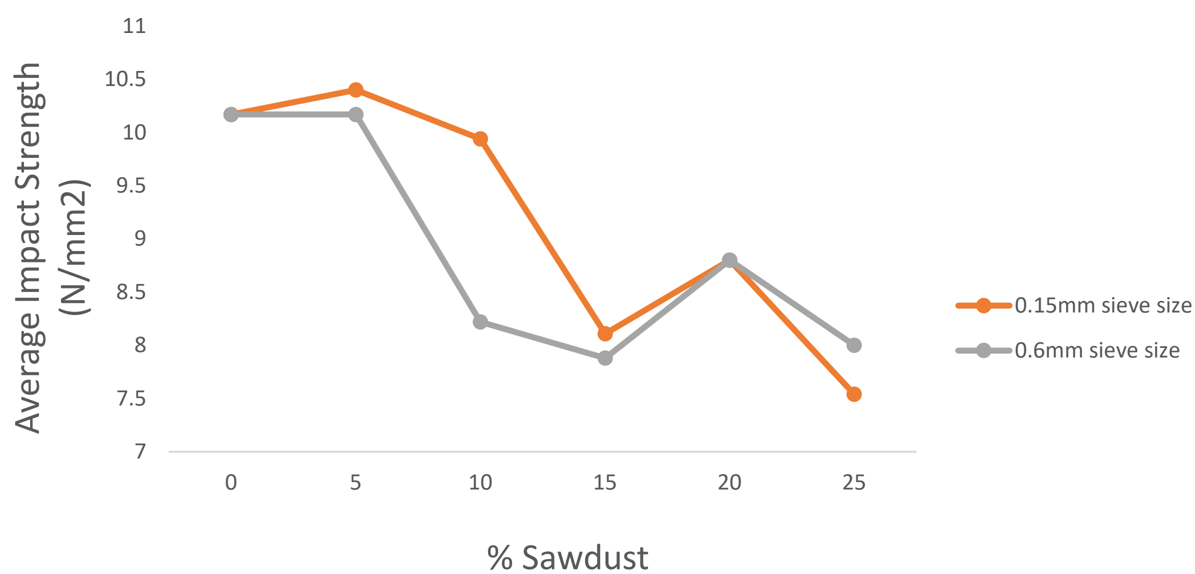

Fig. 15: Average Impact Strength of 0.15 mm and 0.6 mm sieve sizes.

4. Conclusions

The following conclusions can be drawn from the study of the produced composite interlock pavement blocks:

1. The water absorption characteristics of WPC increases with addition of sawdust content from 5 to 20% for both 0.15mm and 0.6mm sieve sizes.
2. The compressive strength of WPC tends to increase with more addition of plastic and decreases with increase in sawdust content. 5 - 25% of sawdust showed a decrease in strength for both sieve sizes while

5 - 10% and 10 - 15% of the 0.15mm and 0.6mm sieve sizes attained the required maximum strength standard for interlock blocks for non-traffic areas.

3. The flexural strength of sawdust–polyethylene waste sachet treatments decreased from 5 to 25% for both 0.15mm and 0.6mm sieves of sawdust addition while increase in plastic increased the flexural strength in the composites.
4. The splitting tensile strength decreased with increase in sawdust content for both 0.15mm and 0.6mm sieve sizes. 0 to 5% addition of sawdust into plastic gave the highest splitting tensile strength in the composites.
5. Impact strength of the composites tended to decrease with addition of sawdust. The 0.15mm sieve size recorded the highest impact strength in the composites.

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INDIGENOUS TECHNOLOGY REVOLUTION AS A PANACEA TO POST COVID-19 ECONOMIC RECESSION IN NIGERIA

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Abstract

This paper examines indigenous technology revolution as a panacea to economic recession in and post COVID-19 in Nigeria. The existing state and position of the indigenous technology transformation vis-a-vis its capacity in pulling a dwindling economy out of recession during and after COVID-19 were looked into. The current inflation rate and causes of economy recession in Nigeria was highlighted, and consumer price spike from the year 2015 to 2020 of some common domestic commodities were evaluated. The paper crowned it all by suggesting "technological revolution" strategies in mitigating the effects of economic recession in Nigeria during and after the novel global pandemic (COVID-19) era.

Keywords: Indigenous technology revolution, economic recession, global pandemic, COVID-19, Nigeria.

1. Introduction

Technological revolution (transformation) is considered to be one of the key driving force in the development of any economy (Park, Ali and Chevalier, 2011). According to Onipede, (2010), "Engineering and technological development are generally regarded as catalyst for national development because they offer among other things the necessary support for change in all the major sectors of the economy." But in recent times, claims and counter claims have been made on the best avenue to drive the country out of the current economic woes. The current economic ulcer bedeviling the nation currently call for serious concern by the economy handlers; especially, after the post Corona Virus 2019 (COVID-19) era. Recession is a term in economics that no nation want to be associated with because of the inability to manage it properly may lead to depression and frustration which is not good for any country. Recently, Nigeria Minister of Finance, Budget and National Planning (by de facto Minister of Economy), Zainab Shamuna Ahmed has warned Nigerians that the country's economy is driving gradually into recession due to the national lockdown caused by the global pandemic (COVID-19).

In view of the struggles by the handlers/managers of the economy of the country, on finding better ways to get out of this economic downturn; technological revolution is seen as a panacea to this economy ulcer that has held the economy by the jugulars. The narratives seem to have shifted to the economic diversification of the economy to the non-oil sectors. These non-oil sectors include a leap into the agricultural sector, the solid minerals, and other extractive sectors (excluding oil and gas), ICT etc. While the list seems in-exhaustive, we believe that no meaningful impact will be achieved if they are not technologically driven modus operandi. Consequently, the impact of "indigenous technology revolution" as a panacea to post-COVID-19 economic recession in Nigeria presently cannot be overemphasized.

2. Economic Recession in Nigeria

2.1 Conceptual Issues

Economic recession is a time of economic slowdown offering low output, liquidity and unemployment (Fapohunda, 2012) as witnessed currently in Nigeria. It is characterized by its length, abnormal increases in unemployment, falls in the availability of credit, shrinking output and investment, numerous bankruptcies, reduced amounts of trade and commerce, as well as highly volatile relative currency value fluctuations, mostly devaluations, financial crises and bank failure (Fapohunda, 2012). Also, according to Bureau of Economic Research (NBER), economic recession is defined as a "significant decrease in economic activity spread across the economy, lasting more than a few months, normally visible in a real gross domestic product (GDP), real income, employment, industrial production and whole-retail sales. "Recently, many organization especially the private sector began laying off staff due to the national lockdown. The economy of the country (Nigeria) is being shock by the COVID-19 pandemic and the sharp fall in the international market oil price. The rapid outbreak of COVID-19 poses a serious alarming health crisis and socioeconomic problems to the world at large, which Nigeria is not an exception. In fact, 94% of the Fortune 1000 across the globe, and businesses in Nigeria have been impacted and are already seeing COVID-19 disruptions (KPMG, 2020). A typical example according to online publication by Urowayino (2020), American University of Nigeria, Yola, has laid off four hundred (400) staff of the organization. Recently, Ereyitomi Thomas, a member representing Warri Federal Constituency from Delta State at the National Assembly condemned the sack of over three hundred (300) casual/back up staff of the Warri Refining and Petrochemical Company (WRPC)by Management (Urowayino, 2020), while other organizations were threatening to lay off staff if the lockdown continue.

The major cause of economic recession in any economy (lesson from great depression, 1981, 1991, 2004, 2008 - 2009 economic recession) may include but not limited to (Noko, 2016):

i. High inflation, general rise in price of goods and services-leading to low purchasing power
ii. Accumulation debt servicing especially foreign debt
iii. High interest rate-discouraging investor
iv. Fall in aggregate demand, fall in wages and income
v. Mass unemployment and general loss of confidence on the government due to economic indices

2.2 Causes of Economic Recession in Nigeria

The economic downturn of a country can be caused by various factors but the following are the major causes of economic downturn (recession) in Nigeria:

1. Crash of Stock: The sudden loss of confidence by investors can create over bearing burden on the market, because investors will start draining or withdrawing capital out of businesses.

2. Poor Management: poor managers and economy handlers causes bad business practices which often lead to economy recession. Savings and loans balancing is of a paramount importance in an economy or else it may cause economic crisis like 1990 economic recession.

3. Loss of Confidence in Investment and Economy**:** the loss of confidence of investors and consumers in an economy will cause them to stop investing in an economy and also, stop buying which will make they move into defensive mode.

4. Falling of Housing Prices and Sales**:** this is one of the major factor that cause home owners to lose equity, “they may be forced to cut back spending as they can no longer take out second mortgages. This was the initial trigger that set of the Great Recession in2008 (Federal Deposit Insurance Corporation, 2020)

5. Poor Economic Planning**:** poor economic planning and no concrete implementation of her economic planning is the major cause of Nigeria's current recession – budget delay, exchange rate policy. Yes, the government has proclaimed the usual generalities that every government indulges itself in about diversifying the economy, improving manufacturing/mining sector,

Raising agricultural output, encouraging foreign investment, among others, yet no concrete evidence of strategic plan for growth. No doubt, the government has taken some steps like the elimination of dollar purchase privileges for importers of 40 items such as – rice, cement, toothpicks, private planes, poultry, meats, margarine, wheelbarrows, textiles, and soaps. The government has, on the other hand, caused serious poverty in the land by herself. Let me explain, the government through her policy, widened the gap between the rich and poor – creating more economic hardship. For instance, when the CBN (Central Bank of Nigeria) was selling dollars at ₦197 and people were buying at ₦300, the highly placed individuals in the country were putting calls across the banking industry to get dollar at the official rate. This they later resell at the parallel market rate of ₦300. Think of how much some of them were making. An individual can make as much as 1billion naira without doing anything according to the former CBN governor (Sanusi Lamido Sanusi). The people that were profiting from this were people that were telling the government that if it didn't devalue the Naira people would suffer. The poor paid the price of a devalued currency and the rich schemed off the profits. For example, should you take dollars, for every $1 billion taken from the Federation Account and sold by the CBN at ₦200 to the dollar, the states were losing ₦100 billion that could have gone into salaries, agriculture, healthcare? Yet, the states were going to borrow from the same government on a bailout when the government was selling dollars cheaply to a small group of people. This incidence is still ongoing and the government is doing nothing about it.

6. High Inflation Rate (Fapohunda, 2012)**:** Governments banning the importation of certain essential agricultural products like rice without considering gestation period it is a great error. Removal of fuel subsidy shouldn't be simultaneous with the banning of these agricultural products. Major Causes of inflation: speculation in stock market due to budget delay, rise in oil price, almost the household items price skyrockets before, during and it also be in post COVID-19 era as seen in the Table 1 below.

Table 1: Consumer Prices Spike from year 2015 to 2020.

Description of Commodity	May 2015 (₦)	May 2016 (₦)	May 2017 (₦)	May 2018 (₦)	May 2019 (₦)	May 2020 (₦)	Price Elasticity
Tomato (Basket)	12,000.00	15,000.00	22,000.00	28,000.00	32,000.00	45,000.00	Low
Pepper (50kg)	25,000.00	30,000.00	37,500.00	42,500.00	45,000.00	52,500.00	Low
Garri (50kg)	8,000.00	10,000.00	11,000.00	11,500.00	12,000.00	15,000.00	Moderate
Foreign Rice (50kg)	9,000.00	14,500.00	16,000.00	17,500.00	19,500.00	29,500.00	Low
Local Rice (50kg)	5,000.00	7,000.00	8,500.00	9,000.00	12,000.00	22,000.00	Low
Beans (50kg)	15,000.00	16,000.00	16,000.00	16,500.00	17,500.00	18,000.00	Low
Onion (Big Sack Bag)	8,000.00	10,000.00	15,000.00	20,000.00	24,000.00	30,000.00	Low

Nigeria inflation rate currently stands at 18.63% that is extremely high; the highest for past last decades (Noko, 2016).

7. High-Interest Rate: Interest rate is between 26.77-27% is extremely high for investors. This high interest rate is discouraging investors. The poor investment culminates into high rate of unemployment in the country (Noko, 2016).

8. High Taxation: It is only in Nigeria that I see government charging high tax rates during economic recession. Small businesses are slaughtered with high interest rate. Both high interest and tax rate has lowered Nigeria aggregate demand (Noko, 2016).

9. Policy Conflict: The economic policies appears conflicting. How? High-interest rate, high tax rate are tight monetary policy measures. But government told the public it is adopting expansionary policy – budget deficit (Noko, 2016).

"It should be noted that the fall in oil price and production is not the major cause of Nigeria economic recession. Yes! Oil only account for 15% of Nigeria GDP. And an economic recession is measured on the basis of GDP growth and some other economic performance indicators" (Noko, 2016).

2.3 Impacts of Recession on Nigeria Economy

Prior to the impact of the meltdown in Nigeria, the banking sector was swimming in a pond of false confidence in the financial policies (Fapohunda, 2012). This affected the economy of the country. "There was a crash in the stock market, the prices of oil sky rocketed and left many financial homes depressed with the fear of an impending crunch. The crash affected the economy. It reduced the ability of the economy to fight off the underlying sicknesses of unevenly distributed wealth, agricultural depression, and banking problems. With the crash, it was apparent that the Nigerian economy faces the crippling effects of global economic crises resulting to breakdown and decline in economic vigour" (Fapohunda, 2012).Opeyemi (2008) observes that there are cases of unemployment, retrenchments, downsizing and layoffs, which served as indications to a troubled economy. According to her "What is worse is that individuals have nowhere to turn to…" except indulging in misconduct and societal condemned activities such as militancy, armed robbery, advanced fee fraud, ritual practices for fetish money among other things and our leaders sit almost helpless. In her words, "there have become a wide spread of distrust in the competency of the financial sector as the question of fund availability in banks pervades the minds of right thinking Nigerians."

The International Labour Organization (ILO) recently revealed that as many as 51 million workers were fired in 2010 globally, while 30 million more jobs are at risk (Fapohunda, 2012). The United Nations, meanwhile, predicts that 200 million workers mostly in developing economies could be pushed into extreme poverty(Fapohunda, 2012). The global unemployment rate is estimated at 7.5 percent in 2010, up from 6.5 percent in 2009 and 6.7 percent in 2008 (Fapohunda, 2012). This implies that the global economic recession is already resulting in a dramatic increase in the number of people joining the labour market and swelling the rank of the unemployed, creating a "labour market epidemic." Downsizing was also a result of the recession. There have been layoffs, downsizing, and retrenchmentsof staff in Nigeria (Fapohunda, 2012).

The research findings by Fapohunda (2012) has equally reviewed there is increase restiveness on the part of the labour union and this has led to most of the times, an increase in industrial action. Another very serious impact of this scourge is the effect of high indebtedness to internal contractors. The payment of pension might become a huge source of worry because of dwindling finances to meet up with statutory financial obligations of recurrent expenditure. Recession affects social life in some respects, from tourism to certain consumption of household(Central Bank of Nigeria, 2012). According to Zagat's (2009), U.S. Hotels, Resorts & Spas survey, business travel has decreased in the past year as a result of the recession. Thirtyper cent (30%) of travellers surveyed stated they travelled less for business today while only 21 per cent stated that they travelled more. Reasons for the decline in business travel include company travel policy changes, dwindled personal economic fortune, uncertainties and high airline prices (Central Bank of Nigeria, 2012). Hotels were responding to the downturn by dropping rates, ramping up promotions and negotiating deals for both business travellers and tourists (Central Bank of Nigeria, 2012).According to the World Tourism Organization (2008), international travels suffered a strong slowdown beginning in June 2008, and this declining trend intensified during 2009. This resulted in a reduction from 922 million international tourist arrivals in 2008 to 880 million visitors in 2009, representing a worldwide decline of 4 percent, and an estimated 6 per cent decline in international tourism receipts (Central Bank of Nigeria, 2012).

4. Contemporary Status of Indigenous Technology in Nigeria

In spite of Nigeria and her counterpart African countries being blessed with abundant human and material resources, its populace continue to face series of developmental challenges. One of the dominant challenges is the poor state of its indigenous engineering and technology. Africa contributes only 2% of the total industrial output of the world's market economies (Okorafor, 2014). In Nigeria, this is essentially a reflection of the poor level of technology in terms of the obsolete nature of tools used in most of its farming, mining and other productive activities (Akpojedje and Ighodaro, 2020). It is regrettable that despite the number of research institutions (Universities, Polytechnics, etc.) in the country, it still heavily depend on imported machines, spare parts and other technical needs. A nation is technologically backward and in bad shape if (Akpojedje and Abu, 2016):

i. It is unable to produce her own military hardware with which to defend herself, if the need arise;
ii. It depends on other countries for the supply of spare parts for industrial machineries;
iii. It is unable to explore and export her natural resources except with the help of expatriates (foreigners);
iv. It cannot produce capital goods such as tractors, lathe machines, milling machines, drillings, cars, trains and other earth moving equipment; and
v. It exports her raw materials to other nations as against finished product.

According to Akpojedje, et al. (2017), Nigeria at present is a consuming nation and not a producing nation. It has been turned to a dumping ground where all manner of engineering and technological production are being dumped for usage. Ever since the existence of the country, it heavily rely on foreign technological inputs to drive its economy. The country still depend on the machines and some consumables that are manufactured in the developed and industrialized nations. The dependent on foreign engineering and technology was much felt in Nigeria at the beginning of the COVID-19 pandemic, when it was still regarded as an epidemic in China by the World Health Organization (W.H.O) there was a distortion in the supply of finished commodities from China. Consequently, the prices of most capital goods (mostly machines and its spare parts) went up in Nigeria. Besides, when the COVID-19 was declared a pandemic by the W.H.O it resulted to a stoppage in the supply of machines, spare parts and other consumables from the industrialized nations; mostly China to Nigeria. This was accentuated in the COVID-19 pandemic where drugs, surgical face mask, medical ventilator among others were inadequate in the country because there was a halt in their production in the developed nations. The state of indigenous engineering and technology has become worrisome as are being undertaken by the Chinese engineering and technology. Consequently, the Nigerian technology and economy survival are still subject to foreign dictates. "There is no shortcut to maturity and in my view, Africa should be recolonized because Africans are still under slavery" (Trump, 2016). In totality, all these make Nigeria to still be facing a debacle syndrome of "technological colonization."

5. Technology Revolution

Technological transformation is a key factor for driving any nation's economy since it represents the change of technical know-how of the people. Consequently, "technology revolution is, in general, a relatively short period in history when one technology (or better a set of technologies) is replaced by another technology (or by the set of technologies)." According to Bostroam (2006), we might define a technological revolution as a dramatic change brought about relatively quickly by the introduction of some new technology." It is an era of an accelerated technological progress characterized not only by new innovations but also their acceptability, adoption, application and diffusion.

