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AGRICULTURAL ENGINEERS

(A DIVISION OF NIGERIAN SOCIETY OF ENGINEERS)

Theme:

Innovative Agricultural Mechanization and Rural Development For Economic Transformation And Food Security

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BOOK OF FULL PROCEEDINGS

Asaba, Delta State, Nigeria

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WELCOME REMARK

On behalf of National Executive Council, members of the Local Organizing Committee, I want to welcome you for participation in the International Conference on Agricultural Engineering of the Nigerian Institution of Agricultural Engineers (NIAE) holding in Asaba, Delta State, Nigeria between September 20 and 23 2022. This is the third time in the history of NIAE when the conference will hold in South-South Region of Nigeria. The first time was in Yenagoa, Balyesa State in January 2006. The second was in Uyo, Akwa Ibom State in October 2013. This is however the first time that the conference will be holding in Delta State State of Nigeria

The Conference was initially scheduled to hold in Calabar, Cross Rivers State but had to be moved to Delta because they were not ready. Asaba is a rapidly growing city in Nigeria with an International Airport and good road network as well as infrastructure. The airport links Lagos and Abuja hence the choice of the venue apart from the fact that it is an Agrarian State. The main aim of this International Conference to provide a forum for engineers and associated professionals for sharing of information and knowledge on current research developments, achievements and practical applications in all disciplines related to Agricultural, Food and Bioresources Engineering.

The theme of the conference is "Innovative Agricultural Mechanization and Rural Development for Economic Transformation and National Food Security". Agricultural mechanization places a key role in sufficiency in Agricultural and National Food Security. We are in a time as a state and nation when economic transformation is germane for our survival. Innovations in Agricultural mechanization becomes vital in order to encourage our small holder farmers who contributes a greater percentage in Food production. It is of note that agricultural production cannot be without appropriate agricultural engineering systems in place. The challenge now is innovate the available technologies and modernize for increased production and economic transformation.

We welcome you to make your contributions through presentations at this conference. The keynote and lead papers' speakers are well experienced and exposed in their chosen area. They are active members of International Commission of Agricultural Engineering (CIGR), American Society of Agricultural and Biological Engineers (ASABE), Canadian Society of Bio Engineering, Nigerian Society of Engineers. There is no doubt that the conference will be enriched by the presentations from these experts. Opportunities will also be opened for comprehensive discussion on specific fields of interest and for initiation of joint activities, collaborations and developing ideas for innovations. The conference will consist of invited papers, oral presentations, technical and social events. English will be the official language in this International Conference.

Accepted papers will be published in the proceedings for the conference. You are most welcome to one of the fastest developing city and state in Nigeria – Delta State.

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LEAD PAPERS

AGRO PROCESSING, APPROPRIATE STORAGE TECHNOLOGY AND VALUE ADDITION: CATALYSTS FOR RAPID AGRICULTURAL DEVELOPMENT AND FOOD SECURITY IN NIGERIA.

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Abstract

This paper aims to review the strategic role of agro processing and appropriate storage technologies/practices as critical components of agricultural and economic development, through value chain addition, reduction of post-harvest losses and enhancement of food availability and security. To achieve this, several relevant literatures were critically reviewed to understand the present food security situation, quality ratings of food products produced in Nigeria as well as the degree of post-harvest losses to principally unearth the importance and role of agro-processing and appropriate food storage technology in a developing economy such as Nigeria. Modern agro-processing and appropriate food storage methods/systems were identified along with constraints in key areas with strategies to be adopted by all stakeholders in the value chains for value addition, increasing export trade, creation of wealth and employment for the teeming youth population in Nigeria. The review findings revealed that Nigeria is endowed with a barrage of agricultural abilities, but with an extremely high rate of post-harvest losses, low food storage and processing capabilities, little or no export potentials due to poor value addition of agricultural produce and pronounced food insecurity. However, a focussed rejigging and restructuring of the agricultural ecosystem with emphasis on policies and reforms, value chain development, strong and efficient agricultural institution will enhance the achievement of significant improvement in agricultural production/development that will create wealth, employment, and revenue in all the agricultural value chains and ensure food security in Nigeria.

Keywords: Agro-processing, storage technology, food security

1.0 Introduction

Nigeria is one of the largest countries in Africa, with a total geographical area of 923,768 square kilometres and over 34 million hectares of arable land. Nigeria has a highly diversified agro-ecological climate, which makes it possible to produce a wide range of agricultural products (Statista, 2022). Agricultural productivity in Nigeria improved tremendously since independence, with cocoa, cotton, citrus, groundnut, oil palm, kernel, benniseed and rubber being the major cash crops until the advent of crude oil. Due to over-dependence on oil wealth, agricultural development potentials plummeted, and Nigeria remained relegated to being a major consumer nation with an annual food import bill of about $10 billion, a huge burden on its developing economy and a termite on the roof of its foreign reserve. Between 2016 and 2019, Nigeria cumulative agricultural import became N3.3trillion, 4 times higher that her cumulative agricultural exports within the same period (AFCFTA, 2020).

Despite low agricultural development, agriculture still constitutes one of the most important sectors of the economy. Over the years, agricultural sector has contributed significantly to Nigerian economy. As at 2021 the sector contributes over 29.94% of the country's GDP, with over 80 percent of small holder farmers producing about 90 percent of the agricultural produce. Well over 70 percent of Nigerians engage in the agriculture sector/value chain mainly at a subsistence level (Statista, 2022). The Nigerian agricultural sector is faced with a lot of challenges ranging from low level of mechanization/irrigation, poor land tenure system, climate change and insecurity. Other challenges include high production cost, high pre and post-harvest losses, poor transport system, policy inconsistence, illiteracy, poor access to credit facilities, pests and diseases, poor access to markets and lack of quality inputs all resulting to low productivity (FAO, 2022).

Amidst these challenges, Nigeria still manages to produce appreciably to support local consumption. However, not all that is produced is *'saved and utilised'.* About 25-50% of the annual agricultural produce/products are lost due to high post-harvest losses arising from poor storage system/facilities, lack of enough agro-processing facilities to turn them into more storable and stable forms among others (Mijinyawa, 2022, Bolarin, *et al*, 2015). Most of the agricultural produce if not consumed, are poorly stored, and/or locally marketed and rarely exported due to several fundamental issues. When produce are exported, they are either exported informally denying the peasant farmers and the country the expected revenue or most of the crops are rejected abroad for reasons, such as not following due process and or not meeting the international and respective destination countries' standards for imported goods (value addition). Considering that Nigerian crop products destined for regulated export market are sometimes of a poor quality, the state of the ones available locally is easy to imagine. Based on all these challenges, agro-processing and appropriate storage technology are major areas where the country can harness to galvanise agricultural development, through value chain addition, reduction of post-harvest losses and enhancement of food availability, security, and export.

2.0 Agro processing

Agro processing principally is the act of processing biomass, agricultural raw materials, which includes ground and tree crops as well as livestock and fisheries to create usable forms, improve storage and shelf life, create easily transportable forms, enhance nutritive value/quality, and extract chemical and raw materials for other uses. It has the potentials to improve food safety, through the separation of endosperm from the bran layers or manual sorting during processing which has been reported as contributing to reductions in levels of both ochratoxin A and deoxynivalenol which are harmful mycotoxins (Biellerman *et al*., 2007). Agro processing stimulates value addition by providing windows for fortification and reduction to appropriate usable forms and packaging. Agro processing galvanizes job creation, industrialization and economic growth through multiplicative agri-business /processing employments and export in various value chains. It also increases food security through reduction of postharvest losses and cost of foods.

Industries who partake in agro-processing could be classified as agro-food industries and non–agro food industries. They may also be classified further into domestic and factory/ commercial outfits (Owoo and Lambon-Quayefio, 2018). While the domestic is largely operated by peasant farmers with small operational and financial capacities, the commercial or factory outfits are normally run by large operators with huge financial base since it is capital intensive. Agro-processed products could be edible or non-edible, enjoy price stability, consume less space and are more storable (Kant, 1989). Only about 10% of agricultural produce are processed in Nigeria, mainly cash crops, cereals, legumes, nuts, oil seeds, root and tubers crops. Urgent attention is needed in the fruits and vegetable sector which accounts for 80% of the post-harvest losses annually. Major Nigeria agro-processing value chains include, cassava, rice, oil palm, groundnut, soybeans, oil seeds yam, legumes, fruit and vegetables, meat, poultry, mushroom, fish, snail, hide and skin, cotton, and shear butter. While the big processors use modern processing equipment, the local/cottage processors use mostly traditional and manual techniques, they are however aware of improved technologies and are willing to adopt them if credit is available. The processing centres are most times concentrated in clusters and most of the agricultural produce in Nigeria are underutilized due to the absence of agro-industries.

The African Development Bank (AfDB, 2019) estimated that 62% of Africa's exports are primary products. As a result, Africa earns just 5.5% of the $100 billion cocoa trade, despite accounting for 75% of the world's cocoa supplies. A similar story applies to tobacco, coffee, cotton, and others, leading to a clear consensus: for Africa to earn more and develop through trade, it must process its raw materials to higher-value semi-finished or finished products.

However, major constraints to agro processing may be likened to productivity, technical and policy issues. The major processing gap is hugely linked to low productivity caused by seasonal production, relative low output per hectare for raw materials or processing inputs. The Nigerian farming population though big, operates self-subsistence agriculture, with small outputs needing informal aggregation thus creating supply related issues such as of mix varieties, non-traceability, transient and non-stable flow of processing inputs. These have forced big processors in Nigeria like Unilever, Nestle, Dangote, Flour Mills to integrate backward to mitigate non-consistent supply of processing inputs. Anchor borrower scheme launched in 2015 by the Federal Government aimed at creating linkages between small producer farmers and agro-processors didn't yield much result. Relevant agricultural policies which should strengthen the processing industries are sometimes lacking such as exemption of agricultural processing machines from import duties and or supporting the indigenous research institutes to evolve more locally made equipment as well as supporting small and medium agro processing industries. Major constraints faced by agro processor in Nigeria include poor power supply, multiple taxation, lack of portable water, lack of access to improved technology on production, preservation and storage, lack of adequate capital and credit facilities, lack of improved/modern machines, poor infrastructure, difficult business operation environment, lack of enough storage and preservation facilities to stock processing inputs.

Alonge (2011) noted that agro processing techniques as an activity that encompasses the development and use of appropriate technologies and machines/equipment to achieve certain jobs, aims to reduce drudgery, save energy, time, minimize waste, and further change agricultural produce into preferable forms. Agro processing involves various unit operations from harvest to consumptions. The processes and equipment involved is crop specific. However, basic processes include, cleaning, sorting, sieving, pressing, crushing, boiling, drying, tempering, mixing, and packaging. The above listed major processes are better achieved with the use of sophisticated equipment and machines, though sometimes could be done manually where time, cost may not be economical. However, local processing machines/equipment have been developed in various institutions and technology incubation centres across the country lately to compliment the exigency of the imported ones. Agro processing turns out a lot of bye products, different end products demand different processes. Choice of unit processing operation/method depends on the desired product. Agro processing could be also wasteful if the entire process is not optimized, thanks to several research works which has helped to optimize every single unit operation in the sector for more efficient output/process. Major areas of comparative advantage in agro processing in Nigeria include cassava, yam, rice, oil palm, groundnut, soybeans, ginger, hibiscus, shear nuts, cashew nuts, tomatoes, cotton, orange, pepper, mangoes and pineapple. Others are hide and skin, cattle, fish, poultry, mushroom, snail, pork, and dairy products among others.

3.0 Storage technology

According to FAO (2022), food storage means the phase of the post-harvest system during which products are kept in such a way to guarantee food security other than during period of agricultural production. Food is stored for different purposes which include, to defer use from period of surplus to lean period, to ensure availability of viable seeds to maintain crop cycle, to maintain regular and continues supply of agricultural materials stabilizing market prices. The primary aim of storage is to slow down the process of deterioration caused by growth of microorganisms, catalysed by favourable temperature, moisture and oxygen conditions. Poor storage system/structures often lead to low quality products (Alonge, 2011).

Nigeria has three level of storage regime characterized by different storage systems/structures

The first level, on-farm/domestic storage being operated by peasant farmers mainly uses traditional storage system and structures such as pit, pots, gourd, baskets, platform, open air, polythene bags, rhumbu and sack. The middle level storage mainly operated by grain merchants and average farmers normally uses bag storage in warehouses while the commercial/large scale storage operated by grain merchants, organised private sectors and the government uses bag storage in warehouses and silo storage.