A difference between technological revolution and technological changes (Jaffe et al., 2012) is not clearly defined. The technological transformation can be described as an introduction of an individual (single) new technology, while the technological revolution as a period in which more new technologies are adopted at the almost same time. These new technologies or technological changesare usually interconnected. According to 3rd Kranzberg's law of technology says: "Technology comes in packages, big and small"(Kranzberg, 1986).
Technological revolution is seen as the greatest force for change in history. It will be a catalyst and sickle in driving and pulling an economy from recession. There is a correlation between technological revolution and the standard of the economy of a nation. Hence, a technological boom is an economic boom.

A new technological revolution should increase productivity of work, efficiency, etc (The Free Encyclopedia, 2020). It may involve not only material changes but also changes in management, learning, social interactions, financing, methods of research etc. It is not limited strictly to technical aspects. Technological revolution so rewrites the material conditions of human existence and also reshapes culture, society and even human nature(The Free Encyclopedia, 2020). It can play a role of a trigger of a chain of various and unpredictable changes (Klein, 2008).

What distinguishes a technological revolution from a random collection of technology systems and justifies conceptualizing it as a revolution are two basic features (The Free Encyclopaedia, 2020):

1. The strong interconnectedness and interdependence of the participating systems in their technologies and markets.
2. The capacity to transform profoundly the rest of the economy (and eventually society)" (Perez, 2009).

The consequences of a technological revolution are not exclusively positive but also not that negative: For example, it can have negative environmental impact and cause a temporal unemployment (so called technological unemployment)(The Free Encyclopaedia, 2020).

The "concept of technological revolution is based on the idea (not unquestioned) that technological progress is not linear but non-adulatory. Technological revolution can be" (The Free Encyclopaedia, 2020):

- **i.** Sectorial: this is a technological change in one sector, for example, the green transformation, commercial revolution.
- **ii.** Universal: this is organized and interconnected radical transformation (changes) in more sectors, the universal technological changes is perceived as a multifaceted of several parallel sectorial technological revolutions. For example, first and second industrial revolution in 1900s, Rebirth technological revolution, green revolution in 1945 – 1975, market revolution, scientific revolution, etc.

Thus, the versatility of technological revolution shows that it can break through all areas of an economy dwindling with recession and pave way for a stable economy. For instance, sectors like the solid minerals, agro - allied business, health, real estate etc. It is quite glaring that a technological revolution will definitely impact positively on the economy.

6. Suggested Technological Revolution Strategies as a Panacea to Reducing the Effects of Economic Recession in Nigeria

Having x-rayed the different effects/impacts of recession on any economy, it beholds on us now to look at some of the strategies of technological revolution which will engender development and ignite a quick fire that will melt the economic recession and change the narratives during and after COVID-19 era. The economic revolution strategies include:

- **i.** Technical Oriented Policy: There should be an urgent need by the Nigerian government to always promulgate social, economic policies that are technically oriented. Besides the government, other stakeholders should make policies that technologically drive and abstain from any form of policy that will retrogress technological development (Akpojedje and Ighodaro, 2019).
- **ii.** Commercialization of Research and Development: There should not be a disconnection between the results obtained through research and development (R & D) in institutions and industries. In addition, any relevant output from R & D should be practically put into use by industries in order to encourage novelty and discovering in the country technological development and advancement (Akpojedje and Ighodaro, 2019).
- **iii.** Adequate Funding of Research and Development (: The government should adequately fund and encourage a bilateral relationship between industries and technical institutions in the country (Akpojedje and Ighodaro, 2019).
- **iv.** Agro-technology: is the fusion of science and technology with agriculture in order to replace the outdated (old) practices of farming in the areas of crop production. "The importance of food to physical, economic and cultural development, together with the importance of efficient, sustainable production makes modern techniques crucial—in fact, there is strong evidence that only such approaches have any significant chance of meeting the world's basic food needs in the next few decades"(William, 2017). "Without advancements in agricultural technology, humanity would likely not have progressed through the 21st century without major famines or devastating food wars. Will we be able to say the same thing at the end of this century, given that a food crisis is already here? I believe the answer is *yes,* because I concur with the U.N. that 70% of this food must come from the use of new and existing technologies and modernized indigenous methods. And these technologies and methods must have no negative impact on the environment, animal welfare or food safety" (William, 2017). This new agro-technology focuses on technological methods that can create and restructure agriculture sector and value chains such as: soil, plants, machineries, animals and their products for sustainability of food production as well as jobs creation in and post COVID-19 era.
- **v.** Information Communication Technology (ICT):Since one of the problems facing an economy in recession is unemployment and a fall in gross domestic product (GDP), the role of ICT in solving these problems cannot be overemphasized. "The ICT sector is, and is expected to remain, one of the largest employers. In the US alone, computer and information technology jobs are expected to grow by 22% up to 2020, creating 758,800 new jobs. In Australia, building and running the new super-fast National Broadband Network will support 25,000 jobs annually. Naturally, the growth in different segments is uneven. In the US, for each job in the high-tech industry, five additional jobs, on average, are created in other sectors. In 2013, the global tech market grew by 8%, creating jobs, salaries and a widening range of services and products."
- **vi.** Waste Management: It is all the activities and actions required to manage waste from its inception to its final disposal (United Nations Statistics Division, 2017). This includes amongst other things, collection, transport, treatment and disposal of waste together with monitoring and regulation (The Free Encyclopedia, 2020).

The introduction of technology into the management of waste in Nigeria, especially in the conversion of the waste to wealth (Recycling) will be the way to go. Areas like Bio-fuel which can be used both for our automobiles and even the gas for our domestic use have yet remained untapped. It will interest you to say here that Nigeria generates about sixty five (65) million tons of waste annually (NTA Weekend File, 4th March, 2017). Effective waste management through technology revolution will kick- start speedily the waste to wealth initiative especially the areas of domestic, commercial, agricultural and industrial wastes management etc.

Scraps material like metals, plastics etc. can be recycled through revolutionized indigenous technologies that will create a reduction on the country's huge spending on importation of foreign goods and also, creation of employment for our teeming unemployed population.

vii. Manufacturing: Nigeria's near-total dependency on imported manufactured goods, ranging from the simplest household consumer items to the most complex industrial inputs makes the economy more vulnerable to both internal and external shocks. Nigeria imports at least 70% of its refined fuel, despite pumping 1.6 million barrels of crude oil a day in June 2016 according to the International Energy Agency (IEA)(Nnamdi, 2016). According to the Minister of Agriculture, Audu Ogbeh (2019) who said that Nigeria spend $18 million dollars to import as low as toothpick into the country yearly which pose a serious disaster to the country economy growth. This lack of strong production base has resulted in imported inflation. Therefore, the government of those economy faced with recession must make deliberate and conscious effort in spending on indigenous technology transformation that will create manufacturing technology.

Manufacturing technology will provide the tools that enable the production of manufactured goods. This master tool of industries magnify effort of individual worker and give an industrial and non-industrial nations the power to turn raw materials into an affordable, quality goods essential for today society. This technology revolution in manufacturing sector will help in the reduction of cost, increase efficiency, enhance reliability and eliminate to a large extent pollution while incorporating safety measures. Therefore, a country faced with economic recession can actually come out of it by embanking on technologically-based manufacturing to enhance productivity so that they can begin to export their produce rather than importing finished products.

viii. Transportation Technology: Technologies for transportation often involve the application of new materials or tools, such as emissions control devices or a long-lived pavements. 'TECHNOLOGIES REVOLUTION' are changing the way we plan, design, build, and operate transportation systems. Transport agencies use them to count traffic, detect crashes, collect tolls and fares, and manage transit operations and traffic signal systems. Travellers depend on *'traffic condition reports, electronic maps, on-board vehicle performance monitors, real-time transit arrival information,'* and a host of other services that did not exist a generation ago. Some of us are already driving hybrid vehicles or commuting in buses powered by hydrogen or biofuels. For the future, we all are counting on additional advances in transportation technology, not just to get us where we want to go, but also to reduce greenhouse gases, improve air quality, and support economic development. Political acceptability of a new technology's impacts, including its social and environmental consequences, may be as important as—or more important than—the technology's effects on mobility or its cost-effectiveness. Planners and engineers need to understand a new technology's potential, as well as its limitations, in order to effectively build it into new project proposals. Decision-makers need evidence on benefits and costs, including social, economic, and environmental effects, to weigh whether to invest in a new technology or stick with traditional approaches. New technologies can disrupt established ways of doing things, and so technology development may need to be complemented by institutional analyses that allow leaders to remove barriers and support innovations" as well as create wealth and jobs for the nation (Transportation Research Circular, 2016).

ix. Nigeria Government should increase Her Expenditure on Technical Skills Acquisition: In the past decades the quest and interest on technical skills acquisition has been drastically reduced because of the lackadaisical attitude by the country handlers toward development for local technical skills and its acquisition. We therefore, put it forward to the country handlers and managers to have interest and increase expenditure on technical skills and its acquisition.

x. Reduction of Tax Rate on Manufacturing Sector: The reduction in tax rate for the manufacturing sector should be the way to go during and after COVID-19 to encourage the sector to increase capacity and alleviate shortfall in finance due to the effect of the pandemic. The Federal and State Government should emulate the Cross State Government where all tax/level collections were banned by the State Government to encourage small and mid-size enterprise (SME) growth in the state. This good stewardship should be emulated by the Federal and other State Government.

7. Conclusions and Recommendations

7.1 Conclusions

Having x-rayed the effects/impacts of technological revolution vis-a-vis economic recession in and post COVID-19 era in Nigeria; you will all agree with me that the recent economic downturn in the world during and after COVID-19 is having negative effects on engagement levels and this is something every businesses both public and private should be concerned with. Pulling an economy out of recession needs technological revolution that will transform and enhance productivity and quality of goods and services rendered; the dependency of Nigeria economy on foreign economies must change and this change in narratives will be through appropriate transformation of indigenous technology that will have impact on jobs creation and also, will translate to economic boom in the country. In dealing with the indigenous technological revolution that will stimulate economic development and raise standard of living of the citizenry, all hands must be on deck.

7.2 Recommendations

1. Government support for commercial technologies should be provided
2. Strengthening commercialization of research and development of technological institutions
3. Strengthening capacity building of science and technology
4. Adequate funding of Research and Development" (R & D)of technological institutions
5. Strengthening educational system
6. Eliminating the existing gaps in workforce training and retraining
7. Strengthening synergy and sustenance of “Public - Private Partnership” (PPP)
8. Incorporating and strengthening a synergy between industries and academic institutions

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APPLICATION OF UNMANNED AERIAL VEHICLES IN AGRICULTURAL CROP MONITORING

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Abstract

The application of drone (UAE) has brought ease to agricultural activities, by allowing the farmer to view crop changes or stress conditions that are otherwise invisible to the human eye. The study showed that Drones capture good image with good spatial and temporal resolution compared to other remote sensing platforms like; Satellite, Balloon (Air borne) and Manned (Helicopter). The area of coverage for Drones ranged between 50-500km, Satellite 10-50km, Balloon (Airborne) 0.5-5km, Manned (Helicopter) 0.2-2km while the special resolution (images) are 0.5-10cm, 1-25m, 0.1-2m, 5-50cm respectively.

Keywords: Spatial resolution, area of coverage, unmanned area vehicle (UAE), drone.

1. Introduction

The world population is increasing day by day and projected to reach 9 billion people by 2050, which will as well lead to increase in agricultural consumption. There is extreme need to fulfill the food demand of each and every person. Agriculture sector is one among the most promising sector, dealing with lot of problems like labour unavailability for farming, extreme weather events, inadequate amount and inefficient application of fertilizer, infection, diseases, allergies and other health problems due to chemical application (fungicide, pesticide, insecticide) or insect/ animal bite. The Use of advanced technologies such as drone in agriculture offer potential for facing several major or minor challenges. The major applications of drone in agriculture are irrigation, crop monitoring, soil and field analysis and bird control (Ahirwar *et al*., 2019).

Drones also known as Unmanned Aerial Vehicles (UAV's) are remote controlled aircraft with no human pilot on-board. It has a huge potential in crop monitoring and in spatial data collection. Despite some inherent limitations, these tools and technologies can provide valuable data that can then be used to influence policies and decisions. Drones in agriculture are simply a low-cost aerial camera platform, equipped with an autopilot using GPS and sensors for collecting relevant data. They can be compared to a regular point-and-shoot camera for visible images, but whereas a regular camera can provide some information about plant growth, coverage and other things, a multispectral sensor expands the utility of the technique and allows farmers to see things that cannot be seen in the visible spectrum, such as moisture content in the soil, plant health, stress levels and fruits. These could help overcome the various limitations that hinder agricultural production.

The birth of a drone Nation UAV was first developed in America during World War I in 1917. The official name for early drone was "Liberty Eagle," but it is more commonly referred to as the Kettering "Bug" to honor its inventor, Charles F. Kettering, who had been assigned to evaluate the possibility of developing an aerial torpedo (Garrett, 2014).

Japan has been the first country to use UAV in agriculture for applications like chemical spray in 1980 (Nonami, 2007), crop wiping in 1990. Around 1220 units of unmanned helicopters manufactured by YAMAHA were sold and used in Japan in the year 2001 (Sato, 2003). Bendiq *et al*. (2012) identify that a technical analysis of UAVs in precision agriculture is to analyze their applicability in agricultural operations like crop monitoring, crop height estimations, pesticide spraying, soil and field analysis. Huang *et al*. (2013) examined that UAVs hardware implementations are purely depended on critical aspects like weight, range of flight, payload, configuration and their costs.

Table 1 shows the components and functions of a drone.

Table 1: Components and Functions of a Drone

S/N	Components	Functions
1	Accelerometer	For measure the acceleration
2	Gyro	For rotational motion
3	Magnetometer	To measure magnetic field
4	WSN	Sensing environmental conditions
5	IMU	Measures angular rate and forces
6	GPS	Provides geo location of an object
7	Camera	To record visual images
8	Multispectral	Camera Images at specific frequencies
9	Hyper spectral	camera Images at narrow spectral bands
10	Thermal Camera	To record low light imaginary
11	Video Camera	Electronic motion of objects
12	Laser scanner 2D	Captures shape of the object
13	Telemetry	To get live data from UAV
14	Altimeter	To measure altitude
15	Air Pressure Sensor	Measurement of gases or liquids
16	BLDC	To motion control
17	ESC	Regulates the speed of BLDC
18	Microsoft Kinect	To motion sensing
19	Barometer	For atmospheric pressures
20	Solar	Energy source
21	PWM controller	For pulsing signal
22	Digital Temperature	Temperature detectors
23	Humidity indicator -	Measures moisture in air
24	Water sensitive paper	For assessing spray coverage
25	Filter papers	To separate fine substances
26	Anemometer	Speed

Source: Huang *et al*. (2013)

2. Agricultural Application of Drones

Drones are used in various fields ranging from soil and field analysis, planting, crop spraying, crop monitoring, irrigation, health assessment. Other field includes the military, humanitarian relief, disaster management to agriculture (Yuwalee *et al*., 2018).

2.1 Soil and Field Analysis

After getting precise 3D maps for soil, planting can be planned and nutrient status can be analyzed for further operations. Plate 1 shows a drone used for soil analysis.

Plate 1: Soil analysis.
Source: (Yuwalee *et al*, 2018)

2.1.1 Planting

Unmanned Aerial System shoot seeds with nutrients in the soil with an average uptake of 75 percent, thus bringing down costs for planting. Plate 2 shows a drone used for planting.

Plate 2: Planting drone.
Source: (Yuwalee *et al*., 2018)

2.1.2 Crop spraying

Drones can scan the ground and spray the correct amount of liquid, modulating distance from the ground and spraying in real time for even coverage. Plate 3 shows a drone used for crop spraying.

Plate 3: Planting drone.
Source: (Yuwalee *et al*,. 2018)

2.1.3 Crop monitoring

Time-series animations can show the precise development of a crop and reveal production inefficiencies, enabling better crop management. Plate 4 shows a drone used for crop monitoring.

Plate 4: Crop Monitoring drone.
Source: (Yuwalee *et al*., 2018)

2.1.4 Irrigation

Drones with hyperspectral, multispectral, or thermal sensors can identify which parts of a field are dry or need improvements. Plate 5 shows a drone used for irrigation.

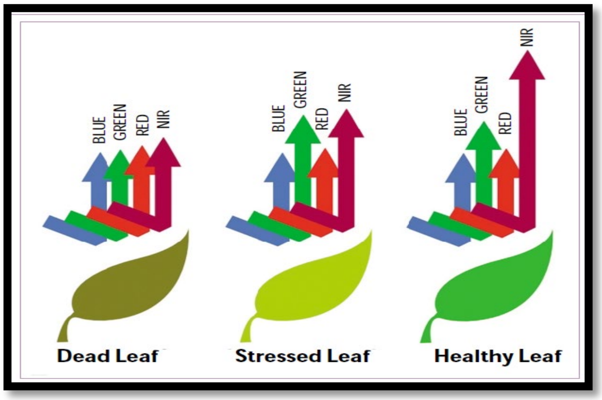
Plate 5: Irrigation drone.
Source (Yuwalee *et al*,. 2018)

2.1.5 Health assessment

Health assessment drone is essential to assess crop health and spot bacterial or fungal infections on trees. Plate 6 shows a drone used for health assessment.

Figure 6: Health assessment drone
Source: (Yuwalee *et al*,. 2018)

By scanning a crop using both visible and near-infrared light, drone-carried devices can identify which plants reflect different amounts of green light and NIR light. This information can produce multispectral images that track changes in plants and indicate their health as shown in Figure 7 below.



3. Crop Monitoring using Unmanned Aerial Vehicles (UAV)

Unmanned Aerial Vehicles for agricultural practices focuses on providing spatial and spectral data for monitoring and analyzing a crop's status. Before now, satellite and manned aircraft photography have been successful in acquiring the necessary data, but there exists a demand today for higher resolution imagery collected and at a lower cost to farmers. Researchers at the Asian Institute of Technology (AIT) have proposed using unmanned aerial vehicles (UAV) as platforms for low altitude remote sensing (Swain *et a*l., 2007). The proposed system uses a rotary UAV to carry a variety of imaging payloads and combine the images with highly accurate GPS information for real-time field monitoring and mosaic map creation. Arguments are made that a combination of sensors and position information allows for a multi-dimensional approach at crop monitoring for lower cost and increased spatial and temporal resolutions. The increase in spatial resolution is derived from the low altitude flights, but also from improved lightweight digital cameras, while the increase in temporal resolution is achieved by creating a system that is readily available to fly with short notice.

Monitoring challenges are exacerbated by increase in unpredictable weather conditions, which leads to risk and field maintenance costs. Previously, satellite imagery offered the most advanced form of monitoring. But there were drawbacks. Images had to be ordered in advance, could be taken only once a day, and were imprecise. Further services were extremely costly and the image quality typically suffered on certain days. Today, Unmanned Aerial Vehicles as giving life to the precise development of crop and reveal production inefficiencies, enabling better crop management (Agrobot, 2017). UAVs are capable of monitoring the crop with different indices and are able to cover up hectares of fields in single flight (Simelli, 2015). For this observation thermal and multi spectral Cameras to record reflectance of vegetation canopy, is mounted to downside of the quad copter (Bendig, 2012). The camera takes one capture per second and stores it into memory and sends to the ground station through telemetry (Rao,2018). For this wireless communication, it uses MAVLINK protocol. The pictures are captures in the visible five brands with different wave lengths: i.e. (i) Blue wavelength 440-510nm, (ii) Green wavelength 520-590nm, (iii) Red wavelength 630-685nm, (iv) Red edge wavelength 690-730nm, (v) Near infrared wavelength 760-850nm. The data coming from the multispectral camera through telemetry was analyzed by the Geographic indicator Normalized Difference Vegetation Index (NDVI) represented in equation 1 (Reinecke *et al.,* 2017).

$$\mathrm{NDVI} = \frac{(\mathrm{R_{NIR}} - \mathrm{R_{RED}})}{(\mathrm{R_{NIR}} + \mathrm{R_{RED}})} \tag{1}$$

where,

R_{NIR} = Reflectance of the near infrared band,

R_{RED} = Reflectance of the red band.

The calculations gives the values -1 to +1; near to 0 (ZERO) indicates no vegetation on the crop and near to +1 (0.8 to 0.9) means highest density of green leaves on the crop. Based upon these results, farmers easily identify the field where can spray the pesticides. The inbuilt GPS module maintains GPS coordinates of the every captured picture. Then The GPS coordinates of that pictures are stored in UAV (Rao, 2018).

4. Comparison of Unmanned Aerial Vehicles (Drones) with Other Existing Methods

Unmanned Aerial Vehicles (Drones) captures good image with good spatial and temporal resolution along with cost effectiveness as compared to other remote sensing platforms. The table 2 presents comparison between UAV and other remote sensing platforms.

Table 2: Comparison between UAV and other remote sensing platforms.

Basic remote sensing platform	Area of coverage	Spatial resolution (images)	Payload	Usability	Cost
Satellite	10-50km	1-25m	-	-	Very high
Balloon (Airborne)	0.5-5km	0.1-2m	Unlimited	Pilot mandatory	High
Manned (Helicopter)	02-2km	5-50cm	Limited	Pilot mandatory	Medium
Unmanned (Drones)	50-500m	0.5-10cm	Limited	No human pilot on-board	Very low

Source: Swain *et a*l., 2007

5. Advantages of Unmanned Aerial Vehicles (Drones)

a) Drones can be operated manually, or programmed to operate automatically or to be fully autonomous.
b) It allows farmers to view crop changes or stress conditions that are otherwise invisible to the human eye.
c) There is no need a qualified pilot to fly it, drone can stay in the air for up to 30 hours, doing the repetitive raster scan of the region, day-after-day, night-after-night in the complete darkness or in the fog and under computer control.
d) Unmanned Air Vehicle performs the geological survey, it performs the visual or thermal imaging of the region,
e) There is no need for a qualified pilot to fly it. It can stay in the air for up to 30 hours, doing the repetitive tasks, performing the precise, repetitive raster scan of the region, day-after-day, night-after-night in the complete darkness or in the fog and under computer control.
f) It can calculate the density and health of the crop and provide the heat signature, alerting the farmer which crops are in need of more water and which crops need less.

6. Challenges of Unmanned Aerial Vehicles (Drones)

1. There is no worldwide acceptable solution for each crop because each crop has different properties so they need to be analysed in a different manner to produce operation-able data.
2. The collection of data is very much affected by weather, cloud, the amount of sun energy reaching to crop and angle of the sun. Due to this reason, entire data gathering must be done in a reiterate manner under same environment.
3. Another technical constraint of the UAV is its payload and gliding time. Li-ion battery is used to power UAV because of its light weight, but it does not stand anywhere in front of gasoline power. However, reduced gliding time can be overcome by the use of fixed wing UAV, but it cannot hang at a place and also faces difficulty in landing.

7.0 UAV in Africa

The first country that starts the use of UAV in Africa is the Republic of South Africa in 2014. Flight trials were conducted using a small UAV to ascertain the value of imagery in detecting vine plant health before and after the application of organic nutrition. Mapping flights were conducted and the nutrients were applied using conventional methods immediately afterwards. High-resolution farm and vine mapping imagery was taken before the crops were sprayed with nutrients and at stages afterwards. This data was shared with farmers, agronomists and soil scientists. The imagery shows improvement in the treated rows relative to untreated rows. The New regulations for operating UAVs in the Republic of South Africa became effective in July 2015 (Wijnberg, 2017). Presently, a total of 15 countries have published dedicated UAV regulation in Africa. Which represent 28 percent of the total number of countries on the continent. Table 3 shows countries in Africa that adopt the use of UAV and it regulations.

Table 3: Countries in Africa that adopt the use of UAV and its regulations

Countries	UAV Regulations
Botswana, Cameroon, Gabon, Ghana, Madagascar, Mauritius, Namibia, Nigeria, Rwanda, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.	Regulations are in place
Benin, Burkina Faso, Chad, Cote d'Ivoire, Mali, Mauritania and Senegal	Small regulations are in place
Angola, Kenya and Malawi	Pending regulations

Source: Wijnberg (2017)

7.1 UAV in Nigeria

Although unverified, it was reported that drones were found in Nigeria around November 2015 (Kusamotu and Kusamosu, 2017). The International Civil Aviation Organization (ICAO) is yet to publish any standards and recommended practices as far as certification and operation of civil use of drones is concerned. Therefore, in an attempt to regulate the operation of drones, the Nigerian Civil Aviation Authority (NCAA) in May 2016 issued some safety regulations. The regulations are to the effect that no government agency, organization or an Individual will launch UAV in the Nigerian airspace for any purpose whatsoever without obtaining requisite approvals/permit from the Nigerian Civil Aviation Authority (NCAA) and office of National Security Adviser (NSA). Oil company like Oando Nigeria Limited has adopted the use of UAV for inspection of Power lines, Oil and Gas pipelines, Transmission towers to tackle the issue of vandals. Drones in agriculture are not widely used by farmers in Nigeria. The barriers to the use of drones in Nigeria's agricultural space, is that small farmers have not started seeing the advantages and results of drones.

8. Future Scope of Unmanned Aerial Vehicles (Drones)

Future scope of UAV includes improvement in its designing, availability of cheaper and good quality hardware, relaxation in regulation, advanced and easy image, data processing method and particle representation of result for better utilization by a farmer. It is crystal clear that UAV applications in farming are still infant and it has lots of scope for improvement in terms of technology and other farming application. Definitely, in the coming years it will bring more advancement in UAV technologies in agriculture field.

9. Conclusion

The importance of agriculture to human cannot be over emphasized as less effort is put in to increase food production. The introduction of the UAVs to agricultural practice will bring about precision in area of crop monitoring, Irrigation, fertilizer application, health assessment of crops as well as soil quality. Thus, Table 2 shows that basic remote sensing like Satellite, Airborne and Manned suffer from various disadvantages such as prohibited use, high price, poor resolution due to great height. While Unmanned Aerial Vehicle (UAV) overcomes the inaccessibility to remote and very dense regions, very low cost, good resolution of 0.5-10cm and usability requires no pilot on- board.

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EFFECTS OF CONTROLLED ENVIRONMENTAL CONDITIONS ON THE DECORTICATION EFFICIENCY OF SELECTED INDIGENOUS VARIETIES OF MELON SEEDS

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Abstract

This study determined some properties of three indigenous melon seed varieties (C. vulgaris, C. lanatus and L. siceraria) as well as the best combination of treatment parameters that ensured optimal yield in relation to decortication. These were with a view to increasing the shelling efficiency of the melon seeds. The physical properties were determined using standard procedure after subjecting the to a combination of treatments involving seven levels of soaking time (5, 10, 15, 20, 25, 30 and 60 minutes) and four levels of freezing duration (30, 45, 60, and 75 minutes) after which the pretreated samples were then subjected to air-drying at ambient temperature. All three the varieties of melon seeds exhibited maximum value of compressive stress at longitudinal orientation. of C. vulgaris (Papa) at a combination of 10 minutes soaking time with 60 minutes freezing time was able to improve dehulling by 16.54% using the NCAM sheller, for C. lanatus variety the dehulling efficiency was increased by 28.15% when subjected to an optimum combination of 15 minutes soaking and 75 minutes freezing while L. siceraria variety was observed to have achieved 11.70% improvement in dehuling performance at an optimum combination of 60 minutes soaking and 45 minutes freezing times. The study concludes that pre-treatment of melon seeds could offer a better avenue for utilization of melon seeds in both domestic and industrial uses.

Keywords: Melon, decortication, pretreatment, shelling.

1. Introduction

Melon (local name: *Egusi*) is an English name for a wide variety of seeds obtainable from some plants in the *Cucurbitaceae* family which are found mainly in the warmer parts of the world. The plant consists of 118 genera with about 825 species. There are four types commonly found in West Africa, namely: *Cucumeropsis manii*, *Citrullus lanatus, Lagenaria siceraria and Citrullus vulgaris*. The most popular among them are *Citrullus lanatus* and C*ucumis melus*. The common cultivars found in South Western Nigeria include *Bara, Serewe, Sofin* (Adekunle *et al.*, 2009). The seeds of *Bara* have a mean length of about 12 mm, width of 8 mm, thickness of 2.3 mm and weighs about 150 mg on the average. Melon is popularly grown for its numerous dietary values and economic importance.

Melon is one of the valuable sources of vegetable protein and oil. Ground melon meals are commonly used in sauces, soups and condiments especially because it is rich in dietary proteins. A number of authors have investigated the nutritional composition of this seed and have discovered that it protein content is between 23.4 to 37.4, fibre content between 2.6-27% and ash content 3.6-3.7%. Ajibola et al. (1990) however reported a 50% fat content for the crop as shown in Table 1.

Table 1: Comparison of values of nutritional composition of Melon seeds as obtained by various authors

	Protein	Carbohydrate	Fibre	Ash	Fat	Ether Extract	Moisture
Adegbulugbe (1986)	28.4	8.2	27	36	-	-	-
Indigo (1998)	23.4	10.6	12.0	3.7	-	45.7	4.6
Ajibola *et al.* (1990)	37.4	-	2.6	3.6	50	-	6.4

Although this crop has a high potential especially for oil production, melon shelling has presented serious challenges to local processors. This has led to the under-utilization of the seeds. Many efforts have been made and many mechanical devices fabricated but the efforts hitherto have not been very encouraging. The highest recorded shelling efficiency for *C.lanatus* and *C. vulgaris* of the NCAM melon sheller at the optimum speed of 860 rpm were 92.44% and 79.69%. From the reviewed literature, there is little information regarding the pretreatment of melon seeds prior to shelling. Studies carried out on the decortication of *Cucurbitaceae* seeds have shown that pretreatments can increase the shelling efficiency of such seeds, this study was therefore undertaken to investigate the effect of pretreatments on the decortication of selected varieties of melon seeds to provide important data that may help optimize shelling using an existing melon shelling machine (NCAM Melon Sheller).

2. Materials and Method

The three popular species of melon *Papa* (*Citrullus vulgaris*)-Plate1, *Sofin (Citrullus lanatus*)-Plate 2 and *Igba* (*Lagenaria siceraria*)- Plate 3 were used for this study. 20 kg of each of the three melon seed varieties were obtained from Sabo Market, Sabo, Ile-Ife, Osun State for the investigation. The seeds were physically inspected to ensure that all impurities such as stones, leaves etc. were adequately removed.

Plate 1: *Papa* (*Citrullus vulgaris*)

Plate 2: *Sofin* (*Citrullus lanatus*)

Plate 3: *Igba* (*Lagenaria siceraria*)

2.1 Determination of Physical Properties

A digital venier caliper with a sensitivity of 0.001µmm was used to obtain the length, width and thickness dimensions of a population of 120 seed from each of the varieties of the melon seeds. Geometric mean diameter was determined for each seed at specified soaking time from the average measurements of the length, width and thickness with the expression presented by Mohsenin (1980):

$$D = (abc)^{1/3} \tag{1}$$

where D is Geometric Mean Diameter, a is length, b is width, c is thickness.

$$Sphericity, s = \frac{(abc)^{1/3}}{a} \tag{2}$$

$$Aspect\ Ratio = \frac{b}{a} \tag{3}$$

Mass was determined by weighing each unit seed of 100 seeds sampling in 3 replicates on an Electronic scale (Model Series) with an accuracy of 0.01g.

Volume of the seeds was calculated from the expression presented by Mohsenin (1980) as

$$Volume\ of\ Solid = (Sphericity)^3 \text{x}\ Volume\ of\ Circumscribed\ Sphere \tag{4}$$

where,

$$Volume\ of\ Circumscribed\ Sphere = \frac{(\pi a^3)}{6} \quad (5)$$

(5)

True density of seeds was determined using equation 6 as suggested by Mohsenin (1980)

$$True\ density = \frac{Mass\ of\ Single\ Seed}{Volume\ of\ that\ particular\ seed} \quad (6)$$

Bulk density was determined as a ratio of the mass of seeds in the cylinder to the volume of the cylinder. The porosity of the seeds was calculated from the values of the bulk and true densities by using the mathematical equation suggested by Mohsenin (1980). Porosity, which is also referred to as the packing factor, PF, was also determined from the following relationship:

$$PF = \frac{Solid\ density\ of\ particles\ (TD) - density\ of\ packing\ (BD)}{Solid\ density\ of\ particles\ (TD)} \quad (7)$$

where PF is the porosity, BD is the bulk density (g/mm^3) and TD is the true density (g/mm^3) .

2.2 Determination of Mechanical Properties

Mechanical properties such as the compressive stress, strain, maximum loading at breaking of the seeds were determined using an Instron Universal Testing Machine (Model 3369, Norwood, USA, 50kN Max.) available at the Centre for Energy Research and Development, Obafemi Awolowo University, Ile–Ife. The melon were inserted either longitudinally or axially with tip-up or down inside the machine. The compressive stress, strain and energy at impact were measured.

2.3 Pretreatments of Melon Seeds

The effect of freezing and soaking time on melon seeds were evaluated for three species of melon seeds. About 100 g of sample were soaked in water for 5, 10, 15, 20, 25, 30, and 60 mins duration. The freezing time considered for the soaked samples were 30, 45, 60, 75 mins at -4^{o}C. The 7 × 4 complete randomized design (CRD) with three replicates was then analyzed using analysis of variance (ANOVA). The pretreated samples were sun-dried at ambient temperature to allow the frozen melon seed to thaw. The pretreated samples were then subjected to shelling under an available machine at National Centre for Agricultural Mechanization (NCAM), Idofian, Kwara State, Nigeria.

2.4 The NCAM Melon Shelling Machine

The NCAM shelling Machine has an impeller type shelling unit, comprising a hopper, a rectangular shaped discharge chute, impeller blade, involute housing and powered by a 5 HP petrol engine (Plate 4). The prime mover rotates the shaft of the impeller blade and the collision against the involute housing brings about the shelling. The machine operates on the principle of kinetic energy absorbed by an object as a result of the impact of collision against a stationary wall. This cracks the seeds in a nut-shell and loosens the seed coat eases removal during separation.

Plate 4: NCAM Melon Sheller

2.5 Shelling of Pretreated Seeds

The pretreated melon seeds were decorticated using the NCAM melon sheller because it is a typical melon sheller available. Machine performance was evaluated by grading the melon seeds into: hulled and whole, hulled but broken, chaff and dehulled. The experiment was replicated thrice and recovery was determined by gravimetry. The speed of the machine was maintained within the range of 700-860 rpm as specified for efficient performance of the machine using the in-built speed regulator. The shelled seeds and the chaff were blown out by the impellers through the involutes housing unit which opens into the outlet end of the chute for easy discharge of products.

3. Results and Discussions

3.1 Shape Indices of Whole and Dehulled Melon Seeds in Relation to Shelling

Summary of experimental data as shown in Table 2 revealed that *igba* (*L. siceraria*) seeds had the largest length, width and thickness for the seeds. *Sofin* (*C. lanatus*) seeds had the smallest dimensions and *papa* (*C. vulgaris*) seed was intermediate though with thicker shell hence the reason why it is also referred to as "thick edge melon". Similarly, *igba* (*L. siceraria*) kernels had the largest length and width hence called the long whitish melon. The volume-area properties of three melon varieties also showed that *Igba* had the largest seeds and kernels as discussed earlier on physical properties of melon. The observed results for the three varieties also correlates with observations made by Ige (1984).

Table 2 : Shape indices of whole and dehulled melon seeds in relation to shelling.

	Property	**Whole Seeds**			**Dehulled Seeds**		
		C. vulgaris	*C. lanatus*	*L. siceraria*	*C. vulgaris*	*C. lanatus*	*L. siceraria*
Axial Dimensions (mm)	**Length, a**	15.13±1.0	14.10±0.83	20.85±1.71	12.54±0.90	12.50±0.91	16.14±1.31
	Width, b	9.46±0.77	8.62±0.63	8.65±0.61	7.07±0.58	7.20±0.54	7.26±0.65
	Thickness, c	1.83±0.25	1.64±0.02	2.44±0.59	1.66±0.23	1.62±0.24	1.59±0.59
	GMD	5.29±0.34	5.72±0.31	7.39±0.66	5.19±0.36	5.17±0.32	5.59±0.33
	AR	0.63±0.04	0.61±0.05	0.42±0.05	0.58±0.06	0.58±0.06	0.45±0.05
	Sphericity	0.35±0.02	0.41±0.02	0.36±0.04	0.41±0.02	0.41±0.03	0.35±0.03

Reported values are mean ± standard deviation

GMD: Geometric Mean Diameter
AS: Aspect Ratio

3.2 Effect of Soaking and Freezing Time on the Shelling Efficiency of the NCAM Melon Sheller for Papa (Citrullus Vulgaris) ***Variety***

Results obtained from varying soaking and freezing time on the shelling efficiency of the NCAM melon sheller for *Citrullus vulgaris* as shown in Table 3 reveals the shelling efficiency for the machine increased as both parameters increased until the optimum level was observed at a combination of 10 minutes soaking time with 60 minutes freezing time which gave the highest shelling efficiency, this condition lead to a 16.54% increase in shelling efficiency when compared with the control condition. After the optimum value was attained a decline in performance was observed, the shelling efficiency was lowest at a combination of 5 minutes soaking time combined with 30 minutes freezing time which also equated to a 75.80% reduction in efficiency of the shelling process.