The choice of storage system and structure to be used in food storage depends on the type of crop, duration of storage, quantity of produce to be stored, intended use of the crop and technical know-how of the farmer (Okolo *et al*., 2017) However, effective storage system entails the conduct of food storage in the most efficient and effective manner ensuring food, human and environmental safety, minimizing losses, and maintenance of quality of the stored products. Effective storage system must be ergonomics friendly with a high value addition and economics of scale potentials. It must be cost effective using international best practices as far as food storage is concerned. On the global scale, cold storage, hermetic storage, and warehouse storage remains most popular systems. The review of food storage system/structures in Nigeria shows that traditional and modified storage structures mainly used by local farmers is ineffective and recorded the highest storage losses estimated between 43% -50% (Osunde, *et al,* 1996, Olumeko, 1991) while hermetic storage system/structures recorded the lowest between 3%-8% (Okolo, 2019). Major challenges with the traditional storage system include insect/pest infestation, integrity of structures, and ingress of water. The review also shows that the most efficient storage system that suites Nigeria's food storage landscape remains hermetic storage technology.

3.1 Hermetic storage technology

Hermetic storage technology is a zero-chemical based method of storing dry agricultural commodities using airtight units to control moisture and insect infestation. Its basic principle is the generation of oxygen depleted and carbon dioxide or nitrogen enriched interstitial modified atmosphere achieved by either natural means through activities of living organisms in a food bulk, or by artificial means in an airtight storage structure (Jonfia-Essien *et al*., 2010; Mudrock *et al.,* 2012). A sufficiently low oxygen and elevated carbon dioxide or nitrogen could either be achieved through natural internal metabolic activities based on respiration of food material if they are living and other micro-organisms such as moulds and fungi in food (organic). It could also be enhanced through artificial mechanism such as enriching the airtight storage structure with carbon dioxide or nitrogen by the means of pumps and scrubbers, and or the deflating/sucking out of oxygen rich air from the storage structure with the aid of a vacuum pump (Artificial gas/vacuum fumigation). Organic hermetic storage is a process which always ends producing a modified atmosphere with zero oxygen which is non-life sustaining as shown in Figure 1.

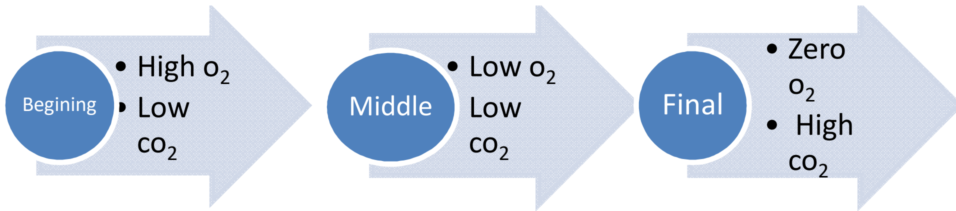

Figure 1: Organic hermetic storage process/stages

When the sealed storage is enriched with carbon dioxide or nitrogen and oxygen is depleted, it will lead to the asphyxiation of the entire living macro and microorganisms in the bulk which are normally agent of deterioration. Organic hermetic storage structures must be filled to brim agitated to reduce the amount of air trapped in the bulk, to reduce the time for complete depletion of oxygen in the bulk through organic means else the insect may have done a substantial damage to stored crop before eventual asphyxiation. One of its major characteristics is a good control of flocculating moisture content of crops especially in tropical climates and the elimination of all chemical based storage problems abound in the tropics (Mudrock *et al.* 2012). Others are the ability to eliminate mould development especially the issue of cancer-causing mycotoxins which has caused death of human and animal in the recent years. The use of hermetic containers is as old as storage itself and equally was a part and parcel of Nigerian indigenous traditional storage structures where foods commodities were kept in plastic containers. Arrays of hermetic storage structures for all levels of storage as presented in Table 1, make it a complete storage system with huge potentials especially for developing economies.

Table 1: Hermetic storage structures for all levels of storage

S/N	LEVEL OF STORAGE	STORAGE STRUCTURES
1	Domestic, on-farm	Low sized hermetic metallic, plastic and glass containers, hermetic storage bags,
2	Middle level storage	Medium sized hermetic plastic and metallic containers, medium cocoon storage structures, hermetic bag storage
3	Commercial storage	Large sized cocoon storage structures, control atmosphere structures, hermetic bunkers, hermetic silo storage. Hermetic bag and warehouse storage

However, the technology has not been fully adopted in Nigeria, due to our large illiterate farmer population that does not understand and trust in the technology. Major constraints to full adoption of hermetic storage structures by farmers include high cost of structure, illiteracy, non-availability of hermetic storage structures, lack of proper introduction of the technology by agricultural extension workers and the fear of farmers experimenting with their crops (Adejumo and Raji, 2007).

4.0 Food security situation in Nigeria

Food security in Nigeria is at all time low, presently bedevilled with a lot of social, and economic challenges. A recently published report by Statista (2022) on poverty rate and food security reported that 23% of poor and food-insecure people in the world live in Nigeria, an increase from the previous 20% in

2019. Nigeria has witnessed tremendous increase in poor and food-insecure people in the last six (6) years from 34.6% in 2016 to 40% as at May 2022. An estimated population of 88.4 million people is food insecure and live in extreme poverty. The number of men living on less than 1.90 US Dollars a day in the country reached around 44.7 million men and 43.7 million women and overall, 12.9% of the global population living in extreme poverty (Statista, 2022). In one decade, the number of households experiencing food shortage has increased from barely 10% in 2010-2011 to over 31% in 2018-2019.

According to FAO, (2022), an estimated 19.4 million Nigerians from 21 states and Federal Capital Territory (FCT) including 416,000 Internally Displaced Persons (IDPs) will face severe food insecurity between June and August 2022. The report equally identified insurgency ridden North-East states, especially Borno, Adamawa and Yobe, armed banditry inflicted areas of North-West states such as Sokoto, Katsina, Zamfara and Kaduna States, as well as North-Central states of Benue and Niger as key drivers to the food crisis. Other states mentioned with minimal resultant effects include Abia, Cross-River, Edo, Enugu, Gombe, Jigawa, Kano, Kebbi, Lagos, Plateau and Taraba.

Since population growth has been identified as a critical component of food security, it is therefore not surprising that with the observed large increases in the country's population, Nigeria faces a crisis in terms of access to food and general food availability. Nigeria's population is approximately 198 million people, making it the most populous country in Africa and the seventh most populous country in the world without a corresponding rise in food production (Owoo, 2021).

The drivers to food insecurity in Nigeria includes, population growth, low productivity, conflicts, banditry, terrorism, climate change, inflation and unemployment, price volatility, post COVID-19 pandemic effect, and most recently Russia-Ukraine war. Though, food insecurity is a global phenomenon, it is believed that with proper agro-processing and storage interventions and restructuring of the agricultural sector, food insecurity will be significantly reduced in Nigeria.

5.0 Agricultural development and value chain development

Agricultural development is a process that creates condition for fulfilling agricultural potentials, which primarily entails measurable development in agricultural sector and agri-business which creates jobs, amassing revenue for private and public sector and providing food and nutrition for the citizenry (Laiglesia, 2006). It remains the bedrock of every developed economy. However, despite the rich agricultural endowment of Nigeria, majority of its population is facing hunger and poverty. 70% of the population lives on less than N100.00 per day and youth unemployment is above75%. The irony of the situation is that the sixth highest producer of crude oil worldwide which earns above USD15 billion annually cannot feed her population, because of low production, growing food import, and problems of micro economic and agricultural policies (Okolo, 2006).

It is important for Nigeria to beam its light on the strategy that can enhance post-harvest management, primary and secondary value addition to attain national food security. One of the best strategies is value chain approach to agriculture. Value chain is the full range of activities from conception to completion by which a firm operating in a specific industry performs its operation to deliver a valuable product or service for the market. Agricultural value chain is integrated range of goods and services necessary for an agricultural produce to move from producer to consumer (Norton, 2014). It also describes the series of value addition activities and actors from production of an agricultural crop to time of consumption. This comprises of producers and labourers, consumers, processors, retailers, and other services providers such as transporters and marketers as presented in Figure 2. The term "value chain" is used for a range of types of chain, including, rice value chain, cotton value chain, maize value chain, coffee value chain, tomato value chain, cold chain etc. A basic value chain map should answer the following questions: "What is being done in the value chain and who are the key players?" "How is the product/service reaching end markets?" "What market channels are available to reach those end markets?

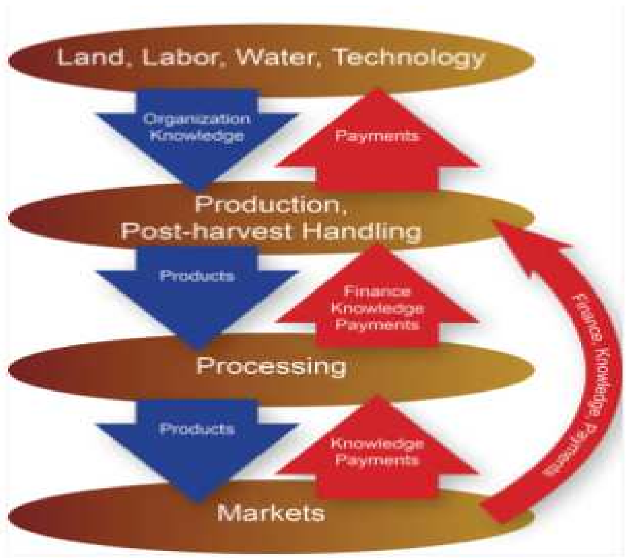

Figure 2: An agricultural value chain chart(Norton, 2014)

It is worthy to note that an efficient value chain approach to agricultural involves availability, accessibility and utilization of quality production drivers, appropriate agricultural processing and storage technologies for value addition to extend shelf life, distribution channels and retailing outlets. Value chain addition entails processes which increase the income of people partaking in the value chain and adds value to the crop. It could be achieved through elimination or improving on poor quality of products at harvest, grading to reduce inconsistent size, good post-harvest handling, ensuring adequate drying and threshing techniques to improve quantity and market value, use of appropriate storage technologies, transportation, packaging, processing, fortification, and ensuring traceability. A value chain approach in agricultural development helps identify weak points in the chain and actions to add value appropriately (FAO, 2022).

6.0 State of food export in Nigeria and constraints.

According to Knoema, (2022) Nigerian total food export in 2021 stands at 3.3%. This is not only grossly inadequate but embarrassing for a country richly blessed with agricultural resources and potential. Challenges are both technical and political, largely due to political will, lack of efficient agricultural production system, weak agro-processing and appropriate food storage technologies. Others are meeting the global quality standards for each product, to be exported, food safety such as chemical residue, toxicity and mycotoxin in agricultural produce. Marketing, logistics institutional related issues also remain significant constraints to agricultural exports in Nigeria.

In the recent past there was an Executive Order on exportation of agricultural produce which created frictions between stakeholders, on who owns the right for what. Proper inspection and certification by Nigerian Agricultural Quarantine Service who is statutorily responsible has not helped. Education of farmers on the products needed for export, traceability, produce grading, handling and packaging are also key. Lack of training of local farmers who intends to export goods on WTO guidelines on sanitary and phytosanitary measures/certification for export still poses problems. Improper packaging and labelling, using botanical names instead of local unrecognizable names by foreigners and adulteration where items are concealed or smuggled into goods to be exported between certification and point of exit among others has been the albatross to poor Nigerian food export.

7.0 Conclusion

Agricultural development as a bedrock to economy development needs a multi-disciplinary approach and all the urgency it desires. As it stands, diversification of Nigerian oil-based economy with special emphasis on agriculture will be the only solution amidst the dwindling crude oil prizes and imminent reduction of crude oil influence on global economy. If Nigeria must assume its rightful place in agricultural development, there must be a significant increase in agricultural production. This can be achieved by promoting enabling policy environment for the development of agro-processing and storage technology for value chain addition and this can turn Nigeria into an investment destination for an array of crop value chains. This will significantly lead to creation of jobs, import substitution, wealth creation and ultimately also lead to increase in the contribution of the sector to the nation's GDP. Effective agro-processing and appropriate storage technology will enhance high quality oriented, well graded and traceable products. Agricultural processing and appropriate food storage technology must be at its best to minimize postharvest losses, transform our agro produce to more stable and profitable forms, to enhance food availability and increased foreign exchange for the farmers and the nation. Government should tackle the constraints of agro processing business in Nigeria; encourage agro processors to adopt improved and appropriate storage technologies, packaging, processing, fortification of agricultural product for value addition. To enhance export there should be an inter-agency collaboration and advocacy for all stakeholders in agricultural exports, FAAN, NAQS, NAHCO, FMITI, farmers and businessmen to cross-pollinate ideas, collaborate, strategize and educate all stakeholders for better agricultural export in Nigeria.

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RURAL DEVELOPMENT, ECONOMIC TRANSFORMATION AND FOOD SECURITY THROUGH SUSTAINABLE MECHANIZATION OF AGRICULTURE.