Table 3: Effect of Freezing and soaking time on Shelling efficiency for *Citrullus vulgaris*

Soaking Time (mins)	Freezing Time (mins)			
	30	45	60	75
5	15.44	33.65	52.62	61.84
10	25.45	40.19	67.42	66.90
15	17.88	30.16	53.25	60.67
20	16.89	45.62	50.96	58.07
25	23.8	34.01	61.69	58.45
30	19.81	39.97	58.71	58.64
60	15.94	47.98	64.27	66.84
Control	57.85	57.85	57.85	57.85

3.3 Effect of soaking and freezing time on the shelling efficiency of the NCAM melon sheller for sofin (Citrullus lanatus) ***variety***

Results from Table 4 shows that combining the different soaking and freezing times in conditioning the *Citrullus lanatus* variety before shelling with the NCAM melon sheller lead to the highest shelling efficiency at a combination of 15 minutes soaking and 75 minutes freezing, this lead to a 28.15% increment in performance when compared to the values obtained from the control experiment. The machine was also observed to have had the lowest performance with a combination of 60 minutes soaking time and 60 minutes freezing time, this also translated to a 40.14% reduction in output when compared with control values.

Table 4: Effect of Freezing and soaking time on Shelling efficiency for *Citrullus lanatus*

Soaking Time (mins)	Freezing Time (mins)			
	30	45	60	75
5	58.39	63.09	58.71	63.22
10	57.17	52.68	53.14	74.44
15	58.30	58.67	81.18	89.49
20	57.42	55.18	63.54	73.85
25	58.73	61.00	64.06	69.06

30	58.20	56.53	54.12	67.49
60	58.59	55.55	41.80	67.23
Control	69.83	69.83	69.83	69.83

3.4 Effect of soaking and freezing time on the shelling efficiency of the NCAM melon sheller for sofin (Lagenaria siceraria) ***variety***

Pre-treatment of *Lagenaria siceraria* prio to shelling with the NCAM sheller as shown in the results on Table 5 reveals that combining the different soaking and freezing times lead to the highest shelling efficiency at a combination of 60 minutes soaking and 45 minutes freezing times, this treatment was observed to have led to 11.70% increment in performance when compared to the values obtained from the control experiment. The treatment also gave the lowest dehulling performance at a combination of 5 minutes soaking time and 30 minutes freezing time, this performance translated to a 35.74% reduction in when compared with results obtained under control condition.

Table 5: Effect of Freezing and soaking time on Shelling efficiency for *Lagenaria siceraria*

Soaking Time (mins)	Freezing Time (mins)			
	30	45	60	75
5	44.87	44.89	56.91	58.39
10	50.01	61.00	56.56	57.17
15	48.89	61.55	50.45	58.30
20	45.56	58.08	45.49	57.42
25	49.30	54.37	57.40	58.73
30	34.12	53.87	61.88	58.20
60	45.52	78.00	64.40	58.59
Control	69.83	69.83	69.83	69.83

3.5 Summary of Statistical Analysis

Statistical analysis of results done by Analysis of Variance as displayed on Table 6 shows that the effect of the seed shape had a significant effect on the performance/efficiency of the sheller in the dehulling process of the three varieties of melon. Further investigation also revealed that the combined effect of soaking and freezing times also was significant in the shelling characteristics of *C. vulgaris* while all other interaction effects with the exception of combined effect of soaking and freezing times was significant for *L. siceraria.* This shows that *L. siceraria* variety is highly sensitive to changes in virtually all of the considered parameters and therefore extra care needs to the taken in conditioning of the *L. siceraria* seeds.

Table 6: Comparison of critical values from Analysis of Variance for the Effect of soaking time, freezing time and shape indices on shelling quality of melon seeds

Source	DF	*C.vulgaris*	*C. lanatus*	*L. siceraria*			
		F Value	Pr > F	F Value	Pr > F	F Value	Pr > F
Soaking Time	6	1.18	0.319	1.41	0.2136	0.49	0.8149
Freezing Time	3	0.31	0.8147	2.23	0.0867	0.26	0.8565
Shape indices	18	2469.73	0.0001*	5628.21	0.0001*	1110.48	0.0001*
Soaking *Freezing Time	2	1.52	0.0873	1.93	0.0166*	0.68	0.8228
Soaking Time*shape indices	12	0.64	0.8098	0.44	0.9450	3.33	0.0002*
Freezing Time*shape indices	6	0.84	0.5371	1.17	0.3271	5.31	0.0001*
Soaking*Freezing*shape indices	36	0.83	0.7393	0.82	0.7496	3.41	0.0001*

*ANOVA is significant at 0.05

5.0 Conclusion

Pretreatment of *Citrullus vulgaris* (*Papa*) at a combination of 10 minutes soaking time with 60 minutes freezing time was able to improve dehulling by 16.54% using the NCAM sheller, for *Citrullus lanatus (Igba*) variety however the dehulling efficiency was increased by 28.15% when subjected to an optimum combination of 15 minutes soaking and 75 minutes freezing while *Lagenaria siceraria* (*Sofin*)variety was observed to have achieved 11.70% improvement in dehuling performance at an optimum combination of 60 minutes soaking and 45 minutes freezing times. The study concludes that pre-treatment of melon seeds could offer a better chance of utilization of melon seeds for both domestic and industrial uses.

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E-AGRICULTURE: CONCEPTS AND APPLICATIONS

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Abstract

The widespread use of ICT and its importance for innovation and economic growth has been recognized widely. Nowadays application and use of Information and Communication Technologies (ICT) in day to day life of the people has become common. As we look on from the past, then, only television and radio were the electronic broadcasting technologies that were used to reach the rural communities. In Nigeria, many strategies have been developed and being executed with the aim of developing the agricultural sector which is one of the main sources of income in the northern and some of the western parts of Nigeria. The traditional methods used in agriculture have been in practiced by farmers for a long period. With the emergence of new technologies and its widespread use, the use of those technologies in Agriculture sector will probably create a positive effect on the growth and development. There are many ways to incorporate the emerging trends in ICT with Agriculture that will aid on the enhancement of rural development and Agriculture sector via efficient information and communication processes. In view of this, the best strategies to achieve the above listed is the application and utilization of the rapid growing technologies in Information and Communication Technology to agriculture.

Keywords: e-agriculture, information and communication technology, geographical information system.

1. Introduction

The widespread use of ICT and its importance for innovation and economic growth has been recognized wide (EIU, 2006). Nowadays application and use of Information and Communication Technologies (ICT) in day to day life of the people has become common (Zahedi & Morteza, 2012). As we look on from the past, then, only television and radio were the electronic broadcasting technologies that were used to reach the rural communities. However, in recent years, there was a rapid emergence of internet and mobile based technologies (Balaji, Meera, & Dixit, 2007). As the result, an easy and fast mode has emerged to reach the urban as well as rural communities. In Nigeria, many strategies have been developed and being executed with the aim of developing the agricultural sector which is one of the main sources of income in the northern and some of the western parts of Nigeria. The traditional methods used in agriculture have been in practiced by farmers for a long period. With the emergence of new technologies and its widespread use, the use of those technologies in Agriculture sector will probably create a positive effect on the growth and development. There are many ways to incorporate the emerging trends in ICT with Agriculture that will aid on the enhancement of rural development and Agriculture sector via efficient information and communication processes (Singh, Kumar, & Singh, 2015). E-Agriculture as an emerging field in the intersection of agricultural informatics, agricultural development and entrepreneurship, referring to agricultural services, technology dissemination, and information delivered or enhanced through the Internet and related technologies (FAO, 2005). The e-Agriculture concept, however, moves even beyond technology to the combination of knowledge and culture which is primarily focusing on the improvement of communication and the process of learning among the different stakeholders of agricultural sector who are engaging at the different levels.

2. Application of ICT Tools in the Agricultural Sector

2.1 Geographical Information System

A Geographical Information System (GIS) makes visual comparisons between different types of data possible. It helps to establish relationships between different data sets and is important in the production of maps, and charts and additional information associated with coordinates and time. It helps in the analysis of post-harvest variation in crop yield measures, and provides a holistic view of the production system (GIS Development, 2006). GIS is a computerized data storage and retrieval system, which can be used to manage and analyse spatial data relating crop productivity and agronomic factors. It can integrate all types of information and interface with other decision support tools. GIS can display analysed information in maps that allow (a) better understanding of interactions among yield, fertility, pests, weeds and other factors and (b) decision-making based on such spatial relationships (Singh, Kumar, & Singh, 2015).

2 GIS in AGRICULTURE

1 PRECISION AGRICULTURE

3 AGRICULTURE - GIS Application

1.1 Handheld Personal Computer

Handheld Personal Computers are small, light, and robust and have been used for providing access to information, mobile mapping and other data gathering activities (GIS DEVELOPMENT, 2007) Through forum and social networking site farmers can get connect with other experts and exchange their views and other details. Farmers can get a lot of information on variety of agriculture topics by surfing. Farmers can get connect foreign customer which can help to improve their product and increase their production capacity. Farmer can get information regarding price, weather, temperature etc. Keeping financial record, Production record, online banking, Buy required resources through internet etc… The amount of water sprinkled in a balanced quantity is also computerized. The production capacity in farming and animal husbandry has increased due to use of computer in agriculture field .There are less losses due to work are monitored by computer. By using computer in traditional field like agricultural field we can increase the productivity and minimize the error happen. Computers are more helpful in receiving necessary details quickly, accurately and computers are also used in imaging and Monitoring .Due to this usefulness of computer in medical field people can be cured as much as possible.

Mobile Workstation

2.2 Mobile (Cellular) Phone Applications

The cellular phone has provided market links for farmers and entrepreneurs. Growth in mobile phones has been explosive and now reaches more than a third of the population. This has reduced transaction costs, broadened trade networks and facilitated searches for employment (Guislain, Qiang, Lanvin, Minges, & Swanson, 2006). Bertolini (Bertolini, 2004).

Agriculture, whenever we read this term images of tractors, bullock-carts, and people working hard on the fields come across our minds. However, the time has changed and now technology has seeped into the agricultural sector. Starting from high-tech ways to find out the best quality seeds to best agriculture processes, there is a lot that can be done using the power of technology. At the same time, even the revenue of the farmers is expected to increase with the use of technology.

3. Role of ICT in Agronomic Practices

Deloitte, *et al*., (Deloitte, Alexander, De Graaf, Mukherjee, & Kumar, 2012) reported that, in identifying the ways in which ICT can help Agriculture, it is useful to view the farming life cycle as a three stage process such as;

* Pre-cultivation: Including crop selection, land selection, calendar definition, access to credit, etc.
* Crop cultivation and harvesting: Including land preparation and sowing, input management, water management and fertilization, pest management, etc.
* Post-harvest: Including marketing, transportation, packaging, food processing, etc. Crop Variety Selection

This sub-system advises the users about the most suitable variety for his/her plantation based on the specific circumstances of the farm and the user requirements. The domain knowledge of this subsystem contains two models, namely: suggestion, and selection. The inference knowledge contains three inference steps namely: specify, select, and count. The suggestion model contains a relation between the environmental conditions and the suitable varieties that is used by 'specify' inference step to suggest the paddy varieties suitable for the surrounding environments. The selection model contains a relation between user requirements and the corresponding varieties that is used by 'select' inference step to select, the most suitable varieties reflecting the user requirements. The 'count' inference step just counts the specified varieties (El-Azhary., 1998).

3.1 Land Use Planning and Management

Among the various ICT tools, Geographic Information Systems (GIS) and Remote Sensing (RS) techniques represent two key tools for land planning and management. GIS offers the opportunity to gather multiple layers of

information, drawn from different sources, into one spatial representation. This can be particularly useful in reaching consensus over land planning when users have different values and preferences linked to a given territory. Similarly, RS techniques are a valuable tool for monitoring land resources (e.g. Vegetation, water bodies, etc.), especially when a single institution is in charge of monitoring a wide area (E-Agriculture.org, 2017).

3.2 Land Preparation and Planting

Land preparation gives specific advises to the user about how to prepare specific land for paddy cultivation, while planting gives the suitable planting methods according to user specific inputs data. The domain model of this subsystem contains two models namely: establishment plan and assignment. The inference knowledge contains three inference steps namely: establish, assign, and select. The establishment plan model contains a relation between farr5 LAND USE: GIS ıs that is used by e:4 AGRICULTURE: GIS : a recommended plan and an alternative plans (Edrees, 2017). Application

3.3 Soil Quality Assessment

Assessment of soil quality can be done in farm level and also in regional level. In regional level it can be done based on soil, climate and land uses. Some useful technologies aid to understand nature of soil and its problems due to management practices. ICTs have developed several folds in the recent past. Soil quality assessment is being done with some useful technologies, like remote sensing.

3.4 *Application of Image processing in Grading Agricultural Products*

At the moment, mangoes are mainly handpicked or plucked with a harvester. These methods are tiresome and involve human capital.

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Water Management Technology

3.5 Role of ICT in Livestock Production

Farmer participation and buy-in Due to the livestock management activities that farmers are able to enter, they willingly participate on a daily basis to update the system with: New birth records and animal registrations; Regular weight recordings; Regular procedure or treatment records; Mating and breeding records; Pregnancy determination records; Movement records within their own herds (mobs / flocks etc.); Deaths or losses of animals; Early warning mechanism whereby the stock theft department could be notified, more quickly; Contribute to livestock statistics; Contribute to the national statistics of reproduction and production; Use more functions of the system to improve their livestock operations (multi-species); Grow with the additional functionalities (become more self-reliant rather than spoon-fed as with certain systems); Allows more public–private interactions vs purely a dominant public sector service (Deloitte, Alexander, De Graaf, Mukherjee, & Kumar, 2012).

3.6 Role of ICT in Agro-Meteorological Knowledge and Weather Forecasting

A common problem in developing countries is the lack of integrated means of processing and delivering agro meteorological information to small scale farmers. Even with improved agricultural technology and improved level of farm inputs the agricultural sectors of these countries operate below their potential level owing to the challenges imposed by the marked weather and climate variability (Mugenda, 2003). The above model shows the flow of information from various sources such as the farmers, the agricultural research institutes, meteorological stations and agricultural extension officers. The knowledge from these sources is brought together in the Knowledge Base (KB). This is then processed by the inference engine with some the algorithms as shown in the diagram. The system can perform various actions as shown. Small scale farmers can then interact with the system through short message services (SMS). The farmers can also obtain information through mass media (Lwande & Lawrence, 2008.).

3.6.1 Weather forecasting

The International Center for Agricultural Research in the Dry Areas (ICARDA) uses weather forecasting ICT tools, including meteorological stations and global information systems (GIS), so that scientists can collect and elaborate data to address the challenges that rural communities in dry areas face from the climatic stresses of aridity, drought, heat and cold. Weather stations are used to collect daily climatic data (for example precipitation, air temperature, and land temperature) that are analyzed by researchers to determine timely planting, crop development, climatic risk assessment and water-use efficiency practices (Zahedi & Morteza, 2012).

4. Conclusion

The primary challenge confronted in Agriculture sector is the need for increased production with the increasing population and decreasing natural resources needed for production. The key factors that impact on this are the scarcity of water, declining of the soil fertility level, effects of climate changes and the decreasing fertile lands that were utilized in cultivation in the past, due to rapid urbanization. However, this rapidly growing demand and the need for high quality products provide opportunities for the improvement of the livelihood of the rural communities. Therefore the Agriculture sector has to be enhanced with the aim of increased productivity that will lead to combat both rural and urban poverty and foster sustainable development through this. Based on this opportunity, the people engaged in Agriculture are in need of producing quality products with quality standards and regulations which will yield high. One of the best strategies to achieve this is the application and utilization of the rapid growing technologies in Information and Communication Technology. Although this is a new phenomenon, there are enough evidences to prove that the contribution of ICT to Agriculture has led to poverty alleviation and development in the livelihood of the stakeholders involved in Agriculture.

And probably the appropriate use of ICT at different levels of agricultural processes will lead to betterment in the efficiency and increased productivity. If the needs and importance of ICT to Agriculture is realized and deployed at proper places, they will be the most powerful tools that will lead to both economic and social empowerment.

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SPATIO-TEMPORAL ANALYSIS OF DROUGHT IN NORTH-WESTERN PART OF NIGERIA

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Abstract

Drought is a complex phenomenon which varies spatially and temporally in its extent, duration, frequency and severity. It becomes important to study the drought distribution characteristics on the time and space of a region and cause of the drought for the design and management of water resource systems (Rhee et al., 2007; Bao et al., 2011). Spatial and temporal analysis can also help to assess the exposure of water resources, vegetation patterns and the entire environment to drought. Researches on drought all over the World have shown that drought analysis gives important information on water deficit and its impact on agriculture and the hydrology of an area, which is a pre-requisite for mitigating drought and the planning of new water project. This study examined the occurrence of drought in north-western region of Nigeria. Problems related to drought includes: unpredictable commencement and end time of rainfall season, seasonal rainfall fluctuations, and long period of no rainfall. Monthly rainfall data was obtained from the Nigeria Metrological Agency (NIMET) for all stations considered. This covers up to 15years for seven different metrological stations namely: Gusau, Kaduna, Kano, Katsina, Sokoto, Yelwa and Zaria. Z-values (0.00) for the stations in the Mann-Kendall test indicate no trend in the rainfall data obtained for all the stations. Standardized Precipitation Index (SPI) was adopted for this study. SPI approach requires a transformation to the initial distribution of rainfall to achieve a normalized distribution. Drought analysis indicates that from 2007 till date, severe droughts have been recorded in all the stations for all the timescales (3, 6 and 12-month). With the observation of normal to severe drought in states within the region, an *appropriate management strategy must be adopted to mitigate these negative effects, as there is always the possibility of a repeat occurrence.*

Keywords: Standardized Precipitation Index, Spatial, Temporal, drought, Mann-Kendall, trend.

1. Introduction

Drought is a very common disaster in most countries of the world, particularly in the arid and semi-arid regions (Achugbu, and Anugwo, 2016). Drought is defined as a "period of insufficient rainfall either in time or in space". It is caused by low rainfall, often associated with high rates of evaporation. This causes crop failure, enough to cause a severe shortage of food in a rural population (Abdullahi, *et al*, 2006). The socio-economic and environmental impacts of drought affect many sectors of African economy (Olatunde and Aremu, 2013). Different types of drought can be distinguished, i.e meteorological drought, agricultural drought (soil moisture drought), hydrological drought and socio-economic drought.

Drought is a complex phenomenon which varies spatially and temporally in its extent, duration, frequency and severity. It becomes important to study the drought distribution characteristics on the time and space of a region and cause of the drought for the design and management of water resource systems (Rhee *et al*., 2007; Bao *et al*., 2011). Spatial and temporal analysis can also help to assess the exposure of water resources, vegetation patterns and the entire environment to drought. Researches on drought all over the World have shown that drought analysis gives important information on water deficit and its impact on agriculture and the hydrology of an area, which is a pre-requisite for mitigating drought and the planning of new water project. Therefore, a shift in focus to the provision of information in this direction is vital (Vicentra-Serrano *et al*., 2012; Masih *et al*., 2014).

There is no uniform method to characterize drought conditions and many different drought indices have been used to monitor meteorological drought since it triggers the onset of other droughts (Heim, 2002; Quiring, 2009). Several indices have been developed to evaluate the water supply deficit in relation to the time duration of precipitation shortage (Keyantash and Dracup, 2002; Heim, 2002). Irrespective of the category of drought, drought indices are the major variables for assessing the onset of drought and for defining different drought parameters like intensity, duration, severity and spatial extent. A large number of drought indices with various complexities have been used in many areas all over the world for various purposes. Drought indices are indicators used to characterize drought to assist decision makers for taking measures for mitigating its effects (Mendiccino *et al*., 2000). Some of the most popular indices used in the past include the Palmer Drought Severity Index (PDSI) (Dai, 2011), the self-calibrating Palmer Drought Severity Index (sc-PDSI), the Rainfall Anomaly Index (RAI), the Soil Moisture Drought Index (SMDI), the Standardized Precipitation Index (SPI) (Vasiliades *et al*., 2011), the Deciles, the Percent of Normal, the Crop Moisture Index (CMI), the Palmer Hydrological Drought Index (PHDI), the Surface Water Supply Index (SWSI) (Mishra & Singh, 2010; Gebrehiwot *et al*., 2011), the Standardized Anomaly Index (SAI), and indices based on the Normalized Difference Vegetation Index (NDVI) (Vangelis *et al*., 2013) etc. Hayes *et al*. (1999) showed from his studies that Standardized Precipitation Index (SPI) is more feasible than PDSI because of its versatile nature and flexibility for different timescales. Hayes *et al*. (2000) from their studies say that SPI has greater importance than PDSI because it provides a clear quantitative appraisal of three drought dimensions such as intensity, duration and spatial extent. Guttman (1998) recommended SPI than PDSI because of its simplicity, spatially consistency and its probabilistic nature in risk decision analysis. Similar advantage of SPI is also observed when compared with other indices like China Z Index (CZI), Z-score index, modified CZI, percent of normal and Effective Drought Index (Morid *et al*. 2006, Karavitis *et al*. 2011).

Keyantash and Dracup (2002) performed an evaluation among different drought indices based on six criteria, which is robustness, transparency, tractability, extendibility, sophistication and dimensionality, and observed SPI as the second highest ranked drought index, after the rainfall deciles. As a result, this index has been much used by different researchers for drought related study (Dutta *et al*. 2013). The main advantage of SPI is that it identifies emerging drought months sooner than the PDSI does (Jain *et al*. 2009). Past researches have proved that the SPI has many advantages over the PDSI and other indices because it is relatively simple, temporally flexible, spatially consistent and thus allowing observation of water deficits at different scales (Guttman 1998; Hayes *et al*. 1999, 2000; Szalai and Szinell 2000). Based on a comparative study between SPI and PDSI, it is suggested that SPI is a better indicator of soil wetness because of short-term representation of precipitation and soil moisture variation (Guttman, 1999).

Despite the increase in interest by many researchers, institutions and government of countries or regions in the area of drought management, there is a limited research capacity in Nigeria particularly in North-western region of the country to inform a dependable early warning system that can enhance the preparedness of the country to drought incidents (Adeogun, 2014). The aim of the study is evaluation of spatio-temporal characteristics of drought over selected states in North-western region Nigeria.

2. Materials and Method

2.1 Study Area

Northwest zone of Nigeria is located between Latitudes 9° 021N and 13° 581N and Longitudes 3° 081E and 10° 151E (Fig.2.1). The area so defined covers a land area approximately 212,350km^2 (Table 2.1). Northwest zone of Nigeria shares borders with Niger Republic in the northern part, Benin and Niger Republic in the Western part, Niger State and FCT to the south, and Yobe, Bauchi and Plateau States to the East. The climate of Northwest zone of Nigeria is the tropical wet-and-dry type (Koppen's Aw climate).

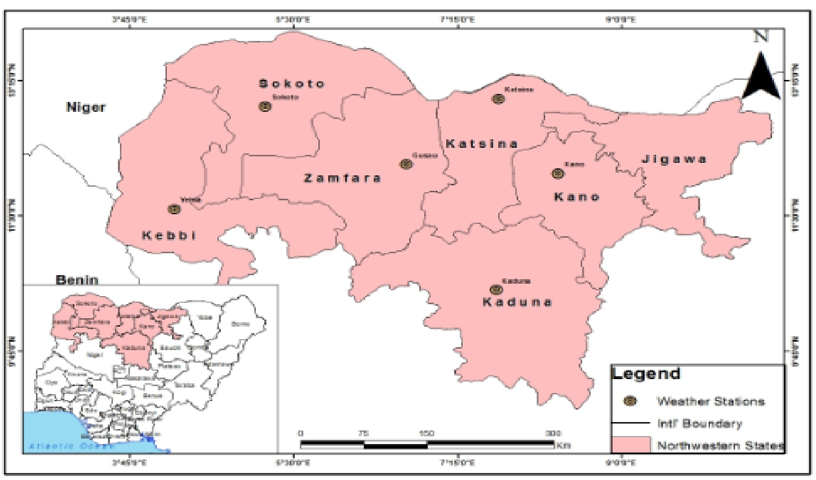


Figure 2.1: Map of North-western Region of Nigeria showing the study meteorological stations

2.2 Dataset

Fifteen years precipitation data ranging from 2006 to 2020 for the available stations under North-western Nigeria were obtained from the National Meteorological Agency (NIMET), Nigeria. Before the datasets were used for the analysis, they were subjected to quality control test. Some of which are days with missing values and possible outliers, which might have occurred due to human or measuring equipment errors.

2.3 Preliminary Data Analysis

Temporal changes in the monthly rainfall were analyzed by Mann-Kendall test to confirm the significance of the observed trends. Mann- Kendall test is a statistical test widely used for the analysis of trend in climatologic and hydrologic time series (Mavromatis and Stathis, 2011; Yue and Wang, 2004). There are two advantages of using this test in parametric test and does not require the data to be normally distributed, suiting perfectly for the nature of distribution observed in the study area. Second, the test has low sensitivity to abrupt homogeneous time series.

2.3.1 Mann - Kendall test for monthly or seasonal series

In line with Hirsch *et al*. (1982), the Kendall test in this regard allows for seasonality in the observations collected over a time period was employed; to do this, the Mann-Kendall test was computed on each season.

Thus, let the monthly or seasonal series be represented by the matrix

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1p} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{np} \end{pmatrix} \qquad (2.1)$$

Here, p is the number of seasons for n years under consideration; similarly, let the matrix

$$R = \begin{pmatrix} R_{11} & R_{12} \cdots & R_{1p} \\ R_{21} & R_{22} \cdots & R_{2p} \\ \vdots & \vdots & \vdots \\ R_{n1} & R_{n2} \cdots & R_{np} \end{pmatrix} \qquad (2.2)$$

denotes the ranks corresponding to the observations in x where the n observations for each season are ranked among themselves. Thus, each column of R is a permutation of (1, 2, . . ., n). Specifically, the rank matrix Rij was computed as

$$R_{ij} = \frac{1}{2}\left[n + 1 + \sum_{k=1}^{n} \operatorname{sgn}\left(x_{ij} - x_{kj} \right) \right] \qquad (2.3)$$

The Mann-Kendall test statistic for each season is

$$S_i = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}\left(x_{ji} - x_{ki} \right) \qquad (2.4)$$

where, n is water years, i = number of seasons and a season here is defined as one calendar month, and Si, the S-statistic in the Mann - Kendall test for season i (i = 1, 2, …, 12)

$$S' = \sum_{i=1}^{p} S_i \text{, p = seasons;} \qquad \sigma^2_{s'} = \sum_{i=1}^{p} Var\left(S_i \right)$$

To account for serial correlation, as in monthly flow or discharge processes, the variance of S' is defined (Otache, 2008) as

$$\sigma^2_{s'} = \sum_{i=1}^{p} Var\left(S_i \right) + \sum_{g=1}^{p-1} \sum_{h=g+1}^{p} \sigma_{gh} \qquad (2.5)$$

where the covariance matrix σgh is expressed as

$$\hat{\sigma}_{gh} = \frac{1}{3}\left[K_{gh} + 4\sum_{i=1}^{n} R_{ig}R_{ih} - n(n+1)^2\right] \tag{2.5.1}$$

$$K_{gh} = \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} \operatorname{sgn}\left[(x_{jg} - x_{ig})(x_{jh} - x_{ih})\right] \tag{2.5.2}$$

This is for a "no missing" data situation, and g and h are different seasons, respectively. The test statistic Z' which is standard normally distributed, is evaluated as

$$z' = \begin{cases} (S' - 1)/\sigma_{s'} & S' > 0 \\ 0 & S' = 0 \\ (S' + 1)/\sigma_{s'} & S' < 0 \end{cases} \tag{2.5.3}$$

2.4 *Standardized Precipitation Index (SPI) Calculations*

SPI is used to estimate the effect of droughts on various water supplies at different accumulation periods such as 3, 6, 9, or 12months and, hence, facilitates temporal analysis of drought events. In practice, the computation of SPI index in a given year i and a calendar month j, for a time scale k requires (McKee *et al*., 1993; Wu *et al*., 2007) the following steps:

1. Computation of cumulative precipitation series $\boldsymbol{X_{ij}^{k}(i = 1, \ldots\ldots, n)}$ for the particular period of interest j, where each term is the sum of precipitation of $\boldsymbol{k - 1}$ past consecutive months.
2. Fitting of cumulative probability distribution (usually gamma distribution function) on aggregated monthly precipitation series. The gamma PDF is defined as,

$$\boldsymbol{g(x) = \frac{1}{\beta^{\alpha}\gamma(\alpha)} x^{\alpha-1} e^{\frac{-x}{\beta}}} \tag{2.6}$$

   where $\boldsymbol{\beta}$ is a scale parameter, $\boldsymbol{\alpha}$ is a shape parameter, which can be estimated using method of maximum likelihood and $\boldsymbol{\gamma(\alpha)}$ is the gamma function at $\boldsymbol{\alpha}$. The estimated parameters can be used to find the cumulative probability distribution of observed precipitation event for the given month and particular time scale. The cumulative probability is obtained by integrating equation (2.), i.e.

$$G(x) = \int_0^x g(x)dx = \int_0^x \frac{1}{\beta^{\alpha}\gamma(\alpha)} x^{\alpha-1} e^{\frac{-x}{\beta}} \mathrm{d(x)} \tag{2.7}$$

3. As two-parameter gamma function is not defined for zero values, and precipitation distribution may contain zeros, a mixed distribution function (zeros and continuous precipitation amount) is employed, and the CDF is given by the following:

$$F(x) = q + (1 - q)G(x) \tag{2.8}$$

   where $G(x)$ is the distribution function for nonzero precipitation probability from the historical time series.

4. Because precipitation is not normally distributed, an equi-probability transformation is carried out from the cumulative distribution function (CDF) of mixed distribution to the CDF of the standard normal distribution with zero mean and unit variance, which is given as follows:

$$SPI = \varphi[F(x)] \tag{2.9}$$

This transformed probability is theSPI. A positive value of SPI indicates that precipitation is above average and a negative value denotes below average precipitation.

A drought period is assumed as a consecutive number of months where SPI values remains below a threshold of -0.8. Based on SPI range, drought period can be classified as moderate drought (-0.8 to -1.2), severe drought (-1.3 to -1.5), extreme drought (-1.6 to -1.9), and exceptional drought (-2 or less) conditions. Drought length or duration (D) is taken as the number of consecutive intervals (months) where SPI remains below this threshold value. Because the drought event is defined at aggregation of monthly time scale, the minimum duration of drought is 1month. Drought severity (S) is the cumulative values of SPI within the drought duration. For convenience, severity of drought event i, $Si(i = 1,2,...)$ is taken to be positive, which is given by (McKee *et al.*, 1993)

$$S_i = -\sum_{i=1}^{D} SPI_i \tag{2.10}$$

where SPI_i is value of ith period SPI for a D duration drought event. Figure2.2 depicts computation of SPI for three consecutive drought events over a particular time scale. In Figure 1, ti denotes initiation of drought event '2', and te shows termination of this specific event. The shaded area of drought event '3' shows the computation of drought severity over a particular time scale.

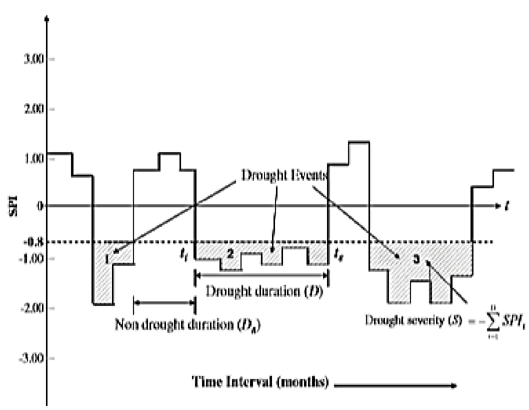


Figure 2.2: Depiction of drought characteristics using standardized precipitation index (SPI).

3. Results and Discussions

3.1 Mann-Kendall Test for Monthly Rainfall

The 15years monthly rainfall data for all the stations was examined in detail for possible changes in trend with the Mann-Kendall test which allows for serial dependence. In line with Hirsch *et al*. (1982), the Kendall test which allows for seasonality in observations collected over a time period by computing the Mann-Kendall test on each seasons was used. Results of Mann-Kendall test for monthly rainfall are presented below.

Table 3.1: Kendall tests on monthly rainfall.

Variables	Gasau	Kano	Kaduna	Katsina	Sokoto	Yelwa	Zaria
S	232.00	188.00	203.00	220.00	226.00	248.00	255.00
τ	0.18	0.15	0.16	0.17	0.18	0.20	0.20
Z	0.00	0.00	0.00	0.00	0.00	0.00	0.00

At 5% level of Significance

At 95% level of significance, the null hypothesis of no trend is rejected if |Z|>1.96. The Z-values for all stations therefore implies no trend in the data collected in all stations.

3.2 Standardized Precipitation Index (SPI) Results

Standardized Precipitation Index (SPI): Standardised precipitation index (SPI) was used for the analysis of the drought effect of annual rainfall in the various stations. The negative values indicate years with rainfall distribution ranging from near normal (normal (<=-1.2)) to extremely dry (severe (>=-1.5)) condition. Fig.3 to Fig.17 shows the SPI values for 3, 6 and 12 months timescales for different years ranging from 2006 to 2020. In the figures below, wet spells years were recorded in 2012, 2016, 2019 and 2020 where most stations have more of the wet spell than the dry spells in all the timescales (3, 6 and 12month). 2006, 2008, 2011, 2013, 2014 and 2015 experienced dry spells for 3, 6 and 12 month timescales. Other years (2007, 2009, 2010 and 2018) experienced equal amount of dry and wet spells for the timescales (3, 6 and 12-month).

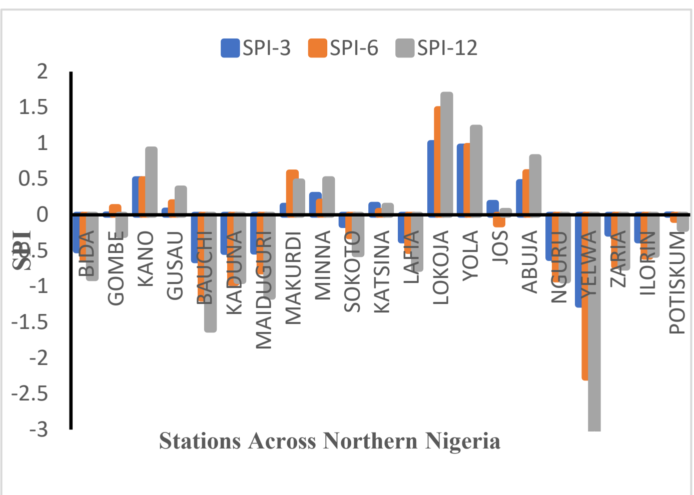


Figure 3: Mean Annual SPI values for the year 2006.

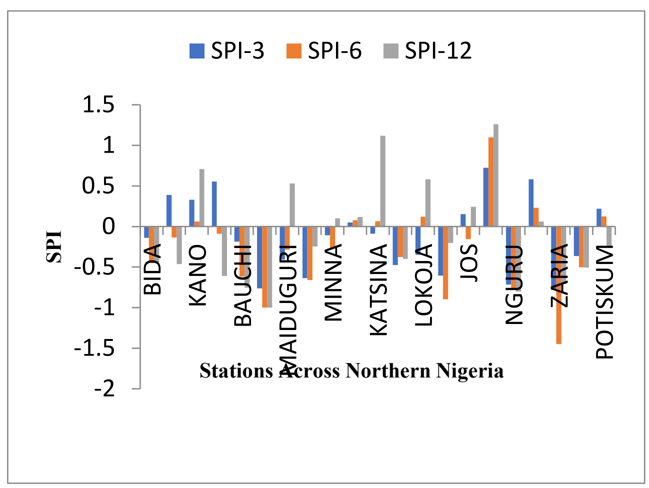


Figure 4: Mean Annual SPI values for the year 2007

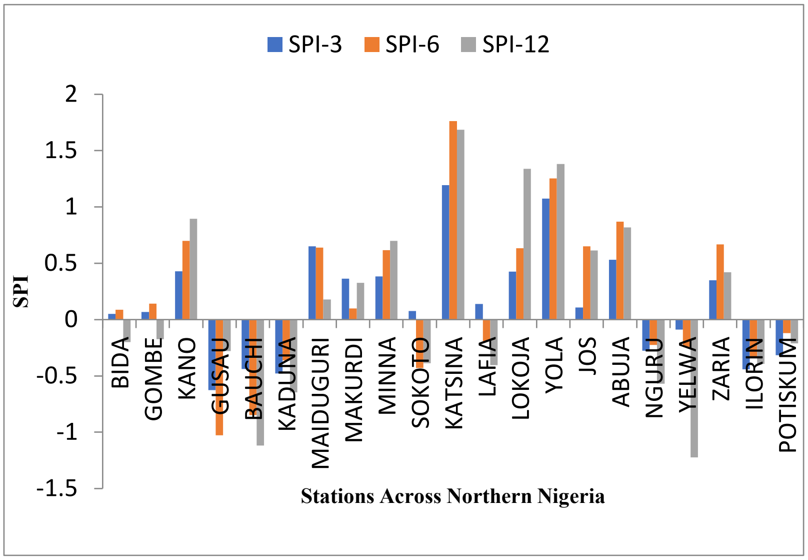


Figure 5: Mean Annual SPI values for the year 2008

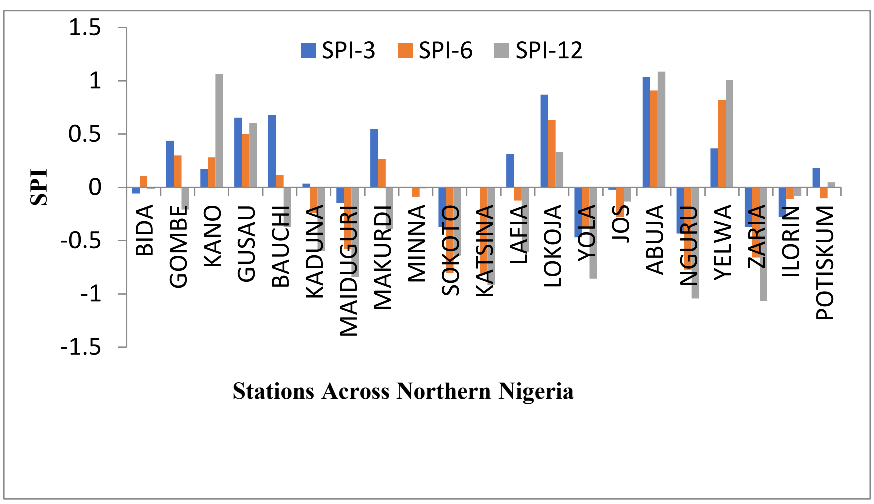
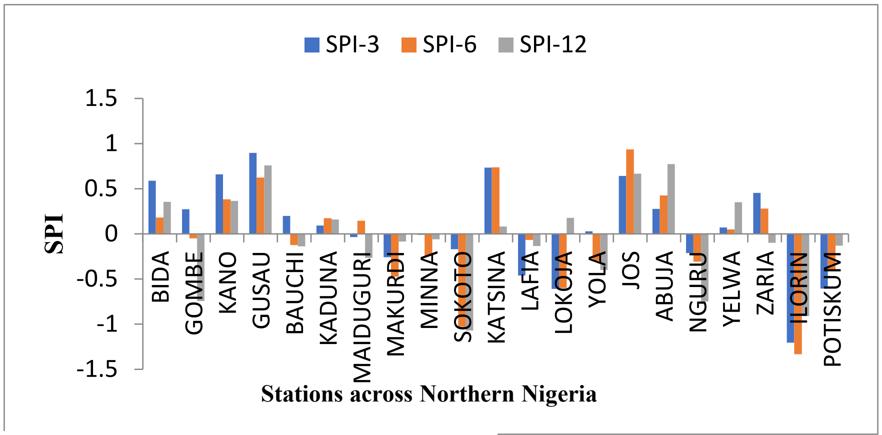


Figure 6: Mean Annual SPI values for the year 2009.