By

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Abstract

This paper presents what should be done to advance rural development, economic transformation and food security through sustainable mechanization of agriculture. Using appropriate literature, the key terms of the subject matter were first defined. The key roles of agricultural mechanization in promoting rural development, economic transformation for food security were highlighted. Food security which is a linked pathway from production to consumption through distribution to processing was traced to mechanization. The four dimensions of food security were expounded by stating the short-term stability and long-term sustainability that pave way for a sustainable future for secure food. Mechanization and its benefits, limitations and scope were discussed, as well as its sustainability through the ingenuity of the farmer-driver. The paper concludes that sustainable mechanization endeavors to: increase the performance and efficiency of farming activities by introducing appropriate machines and technologies, create jobs (entrepreneurship) and sustainable rural livelihoods, promote agricultural development led industrialization and markets for rural economic growth, improve the quality of primary and processed goods, improve working conditions and raise living standards. Mechanization has a significant role to play at all levels along the entire value chain in terms of modernizing and intensifying agriculture; it creates employment in rural areas – a core element of rural development – and ultimately leads to food security. The role of governments in strengthening agricultural mechanization in Nigeria was highlighted.

Keywords: Rural development, economic transformation, food security, sustainable mechanization, agricultural production.

1. Definitions

In order to discuss the above topic, it is pertinent to define some of the terms that describe the subject matter. We will define rural development, economic transformation, food security and sustainable mechanization of agriculture.

1.1 **Rural Development**.

According to *Moseley (2003)*, rural development is the process of improving the quality of life and economic well-being of people living in rural areas, often relatively isolated and sparsely populated areas. While rural development has traditionally centered on the exploitation of land-intensive natural resources such as agriculture and forestry, changes in global production networks and increased urbanization, tourism, niche manufacturers, and recreation have replaced resource extraction and agriculture as dominant economic drivers and changed the character of rural areas (*Ward and Brown,* *2009).* To me, however, agriculture remains the panacea for rural economic transformation and food security.

1.2 Economic Transformation.

Economic transformation refers to the continuous process of (1) moving labor and other resources from lower-productivity to higher-productivity sectors, otherwise termed structural change (Herrendorf et al., 2013) and (2) raising within-sector productivity growth (McMillan et al., 2017). As such, economic transformation emphasizes the movement from low-productivity to high-productivity activities within sectors (e.g. from low-productivity subsistence farming to high-value crops within sophisticated value chains) and across all sectors (which can be tasks or activities that are combinations of agriculture, manufacturing and services). At the level of the national economy, it involves diversification, creation of new subsectors of activity and increased domestic value addition in trade. At the level of firms and households, it implies the acquisition of new productive capabilities and the ability to compete in larger and more distant markets on a growing scale. This movement of resources from lower-productivity to higher-productivity activities is a key driver of economic development (McMillan and Rodrik, 2011).

1.3 Food Security.

Food security is a flexible concept as reflected in the many attempts at definition in research and policy usage. Even three decades ago, there were about 200 definitions in published writings (Maxwell and Smith, 1992). Whenever the concept is introduced in the title of a study or its objectives, it is necessary to look closely to establish the explicit or implied definition (Maxwell, 1996). Taking cognizance of the different definitions, useful working definitions are described below (Sen, 1981):

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life (IFPRI, 2022). Household food security is the application of this concept to the family level, with individuals within households as the focus of concern. Food insecurity exists when people do not have adequate physical, social or economic access to food as defined above.

1.4 Sustainable Mechanization of Agriculture

Agricultural mechanization today has a very broad meaning which includes production, distribution and utilization of a variety of tools, machinery and equipment for the development of agricultural land, planting, harvesting and primary processing. Sustainable agricultural mechanization should encompass manufacturing, sales, repairs, distribution and operation of all types of machines that are used in all facets of crop production (Akinbamowo, 2013; Haruna and Junior, 2013; Mrema et al., 2014; Simalenga, 2000). Agricultural mechanization is the harnessing, controlling and organizing all inputs of production such as land, capital, labor, as well as research, education, communication/information, and engineering/technology in agricultural practices (Asoegwu and Asoegwu, 2007). It embraces the use of tools, implements, and machines for agricultural land development, crop production, harvesting, and preparation for storage, storage, and on-farm processing (Ozumba et al. 2019). The development of agricultural mechanization is improvement of agricultural techniques as well as helping them improve the sustainability of the entire agricultural system (Mrema et al., 2014). Sustainable agricultural mechanization refers to perpetual maintenance of commercial food supply system through improved and appropriate technologies over a very long period of time in order to guarantee food security (Itodo, 2016; Wognum et al., 2011).

2. Introduction

Rural in the western world is described as a country side though necessarily lack the required amenities but in Africa, it is described as an environment being occupied by mostly less privilege people and with inadequate amenities and there the agriculture is being practiced (Owolabi, 2019). Asoegwu (2018) opines that agriculture plays a significant role in both the human and economic resources of a nation; it is seen as the backbone of a nation’s economy as it enables the provision of food and raw materials and generates employment opportunities for a very large proportion of the population via cultivation, distribution, processing, warehousing, and marketing. As a critical sector of the economy, agriculture drives economic development and industrialization of economies by providing necessary raw materials for industries and thereby creating economic transformation both within and beyond the rural communities.

Rural development aims at finding ways to improve rural lives with the participation of rural people themselves, so as to meet the required needs of rural communities (*Pellissery, 2012).* The outsider may not understand the setting, culture, language and other things prevalent in the local area. As such, rural people themselves have to participate in their sustainable rural development. Most developing countries in Africa are bedeviled with undependable food supply chain which is ineffective in ensuring steady food production. To ensure steady food production and supply, it is imperative to mechanize Nigeria’s agriculture.

Farm mechanization does not only include the use of machines, whether mobile or immobile, small or large, run by power and used for tillage operations, harvesting and threshing but also includes power lifts for irrigation, trucks for haulage of farm produce, processing machines, dairy appliances for cream separating, butter making, oil pressing, cotton ginning, rice hulling, and even various electrical home appliances like radios, irons, washing machines, vacuum cleaners and hot plates. Broadly speaking, mechanization of agriculture and farming process connotes application of machine power to work on land, usually performed by bullocks, horses and other draught animals or by human labor**.** Mechanization increases the power applied to agricultural operations and is one tool among many for improving farm productivity and increasing incomes for Nigeria’s farmers and processors (Takeshima and Kennedy, 2019). However, Nigeria has an agricultural sector characterized by both low productivity growth and low machinery growth relative to other African countries (2018, Malabo Montpellier Panel).

Increasing population, decreasing agricultural land, increasing demand for food, extensive land degradation and inadequate infrastructure have been the major debilitating factors of the agriculture sector in Nigeria (Ladeinde et al., 2009). This situation has forced all stakeholders in the private and government sectors to pay attention to agricultural mechanization (Omofunmi and Olaniyan, 2018).

In the face of the above, rural development through economic transformation for enduring food security can be achieved through sustainable mechanization of agriculture. This is the position of this paper to be exounded.

3. Food Security Pathway and Mechanization

Food security is best considered as a causal, linked pathway from production to consumption, through distribution to processing (Berry et al., 2015) which remain in the domain of mechanization. The concept of food security has evolved over recent decades and has been gradually enlarged. Initially it focused mainly on availability of food and on food production (UN, 1975); then it was expanded to include explicitly the accessibility to food (physical, economic and socio-cultural), and its utilization (FAO, 1996) and lastly to encompass the stability of these dimensions (FAO, 2009). FAO (1996) states that food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Berry et al. (2015) summarized it in Fig. 1 which gives the time dimension to food security: short-term stability (left side); long-term sustainability (right side). In whichever level: Regional, National, Household or Individual, mechanization makes the food security possible.

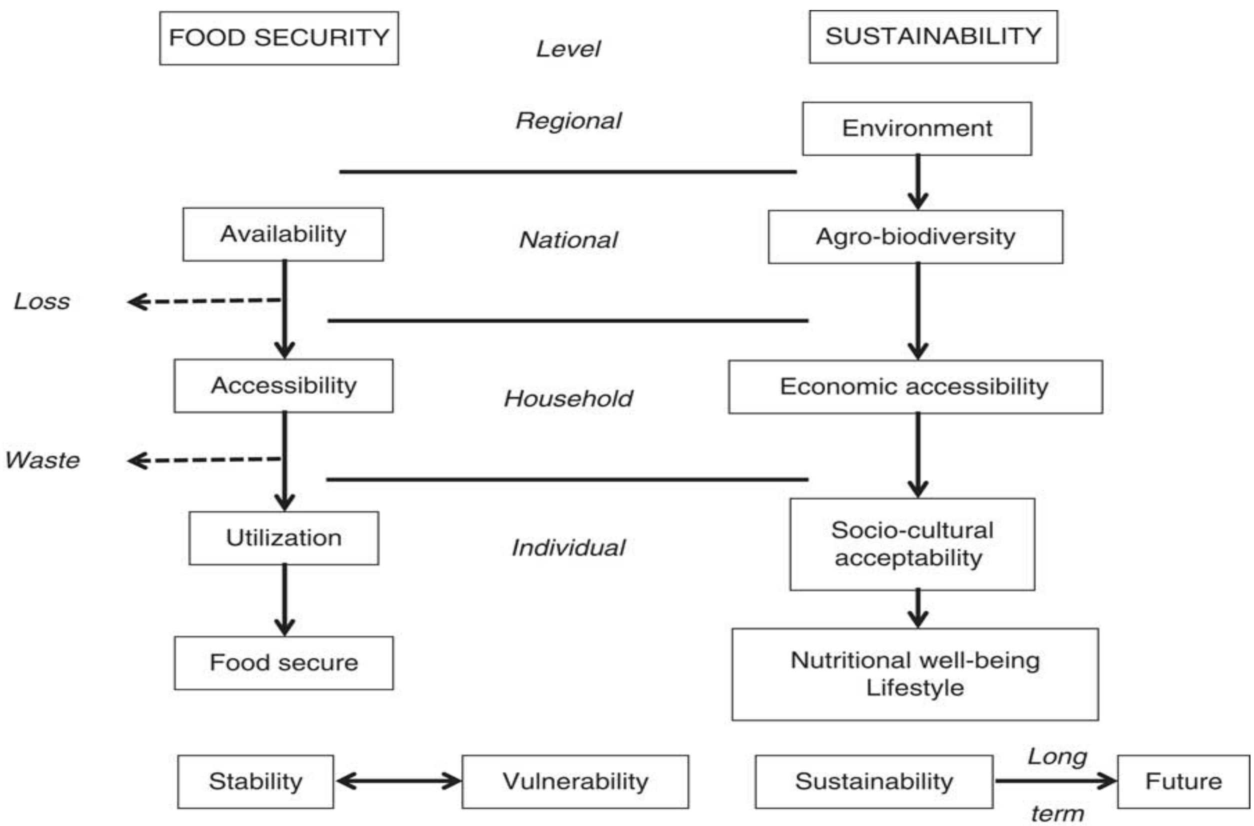

Fig. 1 The time dimension to food security: short-term stability (left side); long-term sustainability (right side) (Berry et al., 2015)

The left side shows the path of food from production to consumption (minus food losses and waste (Parfitt, et al., 2010)) to food security and the right side that of sustainability. For food security objectives to be realized, all four dimensions must be fulfilled simultaneously. It is widely acknowledged that food systems' sustainability must entail long-term food and nutrition security in its availability, access, utilization, and stability dimensions (El Bilali et al., 2018). From this definition, four main dimensions of food security can be identified (Table 1).

Table 1: The four dimensions of food security.

Physical AVAILABILITY of food	Food availability addresses the "supply side" of food security and is determined by the level of food production, stock levels and net trade.
Economic and physical ACCESS to food	An adequate supply of food at the national or international level does not in itself guarantee household level food security. Concerns about insufficient food access have resulted in a greater policy focus on incomes, expenditure, markets and prices in achieving food security objectives.
Food UTILIZATION	Utilization is commonly understood as the way the body makes the most of various nutrients in the food. Sufficient energy and nutrient intake by individuals is the result of good care and feeding practices, food preparation, diversity of the diet and intra-household distribution of food. Combined with good biological utilization of food consumed, this determines the nutritional status of individuals.
STABILITY of the other three dimensions over time	Even if your food intake is adequate today, you are still considered to be food insecure if you have inadequate access to food on a periodic basis, risking a deterioration of your nutritional status. Adverse weather conditions, political instability, or economic factors (unemployment, rising food prices) may have an impact on your food security status.

Source: FAO (2008)

On the other hand, Onyeka (2016) posed three pillars of food security – availability of food, food access and food use and opined that food security should not be seen only from the perspective of availability either in quantitative or qualitative terms but that food hygiene and safety should be given important consideration. I cannot but agree more to that because quantity, quality, hygiene and safety of food may also be seen from the perspective of agricultural production, processing and storage. Food security, to me, should among other things introduce technologies to increase agricultural productivity at the farm and processing levels, decreasing post-harvest losses and introduce low-cost innovative technologies for food production, storage, and preparation to the effect that the preponderance of the food consumed by the populace is mostly produced locally with minimal importation. I may make further to describe food security not only the availability of the food, but the ability to purchase the food (Asoegwu, 2018) produced through mechanization.