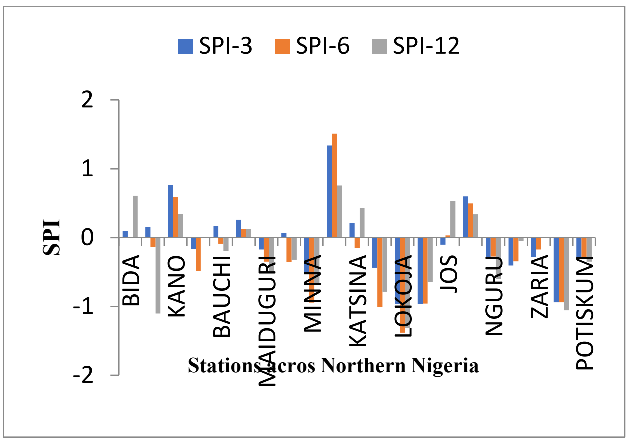


Figure 8: Mean Annual SPI values for the year 2011

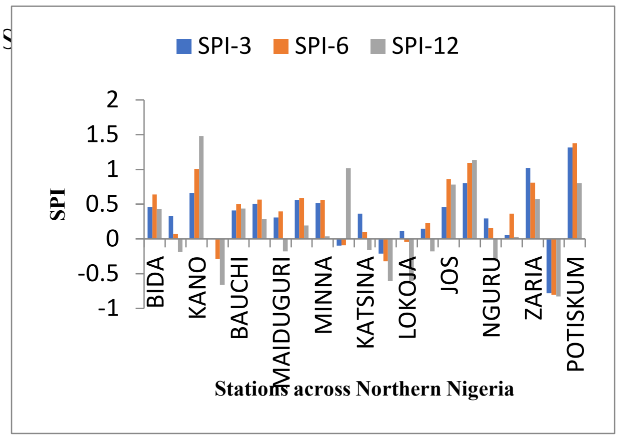


Figure 9: Mean Annual SPI values for the year 2012.

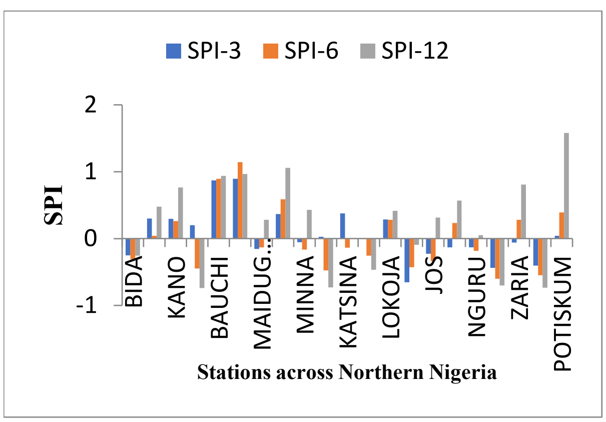


Figure 10: Mean Annual SPI values for the year 2013

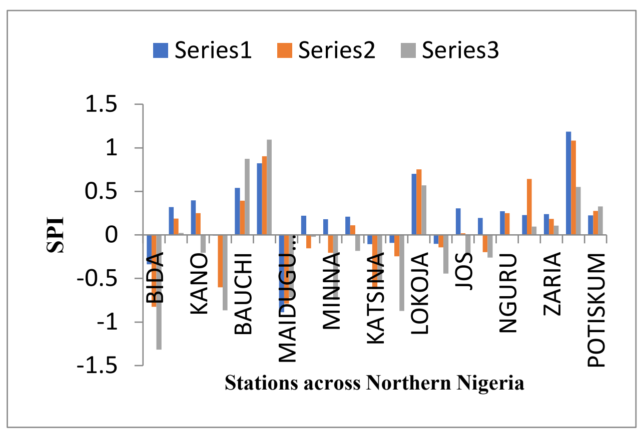
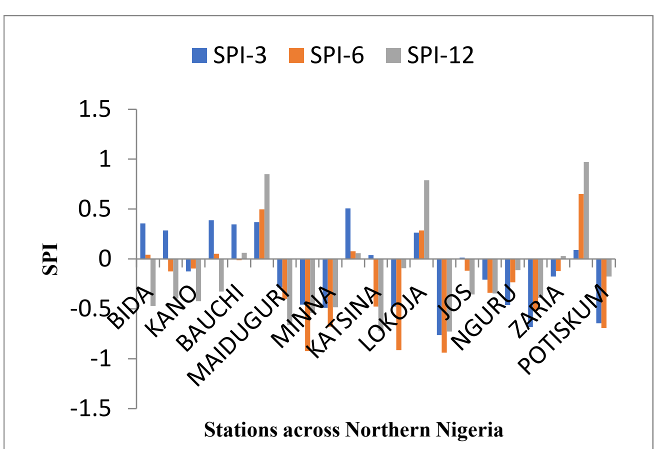
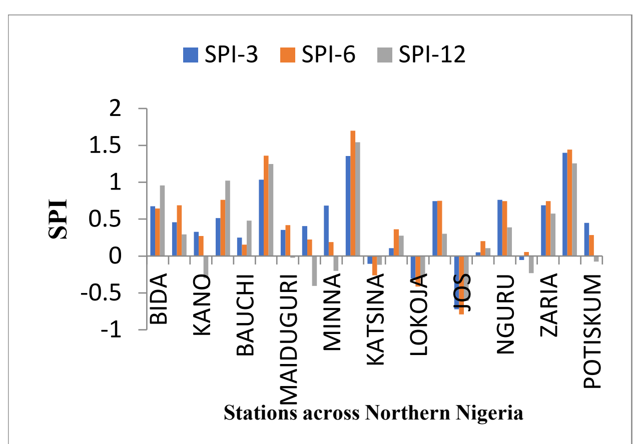


Figure 11: Mean Annual SPI values for the year 2014.





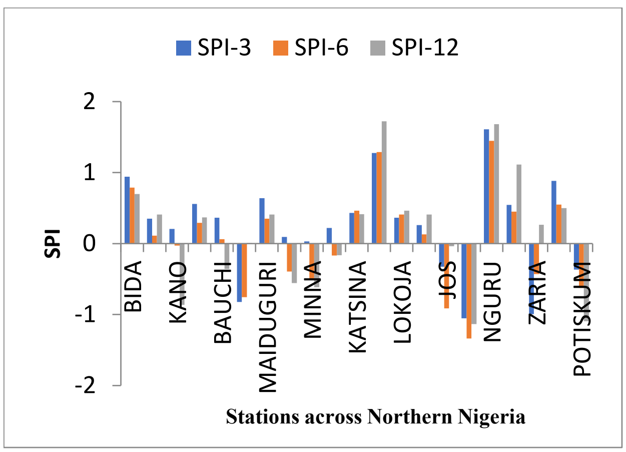


Figure 14: Mean Annual SPI values for the year 2017

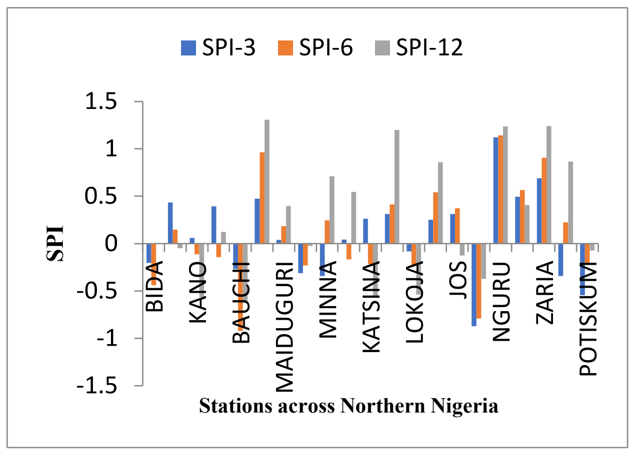


Figure 15: Mean Annual SPI values for the year 2018.

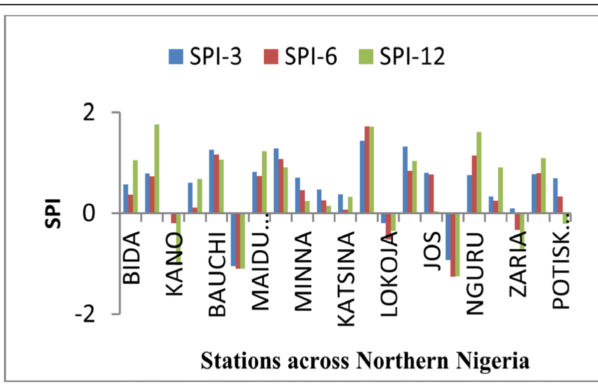


Figure 16: Mean Annual SPI values for the year 2019

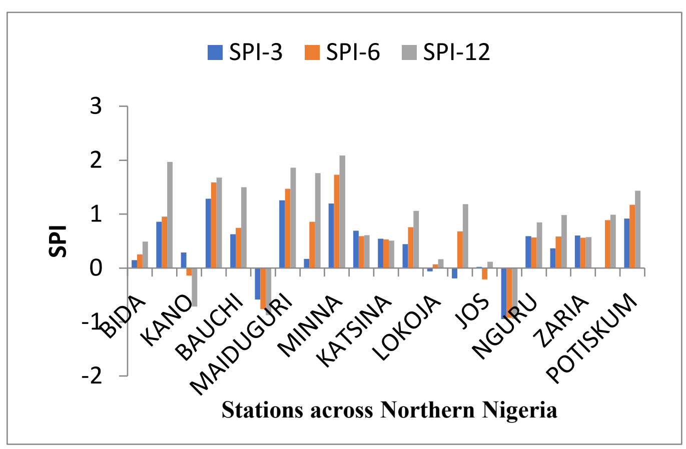


Figure 15: Mean Annual SPI values for the year 2020.

With the observation of normal to severe drought in states within the region, an appropriate management strategy must be adopted to mitigate these negative effects, as there is always the possibility of a repeat occurrence.

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DESIGN, FABRICATION AND PRELIMINARY TESTING OF ELECTRICAL DRYER

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Abstract

An electrical dryer was designed, fabricated and tested. Cassava (Manihot Esculenta) was used for the preliminary test. Mild steel was used for the construction housing of the machine. The essence was to control excessive heat being generated in the dryer; an electric hot plate (heating coil) of 2000 W was introduced as a source of heat. The Cassava was peeled and cut into chips of 2-4mm. This was blanched using water at a temperature of 70 °C to deactivate the enzymes, and then a sieve was used to drain the water. 500 g of Cassava chips was dried in the dryer. The preliminary test was carried out to determine the effect of temperature and drying time using the Cassava chips. The chips were dried with different temperatures of 70 °C 80 °C 90 °C and 100 °C at a drying interval of 0.5, 1.0, 1.5, 2.0 and 2.5 hours respectively. The drying time was varied at intervals of 30 minutes. From the results obtained, 500 g of chips was successfully dried for 2.5 hours at a temperature of 90 °C being the optimum temperature of the dryer. The final weight was 80 g at 13.34% dry basis.

1. Introduction

Drying is an excellent way to preserve food, and mechanical cassava dryers are and appropriate preservation technology for a sustainable world. Drying is one of the oldest methods of food preservation. It is the preservation of food by removing excess water. Actually, food drying is one of the best way in agricultural techniques related to food preservation for several thousands of years, people having been preserving potatoes, milk, corn, meat, and fish by drying, until canning was developed at the end of the 18th century drying was virtually the only method of food preservation (Whitefield, 2000).

The dried fruits and vegetables are light weight, and they do not take up much space and do not require refrigerated storage. The food scientist have found that by reducing the moisture content of food to between 10% and 20%, bacteria, yeast, are all prevented from spoiling it since micro-organism are effectively killed when the internal temperature of food reaches 14°F. The flavor and most of the food nutritional value of dried food is preserved and concentrated. More ever dried food does not require any special storage equipment and are easy to transport. In ancient days, drying was by natural, that is, through 'sun drying' and today in most rural communities of developing countries it is still in existence (Belhamri, 2003).

Drying help in reducing the moisture content of cassava root to the storable moisture content and determine the shelf modified definition of this work, the effort made by farmer to get this root to safe moisture content level for storage using the old method of drying such as open sun drying is ineffective, sometime lead to drudgery and huge losses such as picking by bird, losses due to weather condition. Baryeh, (1982) quotes that post-harvest losses of most West Africa root crops is over 27%. Therefore, to consider this rate of losses, inadequate of cheap open sun drying method and other method of drying including high cost of modern cassava dryer equipment as lead to search of alternative method of drying and dryer that can easily be available to the local farmers or processors irrespective of the weather condition of the atmosphere.

Thus, the objective of the study was to design, fabricate and test an electrical dryer for drying of cassava chips.

Figure 1: Cassava chips sample with different drying temperature.

2. Materials and Methods

2.1 Materials

The materials used for the construction of the mechanical cassava chip dryer which were simple to operate. The cassava chip dryer consists of a heating chamber which is made up of electric element (heating coil) which dissipates heat energy required, the drying chamber is made up of two rectangular trays of 380mm x 580mm and it is perforated at the base to allow air flow through it. The fan apartment which creates air flow within the dryer, the air conveys the heat energy needed to remove the moisture content of the chips and also serve as a means of transport for the moisture content out of the dryer to avoid condensation and rust. The effects of drying quantity, temperature and drying time on the drying rate of cassava chips is used to evaluate the mechanical dryer (Alonge and Adeyemi, 2010 ; Alonge and Adeboye, 2005).

In electrical dryer, the fresh cassava gets dried by passing about 60 ºC hot and dry air through the cabinet dryer. The fresh air through the blower is passed through heater where it gets heated to 60 ºC. For the heat exchange purpose in heat exchanger, it is designed in such a way that the heat from the heating element is transferred to the fresh air through mild steel baffles.

2.2 Design Considerations

- **i.** The total area of the outlet vents does not exceed 100mm.
- **ii.** The parameter used for the dimensions for the frame and casting of the dryer are the length L, width W, and thickness T.
- **iii.** The heating coil which supplies heat for drying of the cassava chips will be electrically powered, to ensure that the chips are properly dried within the specified drying temperatures (70%, 80%, 90%, 100%) with the quantity of 500 g, of cassava.
- **iv.** The fan / blower is used for distribution of air by drawing ambient air from the surrounding to the heating plate discharging heated air to the drawing chamber.

2.3 Design Calculations

2.3.1 Amount of moisture removed

The ambient temperature of the dryer was taken and recorded as 31.8 ºC while the Relative humidity was taken and recorded as 67.5%. Moisture content was determined according to the method of ASABE, (2006) and Oluwole *et al*. (2007b), by using the standard air oven method (Moisture content wet basis) as shown in Equation 1:

$$MC_{wb} = \frac{W_2 - W_3}{W_2 - W_1}\ x\ 100 \quad (1)$$

where: W_1 = Weight of empty Crucible, W_2 = Weight of Crucible + sample before over drying, W_3 = Weight of Crucible sample after oven drying.

2.3.2 Blower/Fan (Capacity)

From $Q_f = ML$ (ASHRAE, 1989)

where, Q_f = Amount of heat required (kJ),

M = Amount of water evaporated = 0.7kg

L= latent heat of vaporization of water (2260 kJ/kg)

$Q_f = 0.7\ x\ 2260 = 1582$ kJ/kg

This is the amount of energy that must be supplied by hot air

Now let mass of air required = M_{air}

Heat gained by fresh air Q_a = *Mwater* × *Lwater* = 40.26 x 2260 kJ

$$M_{air} = \frac{M_{water} - L_{water}}{C_{p,air} - \Delta\theta_{air}} \text{ (ASHRAE, 1989)}$$

= 40.26 x 2260/ (1.009 × (60 – 45))

= 91000/ (1.009 × 15)

= 91000/ 15.135

= 6012.55 kg of dry air for 30min

mass flow rate of air $M^{\cdot}_{air}$ = mass/volume

mass flow rate of air $M^{\cdot}_{air}$ = 6012.55 /(30×60×60)

= 6012.55/(108000) = 0.056 kg/sec

volumetric flow rate of air V= M'/ρ

= (0.056kg/sec) / (1 kg/m^3) [ρ=1 for air]

=0.056 m3/sec.

2.3.3 Heating element (capacity and number)

Heat gained by fresh air $Q_a = mCp\Delta t$ (ASHRAE, 1989)

91,000 = $mCp\Delta t$ = 91000 kJ

As the drying, Δt = 30minutes = 3600 seconds

Heater Capacity for ideal drying = 91000 kJ/(4*3600) sec = 6.32 kW

But for practical purpose, assuming efficiency 35 % only

Total Heater Capacity = 6.32/0.35 = 18 kW.