4. Mechanization of Agriculture

Agricultural mechanization may be defined as the application of agricultural engineering principles and technology in crop and animal production, processing and storage. It includes ways of developing, using and managing improved mechanical aids (tools/implements/equipment) and machines for agricultural production (Asoegwu, 2018). According to FAO (Clarke, 1997), the term "Agricultural mechanization" generally refers to the application of tools, implements, and powered machinery as inputs to achieve agricultural production. In general, three sources of power are used in agriculture; manual, animal and motorized (fossil fuel and electric). The term covers the manufacture, distribution, maintenance, repair, management, and utilization of agricultural tools, implements, and machines. It applies to agricultural land development, crop production, harvesting, and preparation for storage, on-farm processing and rural transport. Mechanization enables the design, fabrication and substitution of machines, equipment, processes and facilities necessary for producing food, feed, fur, fuel and fiber and substituting mechanical power for human and animal power. These aids may be hand-, animal-, or engine-powered, with the sole aim of benefiting agricultural mechanization in the following ways: increased power input into agriculture to enhance timeliness of operation and reduce seasonal bottle necks; improved quality of field operations which provide better soil environment for seed germination and plant growth; reduced production cost and increased labor productivity; reduced losses and improved product quality to increase the farmer's economic returns and improve the dignity of the farm worker; and increased agro-business activities (Asoegwu, 1998).

4.1 Benefits of Mechanization

Kisankraft (2019) identified two ways of mechanization: partial (involving human and animal power doing some work on the one side; and the remaining part done by machines); and complete (with machines completely replacing humans and animals). Both ways have the following benefits, among others:

a. Leads to improvement in agricultural technique

The improvements come in the area of irrigation, land reclamation and the prevention of soil erosion, getting more land under cultivation by smoothing hillocks, filling in depressions and gullies and removing deep-rooted weeds. Additional to these are mechanical fertilization, crop protection, harvesting and post-harvest operations.

b. It modifies social structure in rural areas

Mechanization of agriculture leads to changes in social structure in rural areas and also reduces the farmer's time and effort. It frees the farmers from much of the laborious, tedious, hard work on the farms. The pressure on land decreases and the status of the farmers improves.

c. Introduction of commercial agriculture

Mechanization in farming methods results in a shift from subsistence farming to commercial agriculture. This move happens for the most part because of the requirement for more land and funding to be related with farmers so as to receive the full advantages of technology.

d. Mitigate farm labor shortage

Usage of agricultural machines like tractors, inter cultivator, power tiller, harvesters, millers, shellers, etc. can reduce the dependency on labor and improve the quality of life of the farmers, as well as mitigate labor shortages and urban migration.

e. Best return of farm income

With the mechanization in place, income from farm can be multiplied and it helps in improving the farmer's economic condition. It raises business and other social organizations and enhances economic activities in the rural areas. Increased income levels combined with higher productivity, through mechanization, will lead to lower food prices and enable access to food, resulting in better nutrition, stimulating further economic activities and gains. Furthermore, higher productivity in agriculture will indirectly lead to social improvements.

4.2 Limitations of Farm Mechanization.

The factors limiting the use of farm machines in Nigeria are many and can be summarized as follows (Ugochukwu, 1999; Asoegwu and Asoegwu, 2007):

a. Economic factors: Farm machines are not readily available in the country.
b. Poverty: Most of the farmers are poor and cannot afford to buy or own farm machines.
c. Land tenure system: Land fragmentation and system of ownership like communal do not allow the use of farm machines.
d. Lack of spare parts: Lack of spare parts also hinder the use of farm machines.
e. Seasonality of operation: The seasonal nature of Agriculture in West African can render the machines idle for mouths and this can result to depreciation of the machines.
f. Ignorance: Many farmers are still ignorant of the use of farm machines and some are still reluctant to use them.
g. Lack of extension agents: People to train and educate illiterate farmers are not enough to carry out their job.
h. Illiteracy of farmers: Most farmers are illiterate and cannot operate or use these machines.
i. Maintenance cost of the farm machine is high and cost of hiring the machines are also high.
j. Most of the machines are not adapted to our local soil type.
k. Lack of experts to handle the machines.
l. Peasant farmers have small fragments of farm lands.

With the above limitations, there is no doubt that Nigeria's agriculture requires a lot of power to engineer and propel it past its present status and give it more life (Asoegwu, 1998). The power can come from any or a combination of the three levels of agricultural mechanization that is identified in Nigeria (Upahi, 2018), namely: traditional agricultural mechanization technology (uses man as the source of power for traditional cutlasses, hoes and other tools); draught animal technology (uses a range of implements and equipment that are powered by animals as their major energy source); and engine powered machinery technology (uses engines and motors using fuel or electricity to power machines such as threshers, mill, irrigation pumps and grinders for production, harvesting, processing and handling of wide varieties of agricultural products) (Bako et al. 2018). As more power is invested into Nigeria's agriculture through mechanization, there should be self-sufficiency in food for the populace (to assure food security), agricultural raw materials for agro-industries and sufficient processed agricultural products for export (to propagate economic transformation). Engineering and technology will enhance production as consumers demand consistent supply of top quality products and services, placing emphasis on quality, safety, functionality and sustainability of agriculture (Opara, 2002), to ensure rural development.

4.3 Scope of Mechanization of Agriculture

Mechanization of agriculture has to be viewed in a very broad context. The overall scope of the term "agricultural mechanization" encompasses several components: manufacturing and/or importation, distribution, supply of spare parts and service as well as institutional support. Due attention must be paid to ensure that this system functions in an integrated manner. For the mechanization sector to function well all of the individual components must be in place and all must be working efficiently. An overview of agricultural mechanization Fig. 2 shows clearly the interdependent relationships of the various components as well as the linkages between them (Houmy et al., 2013).

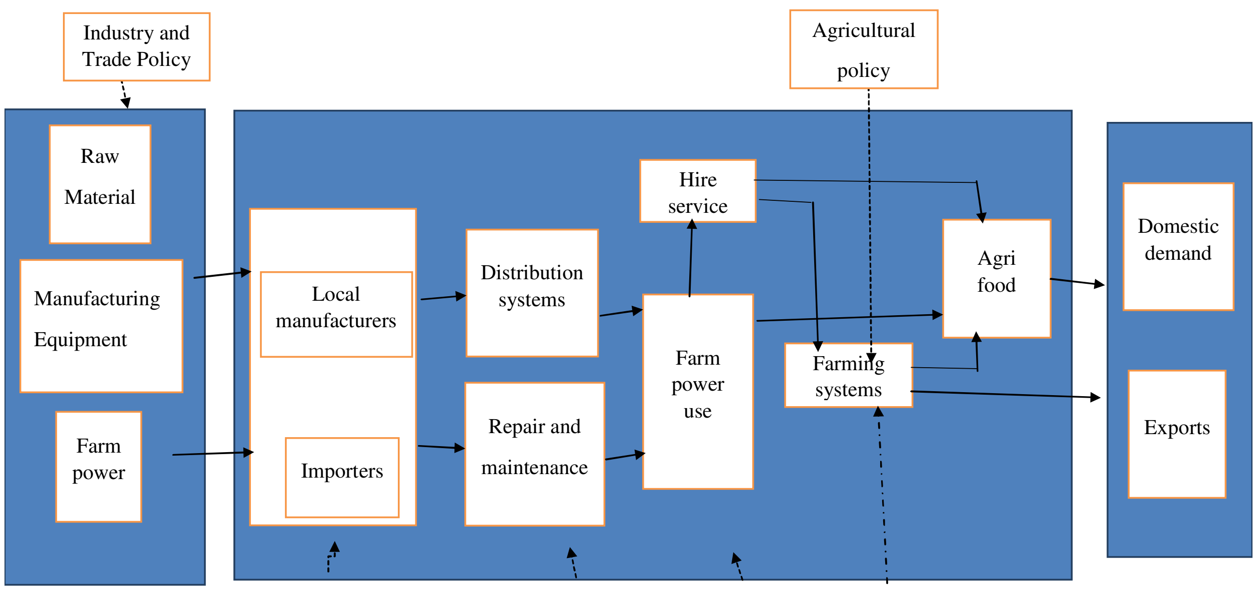

Fig. 2: Agricultural Engineering Sector and Linkages (Houmy et al., 2013).

The diversification of the Nigeria economy through agricultural mechanization is part of agro-industrial development for economic transformation. The potential contribution of agricultural mechanization to green food value chain production is shown in the Table 2.

Table 2: Contribution of Mechanization in Green Food. Sources: Breuer et al., 2015.

Production	Post-harvest/Storage	Processing	Marketing
Crop establishment	Drying	Chopping	Packaging
Weeding	Grading	Milling	Transport
Fertilization	Winnowing	Grinding	
Irrigation	Cleaning	Pressing	
Crop protection	Storage		
Harvesting			

In order to enhance agricultural productivity, as well as to reduce the cost of production, the introduction of new mechanical technology into agricultural production system is inescapable. Therefore, with this aspect in view, the introduction of newly developed agricultural machines and equipment including horticultural equipment are needed at reasonable cost for diversifying and transforming the Nigeria economy through sustainable agricultural mechanization. Mechanization is part of agro-industrial development for the economic emancipation of the rural communities.

4.3.1 Demand for mechanization

There is demand for mechanization when it becomes cost effective for farmers to use it over other available options. Without demand in place, agricultural mechanization will fail as tractor hiring services will quickly collapse, and machines will often be left idle, scrapped, or abandoned (Pingali et al. 1987). Mechanization demand is affected by farm size, labor saving, market demand, the availability of complementary technologies, and demonstration. Table 3 shows the farmland endowments, farm sizes and animal use by region in Nigeria between 2010 and 2012.

Table 3. Farmland endowments, farm sizes, labor, and animal use by region, Nigeria, 2010 and 2012 (Takeshima and Lawal, 2018).

Region	Agricultural area per capita (ha per capita)a		Farm size (ha)		Average manual farm power use (days per farm household per year)	
	Area divided by all households	Area divided by farm households	Average	Median	Labor (family + hired)	Animal traction
NW	0.41	0.46	0.8	0.5	227	6
NE excluding Taraba	0.68	0.74	2.0	1.2	302	9
NC + Taraba	0.73	0.86	1.5	0.8	493	1
South	0.14	0.21	1.0	0.2	380	0

Source: Authors' calculations based on data from Living Standards Measurement Study–Integrated Surveys on Agriculture, Nigeria, 2010 and 2012; Ramankutty et al. (2008); and Nigeria, NPC (2010).
Note: NC = North Central; NE = North East; NW = North West. a. Agricultural area per capita is calculated using the sum of cropped area and pasture area (data from Ramankutty et al. 2008), with population data obtained from the Nigeria 2006 Population Census (Nigeria, NPC 2010)

The sequential nature of mechanization demand is such that power-intensive operations (plowing, threshing and harvesting) are mechanized before control-intensive ones (planting, weeding, winnowing) (Pingali et al., 1987; Asoegwu, 1998) and animal power (where feasible) is adopted before the transition to mechanized power.

4.3.2 Supply chain of mechanization

Diao et al. (2016) defined supply chain as the processes of production and distribution of a good or service across different actors. The supply chains for mechanization cover the manufacturing and importation of machines, mechanized service provision, and spare parts and repairs services for machinery maintenance. The end users of mechanization technology are large, medium and small farmers, who exhibit distinct usage patterns under different circumstances. There are three main importation channels in Nigeria, which includes direct government importation of new machines, and the private importation of new and secondhand machines. In some cases, a government may also import machines through a private company. The supply chain is supported by retailers of imported and second-hand tractors, spare part dealers, fabricators and mechanics.

4.3.3 Role of governments

Demand for mechanization has been emerging in Nigeria, and the private sector channels for machine purchases and mechanized service provision have grown in recent years. The principal role of government is to establish conditions which will enable the development of a largely self-sustaining agricultural engineering sector within a policy of minimum direct intervention (Clarke, 1997) Nevertheless, there are many ways for governments to play a supportive role in the mechanization process, through investing in public goods, developing a favorable policy environment, and providing capacity building and technical support where needed. Focusing on the role in the creation of enabling environment for the private sector to lead mechanization, the governments can play a greater role in generating and providing public goods that are urgently needed by the private sector. Such public goods include spreading knowledge of machinery, the operation of machinery and farming practices that can maximize the benefit of mechanization, and to facilitate the development of suitable institutions for providing such public goods (Ajibola and Zalla 2007). Nevertheless, areas remain in which there may be justification for government involvement. These are mainly in areas that are considered to be "for the common good" and cannot be expected to be provided by the private sector. Possible roles for government are: health and safety; labor laws; education and training; industrial extension; standards; machinery testing; licensing; credit; business promotion and development; market information; trade. In addition, large scale infrastructure investments (such as irrigation and drainage), agricultural marketing infrastructure, and selected research and development activities are often considered important and legitimate areas for support (Houmy et al., 2013). The government support for Research and Development in Nigeria is very much needed.

4.4 Agricultural Mechanization and Sustainable Development

Agricultural mechanization can be looked at from three aspects: economic, social, and environmental (Fig. 3).

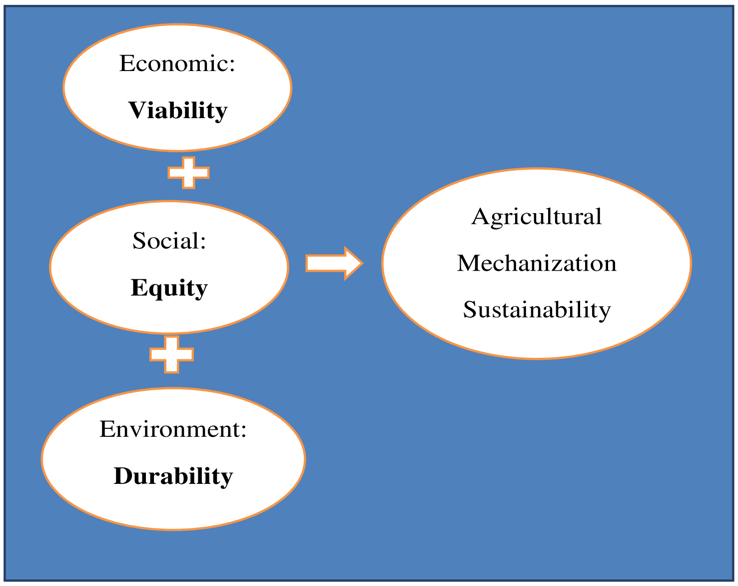

Fig. 3: Three aspects of agricultural mechanization sustainability: economic, social and environment (Houmy et al., 2013).

The economic aspect of mechanization has to do with investment for farmers to generate income and profit from their investment taking into account the commercial and financial links between farmers and other stakeholders such as retailers, distributors, manufacturers, importers and service providers. The fundamental requirement for a sustainable subsector is a strong linkage between these different parties and that all of them must be able to make a livelihood from their businesses (Houmy et al., 2013). These will not only enhance rural development but also ensure economic transformation.

A reduction in the drudgery of farm work, more leisure time and the higher status of a farmer in his local community are all important social aspects of agricultural mechanization sustainability. However, these benefits are very subjective and cannot be easily translated into cash equivalents. Also, the issue of its impact on rural employment – reduction of unemployment and introduction of new employment opportunities such as manufacturing, repair, and provision of mechanization services, is an ongoing debate.

In considering the environmental aspect of agricultural mechanization sustainability, the degradation of natural resources through intensive tillage has come in for criticism. however, mechanization opens up new possibilities for the conservation of natural resources and the environment. Conservation agriculture, has been described by FAO as “a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment” (FAO & UNIDO, 2008).

4.5 The farmer – the driver

Based on the above discussion, it is evident that the farmer is the driver of rural development and economic transformation to achieve food security through sustainable development. While governments will introduce policies, provide the enabling environment for enhancing the delivery on the required inputs including sustainable mechanization, the farmer is central in harnessing these to achieve the required goal of enhancing rural development and economic transformation for food security. The essential support needed by the farmer is given in Fig. 4.

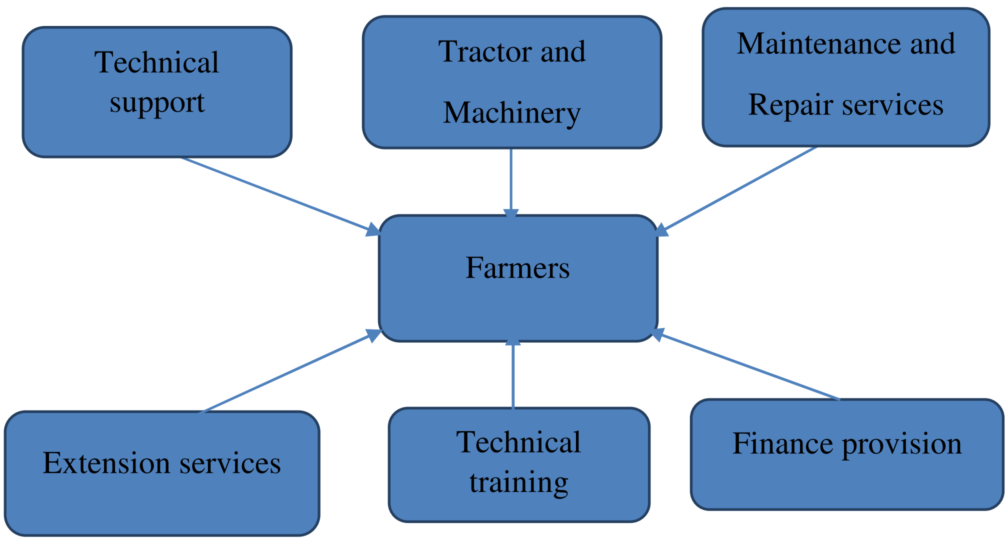

Fig. 4: Farmers Needs for Agricultural Mechanization. Sources; Brian et al., (2016)

If the governments and private individuals can provide agricultural needs and facilities to farmers by investing in agricultural mechanization, it would help to intensify farming through increasing levels of mechanization (Bako et al., 2018). This would lead to increased rural development through improved land use, increased food production, enhanced rural prosperity through economic transformation and, on a national scale; greater export potential and less reliance on imports. Farmers in applying the needs successfully via agricultural mechanization would play a vital role in enabling the growth of agricultural productivity, commercial food systems and increasing the efficiency of post-harvest, handling, processing and marketing operations. Consequently, it would determine food availability and accessibility, as well as food prices, thereby enhancing food security.

5.0 Conclusion

As a major agricultural production input and a catalyst for rural development and economic transformation, sustainable mechanization endeavors to: increase the performance and efficiency of farming activities by introducing appropriate machines and technologies, create jobs (entrepreneurship) and sustainable rural livelihoods, promote agricultural development led industrialization and markets for rural economic growth, improve the quality of primary and processed goods, improve working conditions and raise living standards. Mechanization has a significant role to play at all levels along the entire value chain in terms of modernizing and intensifying agriculture; it creates employment in rural areas – a core element of rural development – and ultimately leads to food security. Making agricultural mechanization more accessible and effective is likely to contribute to African agricultural and economic transformation. Nevertheless, mechanization must overcome a past littered with poorly-planned programs that failed to assess demand, relative neglect by researchers and policymakers, and misconceptions about what mechanization is and is not.

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BUILDING, ENVIRONMENT AND CLIMATE CHANGE

EFFECT OF MICROCLIMATE PARAMETERS ON LOCAL POULTRY BIRD PRODUCTION: KILA OGUN STATE CASE STUDY

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Abstract

Livestock account for one-third of Nigeria's agricultural (GDP) gross domestic product. Farm animal production is increasing drastically with an increase in Nigeria's economy. The climate, especially heat stress, threatens this population. For poultry under intensive care, the lack of research is the microclimate parameter's effect on the birds' production. And because most of the commercial production are under intensive care, there is a need to study the development of the microclimate parameters on the birds' production. Therefore, the main objectives of this study are to determine the impact of ambient and microclimate temperature and relative humidity (RH) on the egg production and bird weight in a battery cage (BC) and deep litter (DL) production systems respectively. While the correlation between the independent parameters and dependent parameters and a regression model relating the independent and the dependent parameters were determined as specific objectives of this study. An intensive local poultry farm located at Latitude: 6° 48′53.68″ N, Longitude:3°11′42.65″ E, Orientation: E-W (240°) on the map of Ogun State: Kila, Odeda LGA, Ogun was used as experimental poultry for this study. It consists of a DL and a BC poultry partitioned by an air wall. Correlation between the following independent parameters: daytime ambient temperature (DAT); nighttime ambient temperature (NAT);
daytime indoor temperature (DT); nighttime indoor temperature (NT); daytime ambient RH (DARH); nighttime ambient RH (NARH); daytime indoor RH (DRH); nighttime indoor RH (NRH); daytime percentage optimum temperature (DPOT); nighttime percentage optimum temperature (NPOT); daytime percentage optimum RH (DPORH); feed consumed (FC); and dependent parameters egg weight (EW) and bird weight (BW) respectively. R-square (R^2) and adjusted R^2 were used to determine which model best predicted the dependent parameters. Results showed that some parameters correlated highly with the egg and birds' weights. The results also indicated that the egg production and bird's weight could be predicted from the daytime percentage optimum microclimate temperature and feed consumption, respectively.

Keywords: poultry, microclimate, temperature, relative humidity, correlation, prediction

1. Introduction

Poultry can be defined as all domesticated birds used to produce meat or eggs for consumption, manufacture other commercial rooster products, restock, furnish game, or breed these birds (FAO, 2009). Livestock farming contributes hugely to the livelihood in urban and rural communities via an increase in meal production, farm energy, farm manure, fuel, transportation and nutritional security, and incomes (Tewe, 2006). In Nigeria, the poultry population is estimated to be 140 million (Ocholi *et al.,* 2016). Livestock account for one-third of Nigeria's agricultural (GDP) Gross Domestic Product. In 2010, farm animal production increased drastically in Nigeria's economy, accounting for about 11% of the GDP (Encyclopedia of the Nations, 2010). This population is threatened

by the climate, especially heat stress, as listed by Mark et al. (2013) as one factor affecting poultry production and reproduction. Investing in poultry will be enhanced if the yield can be predicted through optimum environmental conditions.

Researchers have studied and showed that chickens subjected to heat stress conditions spend less time feeding, more time drinking and panting (Mack *et al.,* 2013), and the effect of ambient climate variables on the production and reproduction of poultry birds (Nayak et al. 2015). Adesoji, *et al.,* (2006) stated that the greatest effect of weather was observed in the sub- Sahara Africa where animal production contributes forty percent (40%) of agricultural Gross Domestic Product (GDP) and supports the well-being of billions of the world's poor by employing about 1.3 billion people. For poultry under intensive care, the lacking aspect is the effect of the microclimate parameter on the birds' production. And because most of the commercial production are under intensive care, there is a need to study the effect of the microclimate parameters on the birds' output. Therefore, the main objective of this study is to check the impact of ambient and microclimate temperature and relative humidity (RH) on the egg production and bird weight in a battery cage (BC) and deep litter (DL) poultry respectively. While the specific objectives are to determine the correlation between the independent parameters and the dependent parameters, and develop a regression model relating the independent and the dependent parameters.
Understanding the relationship between the poultry environment's optimal conditions and the productivity, in this case, egg and bird weight, will help to predict future yield and investment.

2. Materials and Method

2.1 Description of the experimental poultry

An intensive local poultry farm at Kila, Odeda LGA, Ogun state was used as experimental poultry for this study Kila is located on Latitude: 6° 48′53.68″ N, Longitude: 3°11′42.65″ E, Orientation: E-W (240°) as shown on the Map of Ogun State. The systems of production consist of a DL and a BC poultry partitioned by an air wall. The poultry was naturally ventilated and shaded with a galvanized metal sheet roof and wire mesh at the sides. Polyethylene sacks were used for covering the pen at night and during raining season. The poultry floor for BC was 7.8 m in length and 3.5 m in width, with a height of 2.26 m. The DL poultry's length was 4.9 m, width 3.5 m, and height 2.26 m. Parameters recorded are, temperature and RH. The position of the sensors is shown in Figure 1. The sensor at 0.1 m and 1.0 m were used for the DL and BC analysis, respectively. All sensors recorded data every 10mins. The data were collected from the 8th of September to the 6th of November 2021.