2.3.4 Trays (area and volume)

No of trays = 2

Tray length = 0.58 mm

Breadth of tray = 0.48 mm

Area of tray = L x B

=0.58 x0.48 =0.278 mm

Volume of the tray =L x B x L+
= 0.58 X 0.45 X 0.3 = 0.078 m^3
Spread of drying = 50 * 1000/154090 = 0.324 gm/c

2.3.5 Heat transfer rate, Q_{ht}

The heat transfer rate (Q_{ht}) can be determined (comwel, 1978) as:

$Q_{ht} = hAT_B$

where, h = heat transfer coefficient = $N_u k/d$ with N_u (Nusselt) = 121.3 =$0.13R_a{}^{0}.^{33}$
with $R_a = 10^9$, k as thermal conductivity = $0.0305KW/m^{20}C$;
A= surface area of the heat exchanger = $0.4096m^2$, and
T_B = temperature of hot air in the blower = $81^o{}_C$ the value of heat transfer rate (Q_{ht}) is therefore determined to be 818.15KJ.

Thus, the rate of heat transfer was computed as follows:

h = 24.66 $KW/m^2\ ^oC$
A = $0.4096m^2$
T_B = 81^oC
Q_{ht} = 24.66 x 0.4096 x 81
= 818.2KJ.

2.3.6 Quantity of heat loss

The quantity of heat that can be lost through the blower in the process is calculated as:

$q_1 = KAT_{BE}/\delta_k$

where q = quantity of heat lost (kJ), K= thermal conductivity of mild steel = 58 W/M.K, A= surface area of the blower =$0.10m^2$, T_{BE} = temperature difference between the hot air in the blower and the environment = 81-31 = 50^oc; and δ_k = distance = 1. The value of q_1 is therefore calculated to be 0.290KJ. The net heat transfer rate (Q_{htr}) that will reach the cabinet is (Q_{nt} - Q_{htr}) or (818.16-0.290) KJ which is 817.87 kJ.
Thus:

K = 58 W/m.k
A = 0.10 m^2
T_{BE} = 50 ^oC
δ_K = 1
q_L = 58 x 0.10 x 50/1 = 0.290 kJ
∴ Quantity of heat that can be lost = 0.290 kg

2.3.7 Actual heat used to effect drying (H_D)

The quantity of heat used in effecting drying H_D in kJ can be determined as:

$H_D = C_a\ T_c\ M_R$

where C_a = specific heat capacity of air = 1.005KJ/kg ^oc; M_R = amount of moisture to be removed = 53.66kg, and T_c = temperature difference in the dryer cabinet = 50-31 = 19 ^oC. The quantity of heat was therefore calculated to be 7550kJ.

2.3.8 Rate of mass transfer, Q_{mtr}

The mass transfer rate Q_{mtr} in kg is determined as follows:

$Q_{mtr} = M_c\ A_t\ (H_{r1} - H_{r2})\ x\ q_2$

where, M_c = mass transfer coefficient of a free water surface =0.083kg/m^{2}s, A_t = total surface area of the three trays = 0.336cm^2, (H_{r2} - H_{r1}) = (0.016 - 0.008) = 0.008kg/kg dry air, and q_2 = air flow rate = 100.26m^3/s. the mass transfer rate is therefore calculated to be 0.02kg.

$Q_{mtr} = M_c At (Hr^1 - Hr_2) x q_2$

Mc = 0.083 kg/m^{2}s

At = 0.336 m^2

Hr^1 = 0.008

Hr^2 = 0.016

q_2 = 100.26 m^3/s

Q_{mtr} = 0.083 x 0.336 (0.016 – 0.008) x 100.26

Q_{mtr} = 0.02 kg

2.3.9 Thermal efficiency of the dryer, η_c

From equation 1.

$\eta_c = H_D/Q_{ht}\ x\ t$

H_D = 7550KJ

Q_{ht} = 818.2 kJ

T =12 hours

$$\eta_c = \frac{7550 \text{ kJ}}{818.2 \times 12} = 76.9\%$$

(UNEP, 2006)

2.3 Component of the Mechanical Cassava Chips Dryer

(a) Drying chamber
(b) Heating element
(c) The fan/blower
(d) Regulator

2.3.1 Drying chamber

The drying chamber is the part of the dryer where the cassava chips to be dried are fed and drying takes place. The chips are fed into trays first and these trays are then fed into the drying chamber.

2.3.2 The Heating Coil:

The heater supplies heat for the drying of the grains and will be electrically powered. To ensure that the cassava chips are properly dried within the specified drying temperature (40 °C), the right power the rating must be determined.

2.3.3 Fan/Blower

The fan aids in heat distribution by drawing ambient air from the surrounding to the heater housing and discharging heated air to the drying chamber.

2.3.4 Regulator

The regulator is simply the unit that controls temperatures in the drying chamber. It is made up of the off and on switch.

Figure 2: Constructed Electrical dryer.

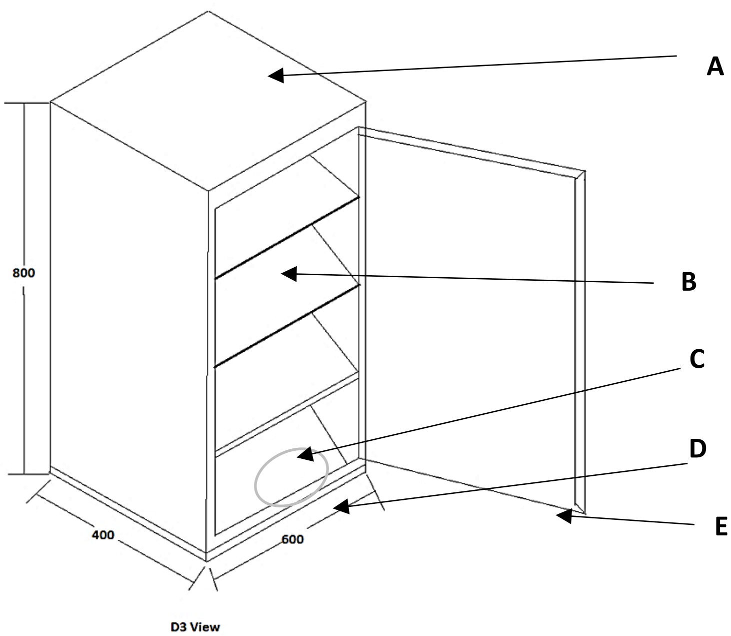


Figure 3: Isometric view of the electrical dryer.

Legend	
Part Label	**Part Name**
A	Dryer casing
B	Tray
C	Hot plate
D	Fab/blower enclosure
E	Dryer door

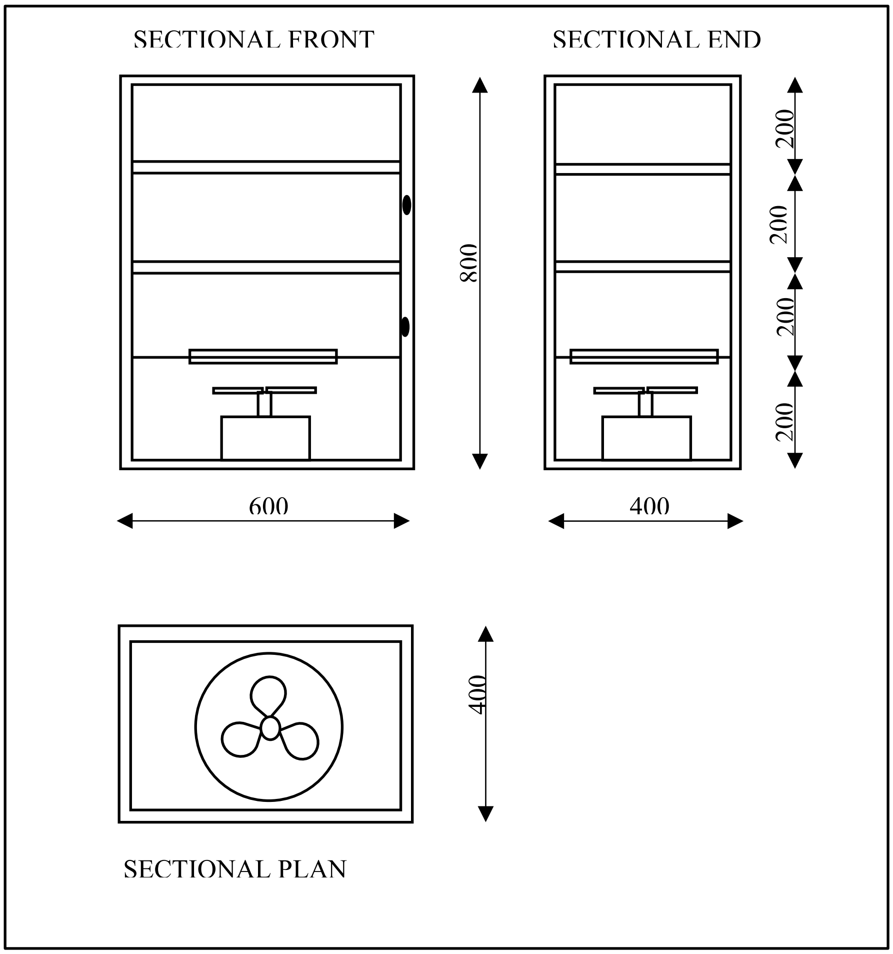
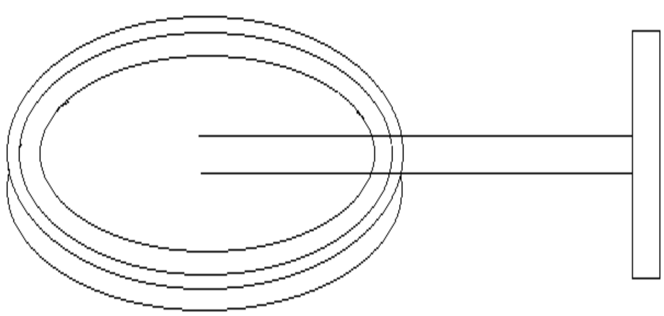
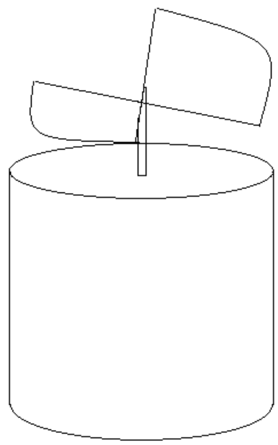


Figure 4: Sectional orthographic views of the electrical dryer.

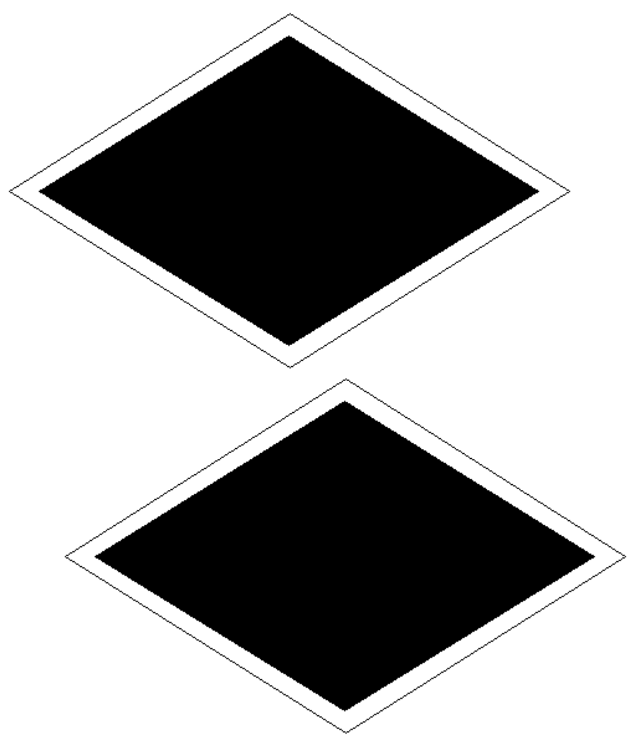


Heating Plate



Fan/Blower

Figure 5: Exploded View of the electrical dryer components.



Tray

Product Description

Table 1: Component Parts and Material Used

Components	Dimension (mm)	Reason(s)
Mild steel housing	400 x 600	Suitable for heat retention
Wire gauge tray	380 x 580	Best for heat radiation
Wooden handle	12	Accurate for opening
Angle pipe	380 x 580	For tray support
Wooden frame	400 x 600	Support for packing
Blower chambers (steel)	380 x 580	Adequate heat circulation
Aluminum base	400 x 600	Strength for the machine
Packing cock	25kg	To prevent excessive heat
Hot plate	Ø 20	Heat source

Measured Parameters

- **i.** The size of the chips was 2mm – 4mm by using a micrometer screw gauge
- **ii.** The quantity of fresh cassava chips using a weighing balance to weigh the chips was 500g.
- **iii.** The drying temperature in the drying chamber was measured using a digital thermometer.
- **iv.** The drying time was measured using a stop watch
- **v.** The ambient temperature of the dryer was measured using a digital thermometer.

2.4 Performance Evaluation

The evaluation of the mechanical chip dryer was carried out using Cassava. The cassava was obtained from a farm in Uyo, Nigeria and was peeled and cut into chips of 2 mm – 4mm with a knife. A quantity of 500 g was weighed and blanched with water at 70 ºC. The purpose of the blanching is to deactivate the enzymes. The weighed blanched chips was feed in the dryer at a temperature of 70 ºC. The moisture content was determined after 30minutes interval. The above process was repeated with temperatures of 70 ºC, 80 ºC, 90 ºC, and 100 ºC respectively. The size of chips was checked and drying time was varied from 0.5 hours to 2:30 min hour intervals of 30 minutes. This experiment was repeated twice and the average drying rate (%/hr) was recorded.

3. Results and Discussion

3.1 Test Result

The dryer was tested with 500 g of cassava chips of 2 – 4 mm thickness for temperatures of 70 ºC, 80 ºC, 90 ºC, and 100 ºC, at drying periods of 0.5, 1, 1.5, 2, and 2.5 hours respectively for drying to a safe moisture content level for storage. The size of chips remains the same and drying time varies from 0.5 hours to 2.5 hours at intervals of 30 minutes. The experiment was repeated twice. The average drying rate was computed.

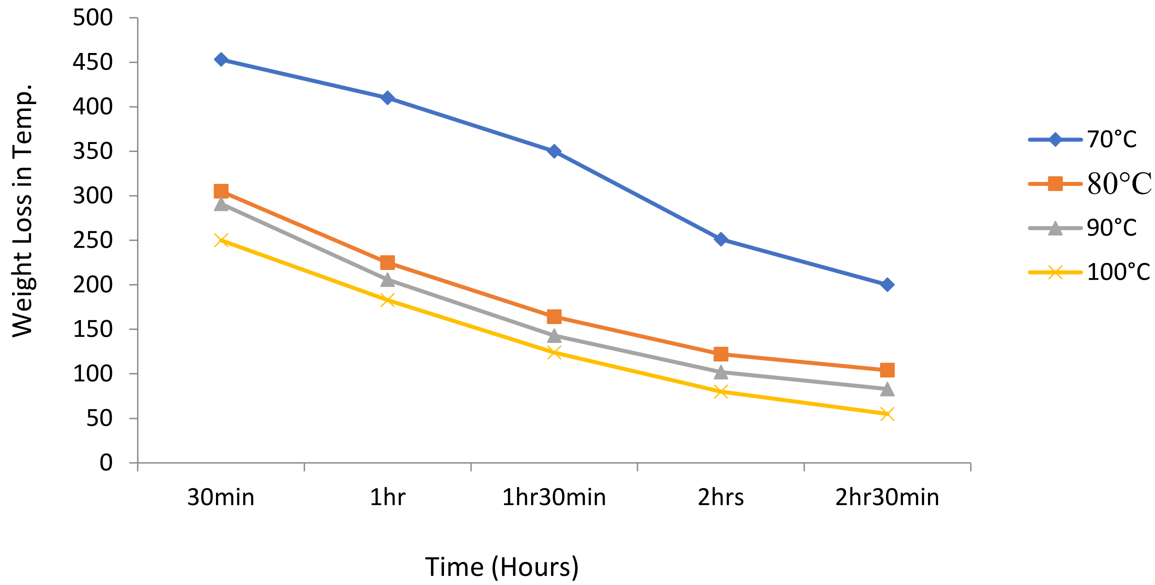


Figure 6: A graph of average weight loss against time for 500g.

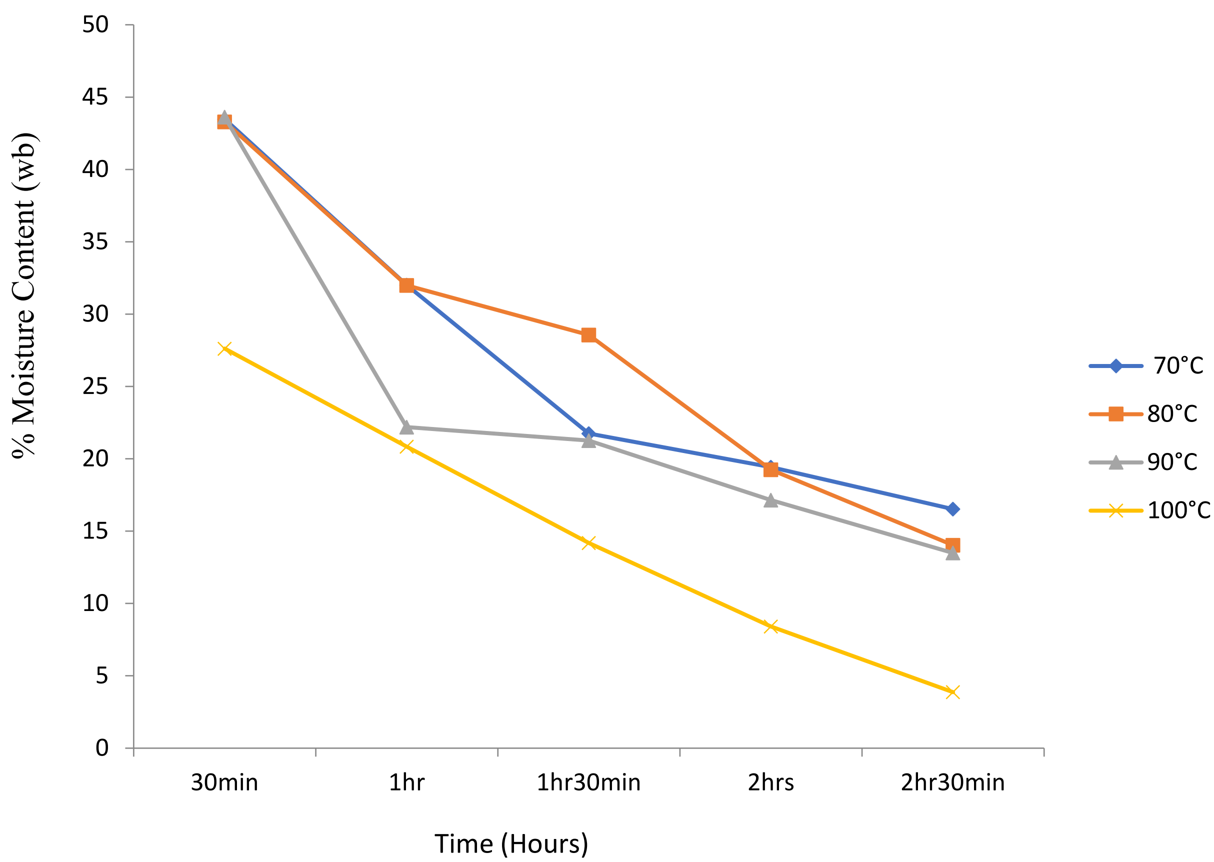


Figure 4.2: A graph of average moisture content (wet basis) against time for 500g.