2.2 Data analysis

Temperature and RH data collected from each sensor (Figure 1) in each poultry were subjected to statistical analysis using the Microsoft Excel 2019 statistical package. Seven and four weeks of data were used to analyze the correlation between the following independent parameters: daytime ambient temperature (DAT); nighttime ambient temperature (NAT); daytime indoor temperature (DT); nighttime indoor temperature (NT); daytime ambient RH (DARH); nighttime ambient RH (NARH); daytime indoor

RH (DRH); nighttime indoor RH (NRH); daytime percentage optimum temperature (DPOT); nighttime percentage optimum temperature (NPOT); daytime percentage optimum RH (DPORH); feed consumed (FC); and dependent parameters egg weight (EW) and bird weight (BW) respectively. R-square (R^2) and adjusted R^2 were used to determine which model best predicted the dependent parameters

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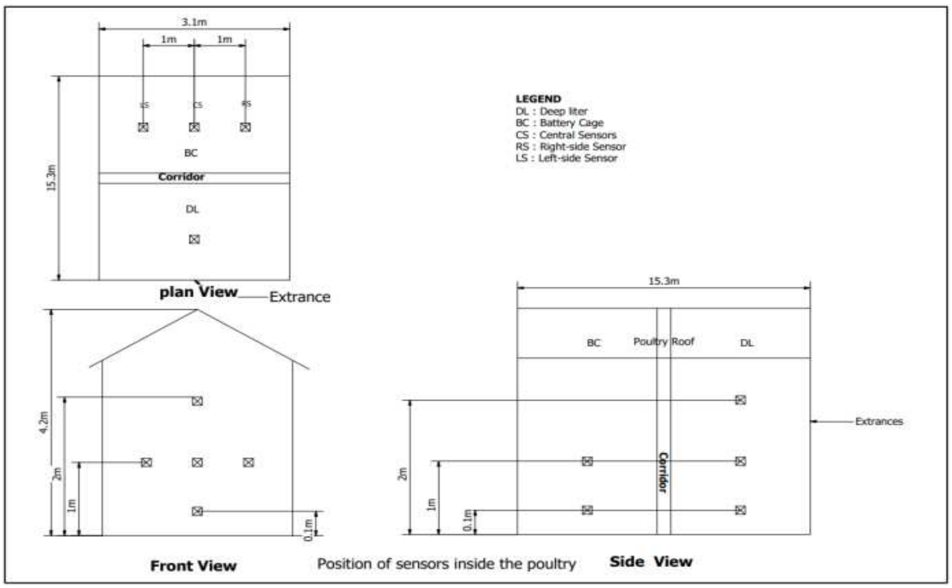

Figure 1. Dimension and position of sensors in the poultry

3. Results and discussion

Tables 1 and 2 show the average measured day and night ambient and microclimate temperature and RH in BC and DL, respectively. They also offer the day and night percentage optimum temperature, day percentage optimum RH, feed consumed, and the egg weight and bird weight in BC and DL, respectively. The average ambient temperature ranges from 23.37°C to 28.37°C, whereas the average BC microclimate temperature ranges from 23.82°C to 30.19°C, and the DL microclimate temperature ranges from 23.91°C to 30.06°C. In contrast, the ambient RH ranges from 76.10% to 96.34%, whereas the BC microclimate RH ranges from 75.59% to 91.75%, and DL ranges from 74.57% to 90.67%. The daytime percentage optimum temperature range in BC was from 0% to 12.80%, while the night-time ranges from 62.20% to 87.80%. The daytime percentage optimum temperature range in DL was from 0% to 2.80%, while the night-time ranges from 57.10% to 77.60%. The optimum daytime RH in BC and DL ranges from 37.1% to 52.4% and 40.0% to 44.3%, respectively. The highest percentage of optimum daytime and nighttime temperature in BC corresponded to the highest feed consumed and egg weight. In contrast, DL was observed to reach only the highest feed consumed.

Table 3 shows a strong positive correlation between the EW, DPOT, NPOT, and NRH. Also, a strong but negative correlation between NT and a weak correlation between DRH and FC. DAT, NAT, DT, NARH, and FC show a strong correlation between the BW but a weak correlation between NT, DARH, and NPOT.

The possible regression models to predict the EW and BW are presented in Table 4. For the EW predicted, the third model shows the highest adjusted R^2 of 0.962 and the lowest error of 0.014, suggesting the best model. The implication is that an increase in the NRH, DPOT, and NPOT will cause an increase in the egg weight. Bhadauria et al. 2014 and Nayak et al. (2015) reported a combination of optimum temperature and RH to affect egg production positively, hence buttressing this result. For the BW, the first model with the combination of the NAT and FC gave the best model with the highest adjusted R^2 and lowest error of 0.008. Nayak et al. (2015) opined that a low air temperature increases birds' body heat production by increasing feed consumption and activity. Instead of the feed consumed translating to increased body weight, the strong correlation to the night ambient temperature, which is usually low, seems to be responsible for the negative effect of the feed.

Figure 2 shows the 1:1 linear regression plot of predicted EW against the actual EW (Figure 2a) and actual EW against the DPOT (Figure 2b). The multivariate regression shows that only DPOT was significant at $p<0.05$. Figure 3 shows the 1:1 linear regression plot of predicted BW against the actual BW (Figure 3a) and actual BW against the FC (Figure 3b). The multivariate regression shows that only FC was significant at $p<0.05$ but with a negative correlation.

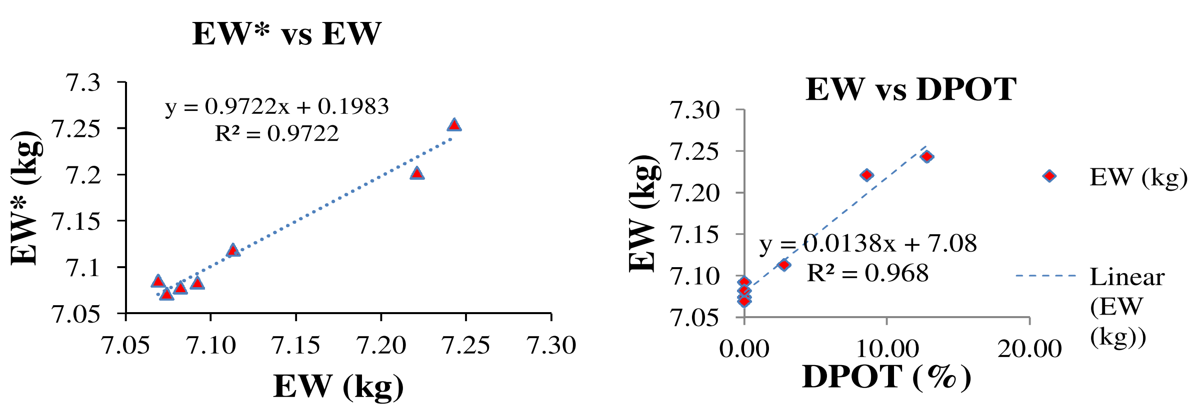

Figure 2. Linear regression plot of (a) redicted EW against actual EW and (b) EW against DPOT

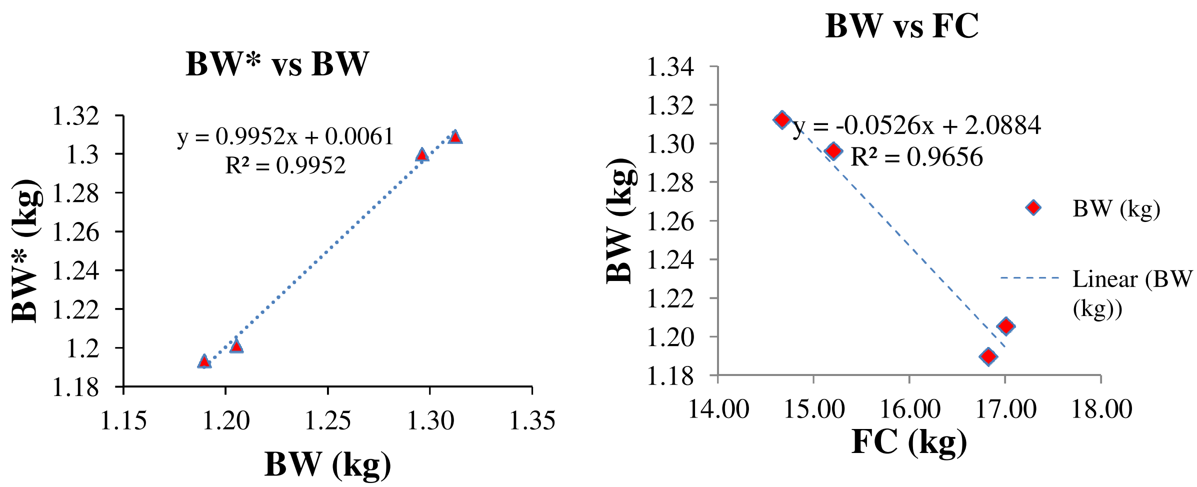

Figure 3. Linear regression plot of (a) predicted BW against actual BW and (b) BW against FC

4. Conclusion

In conclusion, the effect of ambient and microclimate temperature, relative humidity (RH), and feed on the egg and bird weight in a battery cage (BC) and deep litter (DL) poultry, respectively, were studied. The night time microclimate temperature and RH and day time and night time percentage optimum temperature data were strongly correlated with egg weight. In contrast, day and night time ambient temperature and RH; day time and night time percentage microclimate temperature; and feed consumption data highly correlated with the birds' weight. The results indicated that the egg and bird's weight could be predicted from the daytime percentage optimum microclimate temperature and feed consumption, respectively.

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Table 1. The average ambient, microclimate, and productivity data in BC over seven weeks of the experiment.

Date	DAT (°C)	NAT (°C)	DT (°C)	NT (°C)	DARH (%)	NARH (%)	DRH (%)	NRH (%)	DPOT (%)	NPOT (%)	DPORH (%)	FC (kg)	EW (kg)
2022-09-24	27.38	23.37	28.84	23.82	78.83	96.34	77.73	90.64	0.00	71.40	37.10	33.64	7.09
2022-10-01	27.75	24.02	30.06	24.17	81.54	96.28	75.59	90.82	0.00	62.20	47.10	33.15	7.07
2022-10-08	27.65	24.30	29.86	23.76	83.51	96.12	77.65	91.14	0.00	71.40	40.00	33.39	7.07
2022-10-15	27.55	23.71	29.76	23.74	81.57	96.97	75.66	90.41	2.80	74.50	52.80	30.28	7.11
2022-10-22	27.59	23.93	29.33	23.53	81.26	95.83	77.80	91.63	8.60	84.70	42.90	35.34	7.22
2022-10-29	28.17	23.90	30.19	23.66	78.21	95.69	75.83	90.74	0.00	65.30	51.40	41.51	7.08
2022-11-05	28.37	23.83	29.92	23.50	76.10	96.26	77.91	91.75	12.80	87.80	42.80	43.94	7.24

DAT: daytime ambient temperature; NAT: nighttime ambient temperature; DT: daytime indoor temperature; NT: nighttime indoor temperature; DARH: daytime ambient RH; NARH: nighttime ambient RH; DRH: daytime indoor RH; NRH: nighttime indoor RH; DPOT: daytime percentage optimum temperature; NPOT: nighttime percentage optimum temperature; DPORH: daytime percentage optimum RH; FC: feed consumed; EW: egg weight

Table 2. Over four weeks of the experiment, the average ambient, microclimate, and productivity data in BC.

Date	DAT (°C)	NAT (°C)	DT (°C)	NT (°C)	DARH (%)	NARH (%)	DRH (%)	NRH (%)	DPOT (%)	NPOT (%)	DPORH (%)	FC (kg)	BW (kg)
2022-09-24	27.38	23.37	28.99	23.91	78.00	96.68	77.63	90.35	0.00	69.40	41.40	16.83	1.19
2022-10-01	27.75	24.02	30.50	24.27	81.30	96.37	74.57	90.18	0.00	57.10	44.20	14.67	1.31
2022-10-08	27.65	24.30	30.28	23.84	83.51	96.12	76.69	90.67	0.00	71.40	40.00	15.21	1.30
2022-10-15	27.55	23.71	30.06	23.81	81.57	96.97	75.03	89.83	2.80	77.60	44.30	17.01	1.21

DAT: daytime ambient temperature; NAT: nighttime ambient temperature; DT: daytime indoor temperature; NT: nighttime indoor temperature; DARH: daytime ambient RH; NARH: nighttime ambient RH; DRH: daytime indoor RH; NRH: nighttime indoor RH; DPOT: daytime percentage optimum temperature; NPOT: nighttime percentage optimum temperature; DPORH: daytime percentage optimum RH; FC: feed consumed; BW: bird weight

Table 3. Correlation coefficients between environmental and feed and productivity data of the birds.

	DAT (°C)	**NAT (°C)**	**DT (°C)**	**NT (°C)**	**DARH (%)**	**NARH (%)**	**DRH (%)**	**NRH (%)**	**DPOT (%)**	**NPOT (%)**	**DPORH (%)**	**FC (kg)**
EW (kg)	0.38	-0.11	-0.15	-0.72**	-0.47	-0.11	0.54*	0.81***	0.98***	0.94***	-0.15	0.50*
BW (kg)	0.92***	0.89***	0.82***	0.59*	0.68**	-0.84***	-0.42	0.42	-0.49	-0.65**	-0.06	-0.98***

DAT: daytime ambient temperature; NAT: nighttime ambient temperature; DT: daytime indoor temperature; NT: nighttime indoor temperature; DARH: daytime ambient RH; NARH: nighttime ambient RH; DRH: daytime indoor RH; NRH: nighttime indoor RH; DPOT: daytime percentage optimum temperature; NPOT: nighttime percentage optimum temperature; DPORH: daytime percentage optimum RH; FC: feed consumed; EW: egg weight; BW: bird weight

Table 4. Possible regression models for productivity responses of the birds based on environmental and feed data

PI	Regression model	MR	R^2	Adj. R^2	SE
EW (kg)	0.003NRH + 0.011DPOT* +0.001NPOT + 6.70	0.986	0.972	0.944[c]	0.017
	0.012DPOT* +0.001NPOT + 6.993	0.986	0.972	0.958[b]	0.015
	0.014DPOT* + 7.08	0.984	0.968	0.962[a]	0.014
BW (kg)	0.045NAT - 0.04FC* + 0.822	0.998	0.995	0.985[a]	0.008
	7.08 -0.052FC*	0.983	0.966	0.948[b]	0.014

NAT: nighttime ambient temperature; NRH: nighttime indoor RH; DPOT: daytime percentage optimum temperature; NPOT: nighttime percentage optimum temperature; FC: feed consumed; EW: egg weight; BW: bird weight

PRECIPITATION CHANGE PROJECTION UTILIZING GENERAL CIRCULATION MODELS OVER ONDO NORTH REGION, NIGERIA

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Abstract

A hybrid Statistical Downscaling Model (SDSM) was used to downscale and generate future precipitation over Ondo North Agro-ecological Zone (ONAEZ), Nigeria. The ensembles of six General Circulation Models (GCMs) were used, including CCCMA by the Canadian Centre for Climate Model and Analysis version 3.1, MPI, MIROC by the Model for Interdisciplinary Research on Climate, Irish High-End Computing (ICHEC), and CNRM. The observed precipitation data from the six meteorological stations in the study area and the downscaled historical precipitation data were compared. Projected precipitation was generated under Representative Concentration Pathways (RCP 4.5) for the periods 2035-2065 (the 2050s) and 2070-2100 (2080s) relative to the baseline (1975-2005). The outcome showed that the SDSM demonstrated that all GCMs had significant capabilities to reconstruct monthly historical precipitation with a low bias value. In the 2050s, falls of -14.2 percent and -1.6 percent were anticipated using MIROC and CNRM over ONAEZ by four GCMs (ICHEC, MPI, MOHC, and CCCMA), whereas increases of 18.5 percent, 18.3 percent, 23.7 percent, and 40.0 percent were forecasted using four other GCMs (ICHEC, MPI, MOHC, and CCCMA). In conclusion, the CCCMA model simulation runs for downscaling precipitation are deemed superior to those of the other chosen GCMs, and this is significant for studies of climate change.

Keywords: Precipitation, General circulation models, Statistical downscaling method, Climate change, Ondo North Region

1. Introduction

Precipitation is one of the most important components of hydrological cycle. Increases in temperature and evapotranspiration affect water balance cycle and causes rainfall fluctuations which could lead to drought or flood. Oguntude *et al* (2012) reported that spatial and temporal variations in temperatures were noticed in Nigeria where air temperature has been on the increase gradually since 1901 and with a noticeable increase from 1970.

The growing population in Ondo North Agro-ecological Zone (ONAEZ) in Ondo State needs increased energy, food and rapid economy expansion. However, availability of sufficient amount of water is important to balance these demands. Precipitation determines the magnitude of available water and is an important factor (Tripathi *et al.,* 2015). The variability of rainfall and the pattern of extreme high or low precipitation are very important for agriculture as well as the economy of Ondo state. In ONAEZ, farming sector is the major activity which only serves the purpose for food production and raw materials

for the emerging small-scale industries in Ondo State. This region has a total irrigable land of 20,500 hectares which is expected to be irrigated from Awara dam. Most of the crops (plantain, yam, cassava) productions in this region are under rainfed cultivation and this allows the food production to be highly vulnerable to climate change. It is not very clear the dynamics of future rainfall patterns and how this will have effects on crop water requirement and irrigation demand.

Evaluation of possible future precipitation occurrence requires good understanding of baseline rainfall trends of the region. Investigating how change in climate will alter future precipitation and its spatial and temporal variability is an area of active research (Basistha *et al*., 2009). In projecting future precipitation, different uncertainties such as climate change scenarios which are based on future greenhouse gases emission must be considered. General circulation models (GCMs) are useful tools to simulate baseline and future climate using hindcast simulations (Chistensen, 2011). As a result of coarse spatial resolution of GCMs, the outputs cannot be directly applied without downscaling (Wilby and Dawson, 2014) . Downscaling techniques are used to obtain the weather and climate information at a local scale from relatively coarse-resolution GCMs (Wilby and Dawson, 2014). In most of the climate studies, statistical downscaling method (SDSM) is always considered above dynamic technique because of its simple computing algorithms and applications. Using SDSM, large scale atmospheric variables (predictors) of GCMs are related to station-scale climate variables (predictands) based on empirical relationship (Kim *et al*., 1984; von Storch *et al*., 2000).

In this study, Statistical Downscaling Model is applied to downscale precipitation from large scale predicators accessed from Canadian Centre of Climate Modelling & Analysis (CCCMA), Met Office of Hadley Centre (MOHC), Model for Interdisciplinary Research on Climate (MIROC), Irish Centre for High-End Computing (ICHEC) and Max Planck Institute for Meteorology (MPI) to local scale predictants. The future precipitation predictions were made under the newly updated emission scenario-representative concentration pathway 4.5 (RCP 4.5) for two different periods 2050s (2035-2065) and 2070s (2070-2100) respectively. In conclusion, the primary objectives of this study to analyze the capability of statistically-downscaled GCMs to reproduce observed precipitation predict future precipitation and estimate its changes in response with baseline period of 1975-2005 in Ondo-North region of Ondo-State, Nigeria.

2. Materials and Methods

2.1 Study area

Ondo North Agro-Ecological Zone is one of the three Agro-Ecological Zones in Ondo State. It shares boundary with Edo-State by east, Ekiti State by west and Kogi State by north (OSMA,2007). The region comprises of six local government areas namely; Akoko North East, Akoko North West, Akoko South West, Akoko South-East, Owo and Ose as shown in Table 1. It falls in the sahel savanna climate and an average annual rainfall of 1224 mm, minimum and maximum temperature range from 25.5°C to 33.3°C with average air temperature of 29.9°C (OSMA,2007) (Table 1 and Figs.1a and 1b).

Table 1: Categorization of Local Government Areas to Agro-Ecological Zone in Ondo-State

S/N	OSAEZ	OCAEZ	ONAEZ
1	Odigbo	Akure South	Akoko N.W
2	Okitipupa	Akure North	Akoko N.E
3	Irele	Ileoluji/Okeigbo	Akoko S.W
4	Ilaje	Ifedore	Akoko S.E
5	Ese-Odo	Ondo-East	Owo
6	Idanre	Ondo-West	Ose

Source: Ondo State Ministry of Agricultural & Natural Resources, 2009

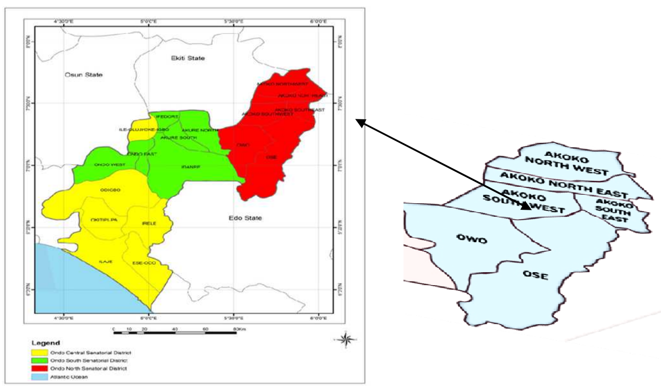


Fig.1a: Map of Ondo-State,   Fig.1b: Location map of study area

2.2 Precipitation dataset

Dataset used for this climate study is made up of station-observed and downscaled precipitation. Baseline precipitation which is available on daily basis from 1975-2005 was obtained from Ikare-weather Station, Okeagbe-Weather Station, Iwaro-

Weather Station, Isua-Weather Station and Owo-
Ose Weather Station as shown in Table 2. The rain gauges are of the heated tipping-bucket type (Wilh. Lambrecht GmbH model 1518) with a tip resolution of 0.1 mm and a sampling time resolution of 30-min. However, using a statistical downscaling model (SDSM), 30-year historical dataset from these stations (local scale) was reproduced from six selected GCMs

2.3 Model evaluation

The representativeness of the global climate models is evaluated before applying GCMs to simulate future precipitation under Representative Concentration Pathways (RCP 4.5). SDSM is a hybrid between a stochastic weather generator and a multilinear regression method, forcing synoptic-scale weather variables to local meteorological variables using six statistical relationships (Pervez and Henebry, 2014). Predictor variables are available for period 1901-2100 for selected GCMs. Spatial resolution of data considered for climate study is shown in Table 3. The predictors are simulated under RCP 4.5 for the future periods 2035-2065 and 2070-2100. Performance of SDSM in reproducing baseline precipitation was estimated using bias corrected value by comparing downscaled precipitation from large-scale predictors with station-observed precipitation from 1975-2005 for the study region. Equations 1-3 are applied to compute bias corrected value (BCV) and future precipitation changes for periods 2050s and 2100s. Coefficient of determination (R^2) and Root Mean Square Error (RMSE) were used to measure the models performance as shown in equations 4-5.

Table 2: Meteorological stations with approximate coordinates

S/N	LGA	Location	Station ID	Long (degree)	Lat (Degree)	Elevation (m)	Record
1	Akoko N.W	Okeagbe	203K	5.76	7.67	508.1	1975-2005
2	Akoko N.E	Ikare	205R	5.40	7.31	462.2	1975-2005
3	Akoko S.W	Iwaro	303W	5.45	7.24	373.1	1975-2005
4	Akoko S.E	Isua	305U	4.98	6.99	252.6	1975-2005
5	Owo	Owo Poly	288P	5.59	7.23	305.3	1975-2005
6	Ose	Ifon	306F	5.58	7.18	288.7	1975-2005

Table 3 **GCMs downscaled for the research study**

Models	Emission scenarios	Spatial resolutions
CCCMA	RCP 4.5	48×96 cells, $3.75^0 \times 3.75^0$
MPI	RCP 4.5	96×192 cells, $1.9^0 \times 1.9^0$
MOHC	RCP 4.5	88×176 cells, $2.0^0 \times 2.0^0$
MIROC	RCP 4.5	67× 134 cells, $1.12^0 \times 1.12^0$
CNRM	RCP 4.5	64×128 cells, $2.8^0 \times 2.8^0$
ICHEC	RCP 4.5	60 × 120 cells, $2.9^0 \times 2.9^0$

$$\mathrm{BCV}_{(\mathrm{ICHEC})} = \mathrm{P}_{(\mathrm{ICHEC-Predicator})} - \mathrm{P}_{(\mathrm{ICHEC-Predicant})} \quad (1)$$

$$\mathrm{P}_{(\mathrm{MOHC\ 2050s})} = \frac{\mathrm{Prec}_{(\mathrm{MOHC\ 2050S})} - \mathrm{Prec}_{(\mathrm{observed})}}{\mathrm{Prec}_{(\mathrm{Observed})}} * 100 \quad (2)$$

$$P_{(MOHC\ 2080s)} = \frac{Prec_{(MOHC\ 2080s)} - Prec_{(observed)}}{Prec_{(Observed)}} * 100 \quad (3)$$

$$R = \frac{\sum_{i=1}^{N}(x_{obsi} - \dot{x}_{obs})(x_{simi} - \dot{x}_{sim})}{\sqrt{(\sum_{i=1}^{N} x_{obsi} - \dot{x}_{obs})^2 \sum_{i=1}^{N}(x_{sini} - \dot{x}_{sim})^2}} \quad (4)$$

$$RMSE = [\frac{1}{N}\sum_{i=1}^{N}(x_{simi} - \dot{x}_{obs})½] \quad (5)$$

Where, BCV is Bias corrected value; Prec is precipitation (mm), P changes in precipitation (%), ICHEC and MOHC are climate models. Where $X_{obs,i}$ is the ith observed precipitation (monthly), $X_{sim,i}$ is the ith simulated (raw GCM or downscaled) precipitation (monthly), and N is the number of data (Pervez and Henebry, 2014). R and RMSE is coefficient of correlation and root mean square respectively. Coefficient of determination (R^2) measures the discrepancy between simulated and observed parameters using a linear fit model.

3. Results and discussion

3.1 Model calibration

The statistical downscaling model (SDSM) is calibrated for downscaling precipitation using 30years (1975-2005) for the study area. Model efficiency was evaluated using statistical metrics such as Root Mean Square Error and Coefficient of determination (R^2). Table 4 shows the result of calibration between the station-based and GCMs downscaled precipitation. Figs. 3a-3f shows the comparison of six GCMs downscaled precipitation to the matching baseline precipitation on annual basis. All the selected GCMs performed very well to reproduce baseline precipitation as depicted in Table 4 and Figs.3a-3f.