Cassava chips were dried in a mechanical dryer at four temperatures 70 ºC, 80 ºC 90 ºC and 100 ºC. From the experimental analysis, it was observed that drying took the single falling rate period except at 100 ^{0}C where samples experienced second falling rate period. Also temperature played an important factor in removing moisture in the samples; at higher temperature of 100 ºC, samples dried faster than at 70 ºC. The effective moisture diffusivity of the sample was within the range of agricultural produce and it increased as temperature increased. The activation energy of the sample was comparable and was within the range of other agricultural product. Fick's law of diffusion which state that moisture diffusion is temperature dependent. The value of Deff increased as the temperature increased.

From the results obtained, it indicates that the time taken for drying was faster with an increase in temperature, that is to say an increase in temperature will decrease drying time and vice versa. This trend is based on the principles of Fick's law of diffusion. This indicates that less time is needed for drying when the temperature is at a high degree.

It was also revealed that at a lesser temperature of 70 ºC the cassava chips are dried for a period of 2.5 hrs to attain a measured weight of 200 g. Consequently, at the highest degree of temperature which is 100 ºC the chips attain an average of 250 g at 0.5 hrs.

4. Conclusions

The electrical dryer was developed to determine the efficiency and the agricultural product used was cassava. The performance of the dryer was determined using cassava chips during the experiment with respect to temperature at different time intervals.

Therefore, the following conclusions were made:

1. Drying rate increased with increase in temperature
2. The product used for testing attained it safe moisture content before 30mins of the first reading.
3. The drying product got burnt at the time 1 hr and above.
4. The dryer is very hot that the least temperature 70 °C used for the practical was the most suitable for the drying.

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WASTE GENERATION IN SHEA BUTTER (*Vitellaria paradoxa*) PRODUCTION AND ITS MANAGEMENT: A REVIEW

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Abstract

Waste disposal is a big challenge in shea butter industry in the presence of tannin, an environmental pollutant which is toxic to soil microbes, makes the waste recalcitrant to biodegradation and unacceptable to animals as feed. Wastes generated during Shea butter processing are indiscriminately disposed thereby becoming menace to the environment There is lack of enough research into handling and Management of waste from shear butter production. There is different method of shea butter processing and each resulted to waste generation. These methods include: Traditional (local), Mechanical and chemical methods. Local method of shea butter production generates more wastes than mechanical and chemical methods. The negative effects of shea butter waste on environment includes: choking of drain, breed mosquitoes, water borne ailments, generate foul odors and also people using local method of processing normally suffer from smoke related diseases. Waste generated in shea butter production includes: Husk- for removing heavy metals from waste water, making flower vase, plates and decorations, Slurry- Used for local air fresheners, local provision of lightening (candle), Black deposits- used for the filling of cracks in buildings, paint making and local ink usage on slates and board and Waste Water- After potential treatments, can be used for domestic activities of washing, as insecticide and for irrigation farming.

Keywords: Shea production, wastes, Husk, slurry, lManagement, and environmental protection

1. Introduction

For millions of years, shea trees have grown across Africa within a semi-arid zone known as the Sahel-Savannah. And for thousands of years, people have used shea nuts from the trees to make shea butter, an edible fat that is a part of daily life for millions of Africans and, today, for billions around the world (Lovett, 2018). The tree is considered a valuable asset in many parts of Africa where it can be found because of its high yielding edible oil for domestic use and products for cosmetic and pharmaceutical uses. It is important for the livelihoods of the rural population as it has been for over centuries (Lovett and Haq, 2000). Almost every part of the tree has its use, for example: the fruit is eaten and the leaves are used as fodder and serve as an ingredient for making alkaline and paint (Lovett and Haq, 2000). When the leaves are put in water, it forms a frothy opalescent liquid, which is used to bath a patient. The shea tree grows well in 19 countries across the African continent including Nigeria.

Despite the nutritional and economic benefits of Shea, its processing causes a major environmental issue which has become a major public health and environmental concern. Wastes generated during Shea butter processing are indiscriminately disposed thereby becoming menace to the environment.

2. Uses and Application of Shea and Shea Products

Almost every part of the shea tree is used, for example, the fruit is eaten and the leaves are used as fodder for animals and a good alkaline for the paint industry. It also has a wide range of medical and industrial applications. Shea provides fruits for direct consumption, providing good quality vitamins and energy to rural dwellers. The shea seeds/kernels (nuts) from these fruits are sold raw as kernels or further processed into shea butter for cooking, skincare, medicine, and other benefits in many areas of human well-being and rural development (Lovett, 2004) Again, the fruit pulp is an important local nutritional resource, widely eaten by adults and children, and provides a rich source of ascorbic acid, iron, calcium, and vitamins A and B (Hall *et al.,* 1996). The vitamin and mineral-rich vegetable butter extracted from the nut provides a preferred cooking oil of most households especially in rural settlements. It enhances the taste, texture and digestibility of the local dishes. The kernel of the seed contains a vegetable fat known as shea butter.

Lovett (2000) reported that the trees provide regulation through carbon sequestration, wind breaks, and preventing erosion in addition to serving as a habitat for other organisms and direct provisioning of fruits. Shea butter is also used locally as a skin and hair `moisturizer, in soap making, as a waterproofing wax and illuminate. It is applied to African percussion instruments (djembe shells, calabash gourds) to increase the durability of wood and leather tuning straps (Hall *et al.,* 1996).

The wood is used for charcoal, construction, for furniture and as pounding mortars (Dalziel, 1937; Abbiw, 1990). The bark is used for traditional medicines and the latex is used for making glue. Shea trees provided fodder for 70% of surveyed households in Nyankpala, northern Ghana (Poudyal, 2011). The husks of the seeds make a good mulch and fertilizer. Studies on the by-products of shea-butter processing have shown that heavy-metal ions can be removed from aqueous solutions, for example waste water, using *Vitellaria* seed husks. Other uses Shea butter as a vegetable fat obtained from the seed. Allantoin, an un-saponifiable compound, is responsible for the anti-inflammatory and healing effect on the skin. Shea butter is also very suitable for making candles because of its high melting point. The black sticky residue, left after oil extraction, is used to fill cracks in walls and as a waterproofing material. Waste water from shea butter production has pesticidal properties. The press cake and the husks remaining after oil extraction are potential fertilizers and fuels. The leaves, soaked in water, produce a good lather for washing.

2.1 Medicinal Uses

Medicinally, Shea Butter is used for topical medicines against rheumatic and joint pains, wounds, swellings, dermatitis, bruises, and other skin conditions. It is also useful as relief from nasal congestion and rhinitis. (Protabase - Plant Resources of Tropical Africa. The leaves are used to treat stomach pain and headache. Ground roots and bark are used to treat diarrhea, jaundice, and stomach ache. Bark infusions have antimicrobial properties and are used against dysentery, (Gaertn, 2012).

3. Methods of Shea Butter Extraction

The traditional water-based extraction (Home-based) method is the commonly used method Mechanical extraction also known as the press method (Cold/Wet press and Hot-press) uses screws and hydraulic instruments. Chemical extraction method which uses solvents such as Ether is industrial-based extraction process, which depends on improved technology and inputs (Hall *et al.,* 1996).

3.1 The Traditional Extraction Method

Iddrisu (2013) list the equipment for primary processing of shea nut into butter and cake to include pan for boiling water, drying mat, mallets, pestles, winnowing basket, and clay pot**.** He stated that there are two main methods for shea butter extraction: a traditional village process and a mechanical procedure. The traditional process involves many time consuming stages. Using a shea nut press does not only alleviate time consuming process but also improves the fat output. For example, using a shea press fat output will be between 40 to 45% whereas fat output using the traditional method will be about 25% (Niess, 1983)

The traditional processing of shea fruit and extraction of shea butter, also reported by Dalziel (1937) as labour-intensive, women dominated, time consuming and tedious, yielding only 25% of butter (Iddrisu, 2013). The dried kernel is crushed by pounding in large mortars, crushing with stones or mills and roasted to concentrate the oil. Roasted and crushed kernels are dried to further reduce moisture content and ground into paste. Kneading of paste vigorously with warm water is carried out until a white coagulated crude shea butter paste containing oil separates from the water suspension. This paste is whisked out of the water into a pot and boiled in water until oil floats on top. The remaining brown suspension containing mainly nut deposits which solidifies to form the shea nut cake is discarded as waste. The oil, in liquid form, is scooped out into containers leaving behind in the pot a black paste as waste being charred nut deposits that followed the crude shea butter. The oil is then allowed to cool and solidify at room temperature into shea butter. This process is aided by constant stirring with clean dry sticks. The solidified butter is then packaged either as balls or into large containers for market

Figure 2: Local Method of Shea Production.

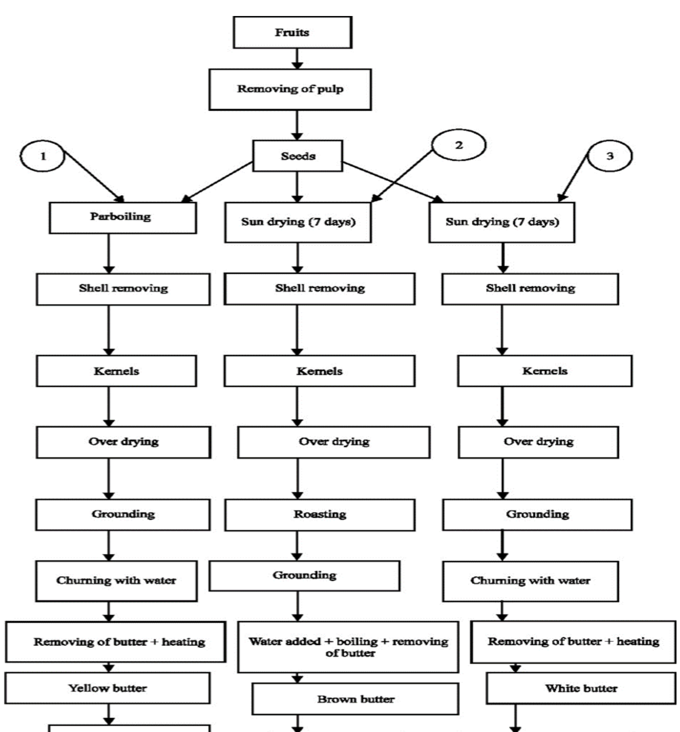

Fig. 3: Flow chart for local processing of shea butter (Agyente *et al.*, 2010)

3.2 Mechanical Extraction Method

Despite the introduction of some technological innovations in the traditional extraction processes such as mechanical crushers, mills and kneading machines, shea butter yields and extraction efficiency by this method are still woefully low (Iddrisu, 2013 cited in Danikuu, 2016). The mechanical extraction method involves the use of expellers and hydraulic pressers.The mechanical extraction technique involves heating the nuts to 15-20^{o}C crushing and then pressing the crushed nuts to release the oil and a first extraction cake. The first extraction cake is further pressed in a second expeller to release more oil and a second extraction cake. As much as 25-80% of shea butter is produced from shea nuts with the mechanical process as against about 25% from the traditional water-based method (Iddrisu, 2013 cited in Danikuu 2016).

Figure 4: Local Method of Shea Production.

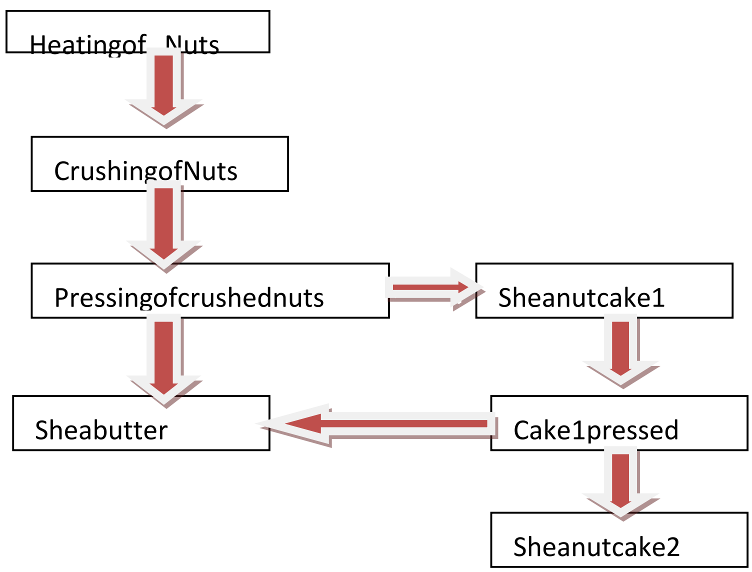

Figure: 5: Flow Chart for Mechanical Processing of Shea Butter (Iddrisu, 2013).

3.3 Chemical Extraction Method

This method employs a solvent such as hexane or ether and extraction efficiency is highest as compared to the two techniques described above. The solvent is mixed with the crushed shea nut and after the butter is extracted in the solvent the solvent is subsequently separated from the solvent-oil mixture by distillation. The method can be applied alone or in combination with the mechanical press method (Iddrisu, 2013). In this integrated method the second extraction cake is directed into a chemical plant where a suitable solvent, such as hexane is added at a ratio of 5 L to a tonne of shea nut (Iddrisu, 2013). The solvent is subsequently separated in a distillation plant. The process yields 98% extraction efficiency (Iddrisu, 2013 cited in Danikuu , 2016). Extraction efficiency is higher in mechanical than traditional and highest in chemical method of extraction, especially when mechanical and chemical are combined.

4. Shea Butter Production in Niger State

Niger State is on the verge of becoming the main hub for Shea Butter in Nigeria. Currently, the state boasts of having the largest collection of Shea trees in the world, controlling about 54 per cent of all the trees in Nigeria and of the vaunted 325,000 metric tonnes of Shea nut and butter exported from Nigeria (Olumide, 2018). According to Olumide (2018), for the State to tap fully into the economic potentials of the Shea tree, it appointed a consultant, First Heritage Global Investments Limited, leading a team of experts, to come up with the Niger State Shea Sector Development Programme (NSSSDP).

Women in Niger State have found the real gold mine in shea processing. From shea butter alone, they have established a major export hub in the state, reputed as the leading exporter of raw shea nut in Nigeria. From Lavun to Bosso, Katcha, Rijau, Mokwa, Mashegu, Mariga, Tafa, Agaie, Wushishi and Edati Local Government Areas (LGAs) lie sprawls of shea trees in the wild from which families in Niger State derive their subsistence, especially from shea butter, one of the most used products obtained from the shea nut. (Onche Odeh, Daily Independent Newspaper)

A survey conducted by Solomon *et al.* (2017) in four local government area of Niger State (Lapai, Katcha, Gbako, and Bosso) with the highest shea butter producers revealed that about 63.2% of the respondents produce between 10 and 30kg of Shea butter per month at the peak period of production. Only about 1.3 percent of the respondents produce above 50kg of Shea butter per month during peak production period while about 5.2 percent produce less than 10kg. According to Solomon *et al.* (2017) the butter production output per month is very low considering the level of work done in the realisation of the butter and recommended that Adoption of improved Shea nut processing technologies and introduction of best practices in Shea butter production by the processors could provide needed intervention to improved butter production output. Below is the table that shows the Respondents Shea Butter Production Output per Month

5. Wastes in Shea Production and Potential Usage

Husk: for removing heavy metals from waste water, making flower vase, plates and decorations. **Slurry:** Used for local air fresheners, local provision of lightening (candle).**Black deposits:** Can be used for the filling of cracks in buildings, paint making and local ink usage on slates and board. **Waste Water:** After potential treatments, can be used for domestic activities of washing, as insecticide and for irrigation farming.

Figure 6: Slurry and Wastewater and Husks from Shea Production.

Waste disposal is a big challenge in shea butter industry in the presence of tannin, an environmental pollutant which is toxic to soil microbes, makes the waste recalcitrant to biodegradation and unacceptable to animals as feed. Inadequate funding by central government, stakeholders and non-governmental organizations to unearth and exploit the full benefits of the sector. Training in the sector geared towards improving the sector which still depends on very old extraction methods is lacking. There is therefore lack of enough research into handling and Management of waste from shear butter production. Local method of shea butter production generate more wastes than mechanical methods and list negative effects of the waste on environment as. It chokes the drain, breed mosquitoes generate foul odours and also reported that people using local method normally suffer from smoke related diseases. It generate large quantity of wastewater which breed mosquitoes and other water borne ailments (Figure 8).

Figure 7: Scene from Improper Management of Shea Wastes.

Figure 8: Pollution of River Course by Wastewater from Shea Production.

5.1 Potentials of Shea Wastes

(Quainoo *et al*., 2015) reported that Shea shells can be used to phytoremediate soil polluted with Iron, Manganese, Zinc and Copper. (Abdul- Mumeen *et al.,* 2013) also reported that Shea nut cake can be converted into briquette and also has bio-phytochemical properties. (Adazabra *et al.,* 2017) also reported that spent shea water can be added to clay to produce fire clay brick and that the wastewater if sedimented and dried, the slurry can be used as bio fertilizer with some additives (Figure 9.) Ray, 1994 and Mazzafera, 2002, have also reported the use of microbes or microbial enzymes to decompose toxic pollutants in Shea slurry into harmless substances. This innovation has worked and has converted tannin-rich shea husks slurry and pulp to animal feed.

Figure 9: Organic Fertilizer Produced from Combination of Shea Slurry and other Additives.

6. Conclusions and Recommendations

6.1 Conclusion

In the extraction of Shea butter, it is very obvious that a lot of problems are encountered. These problems reduce the efficiency of shea butter production most especially its quality and quantity as seen in the amount of waste generated from it. It is therefore evident that by solving all these problems, there will be improvement in the extraction of Shea butter (the quality and quantity). Since Shea butter is a very good vegetable oil used for so many purposes, improvement in the yield and quality will bring about improvement in income for the people that engages in this occupation and also more Shea butter in the market. Deforestation is also identified as one of the menace contributing to low productivity of the Shea nut.

6.2 Recommendations

Training should be provided and encouraged for the people involved in this extraction on the use of the equipment and also its maintenance and management of the waste. Finally, the government should render the necessary assistance required in supporting research and development in terms of funding upgrading of the existing Shea butter local cottage. Marketing of the finished product (Shea butter) to the right channel. Encourage concerted research effort on Shea butter; an initiative similar to Cassava and Rice production.

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