The accurate estimation of baseline precipitation indicates sensitivity and precision of using statistically-downscaling method for climate change studies. Calibration of observed climate and reproduced atmospheric variables for precipitation had highest correlation values (R^2) of 0.93 and RMSE of 23.7 for CNRM, whereas R^2 and RMSE 0.91 and 26.6 were estimated by MOHC model. The outputs of this simulation revealed that SDSM has strong capacity of downscaling precipitation at annual scale for both control and future periods. Agreement of GCMs reproduction with referenced precipitation is very important for future projections. Many models that reproduce the past regional temperature and precipitation similarly produce very different future projections (Chylek *et al.,* 2016; Kieh, 2007). Chylek *et al.* (2016) reported that SDSM may not be the most efficient tool while downscaling future extreme precipitation events at a daily scale, but it is an efficient tool for providing future downscaled precipitation at a monthly time scale. Evaluation of the bias difference between GCMs reproduced and station-based precipitation is primarily to measure the representativeness and capability of GCMs to simulate baseline climate (Power *et al.,* 2017). Computed monthly bias values from the six selected GCMs are depicted in Fig.2. Maximum annual precipitation bias values (BV) of 34.3 mm and 31.6 mm were estimated from the simulation outputs of CNRM and MOHC whereas -28.8 mm and -24.0 mm were obtained from MPI and CCCMA respectively.

Table 4: Calibration of observed and GCMs-SDSM Precipitation for Ondo-North(1975-2005)

Models	STDV	RMSE (mm)	Slope	Intercept	R^2
MPI	94.7	34.9	1.03	-3.44	0.84
MIROC	129.2	27.8	1.46	2.06	0.90
MOHC	125.5	26.6	1.42	-0.66	0.91
ICHEC	117.9	37.9	1.27	8.69	0.81
CCCMA	105.7	37.6	1.14	-12.7	0.82
CNRM	107.5	23.9	1.19	0.25	0.93

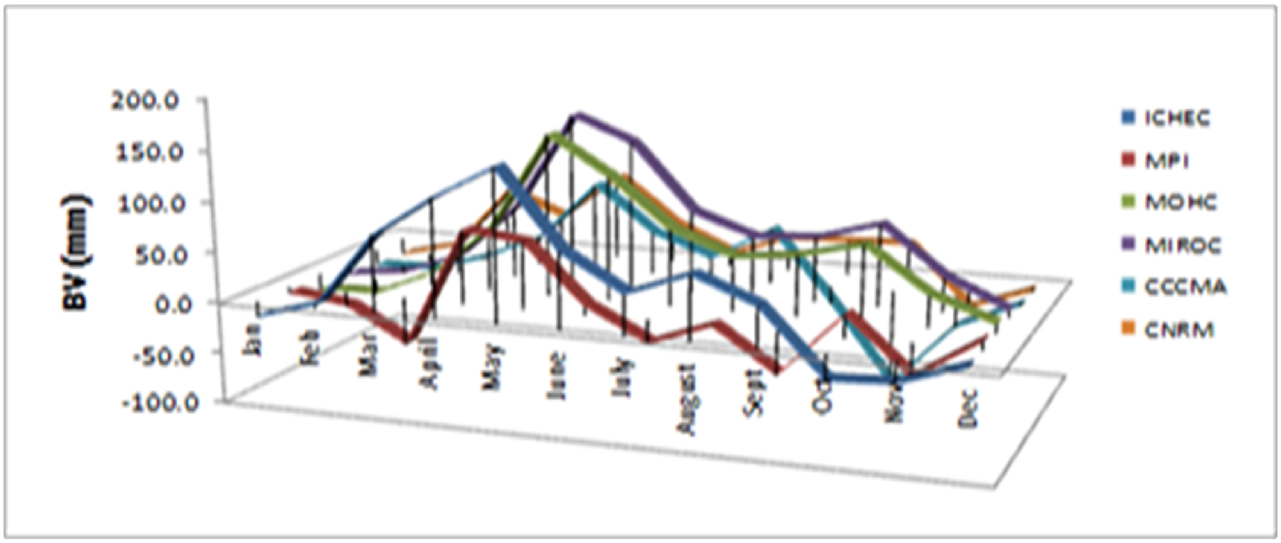
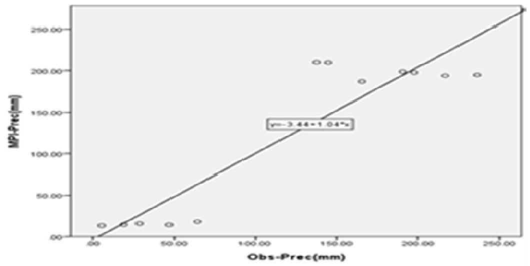
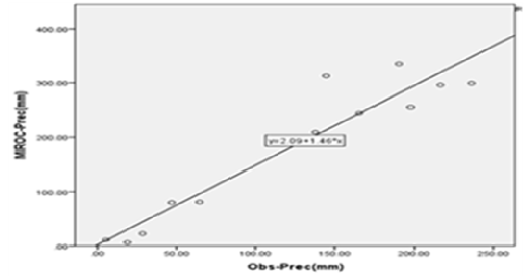


Fig.2: Bias values for monthly precipitation for six GCMs over ONAEZ for calibration period 1975-2007



(A)



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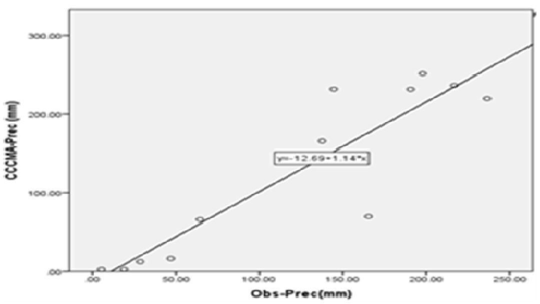

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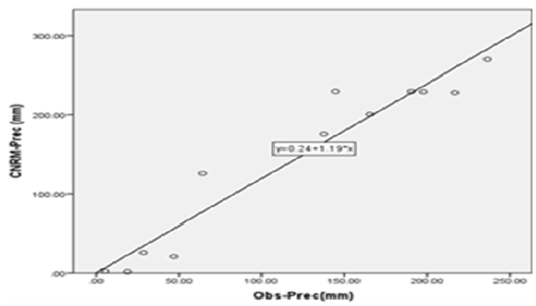

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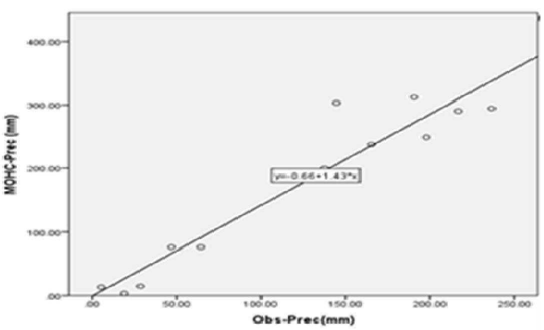

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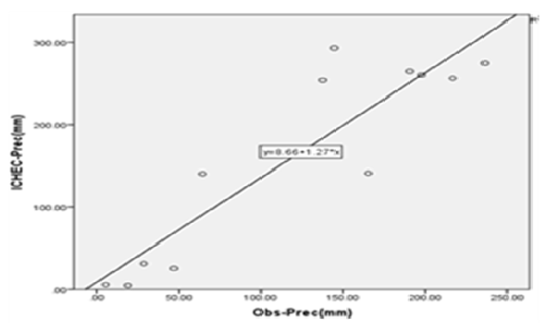


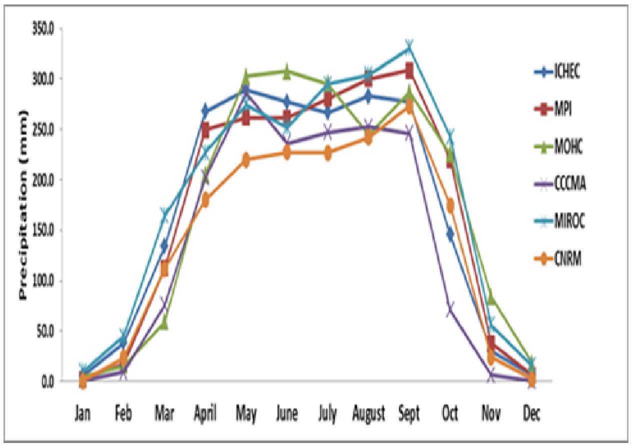
(F)

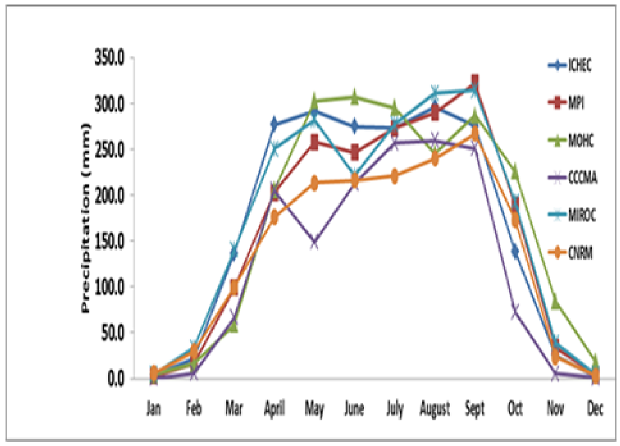
Fig.3. Calibration (1975-2005) of GCMs-SDSM with station-based precipitation (a) Scatter plot of observed and MPI simulated precipitation, (b) Scatter plot of observed and MIROC simulated precipitation, (c) Scatter plot of observed and MOHC simulated precipitation, (d) Scatter plot of observed and ICHEC simulated precipitation (e) Scatter plot of observed and CCCMA simulated precipitation and Scatter lot observed and CNRM simulated precipitation at annual scale.

3.2 Precipitation Projections

Statistical downscaling model was used to downscaled baseline and generate future precipitation over ONAEZ from six selected GCMs. The projected changing dynamics of precipitation was evaluated with comparison outputs of downscaled future precipitation and referenced precipitation. Projected monthly precipitation (2035-2065 and 2070-2100) against the observed precipitation from 1975-2005 is shown in Fig.4. The output of the future precipitation projections from four GCMs (ICHEC, MPI, MOHC and CCCMA) showed an overall annual mean increase of 18.5%, 18.3%, 23.7% and 40.0% while decreases of -14.2% and -1.6% were predicted using MIROC and CNRM over ONAEZ for 2050s which agrees with

Dharmaveer *et al. (*2015) and IPCC, 2007. Although the increase in projected precipitation for 2080s is relatively less as compared to the GCMs predictions for the near period under RCP 4.5 with CCCMA having the highest projection of 18.2% and MIROC indicated precipitation decrease of -23.9% respectively (Paul *et al.*, 2008). The GCMs that reproduced larger precipitation over ONAEZ than that of the referenced observation which may likely due to topographical orientation and the coarse-resolution of general circulation generation simulations (Chen *et al.*, 2010). These models overestimate the precipitation over ONAEZ by 2.1%-10.1% for ICHEC, while CCCMA and MOHC overvalued with 10.1%-20.6% and 10.6%-13.6% for periods 2080s and 2050s respectively. The results obtained from selected GCMs is shown in Figure 5.





A B

Fig.4. Projected precipitation for six GCMs-RCP 4.5 for periods 2035-2065 (a) and 2070-2100 (b) over ONAEZ relative to baseline (1975-2005).

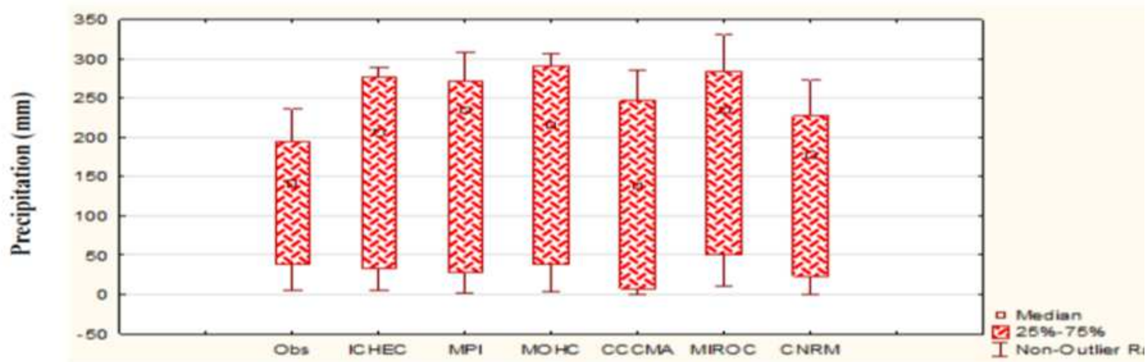
The outputs of the general circulation models for monthly projected precipitation are depicted in Tables 5 and 6 respectively. All the GCMs indicated large decrease in precipitation for 2050s and 2080s in January, whereas in February there may likely be increase precipitation of 33.2% and -66.8% as predicted by ICHEC in 2050s and increases of 16.8% and 4.2% were projected from MIROC and CNRM models for 2080s. The same predictive trends were observed by some GCMs from October through December. Although this period is categorized as dry season with small rainfall depth, low rainfall intensity and few number of raining days (NRD). All the GCMs predicted increase in projected precipitation from the month of March through September for both 2050s and 2050s. This development may influence early onset to rainfall date (ORD), increase (NOR) and prolong the raining cessation date (RCD) over ONAEZ.

Table 5: Changes in monthly precipitation(%) using six GCMs-4.5 for 2070-2100

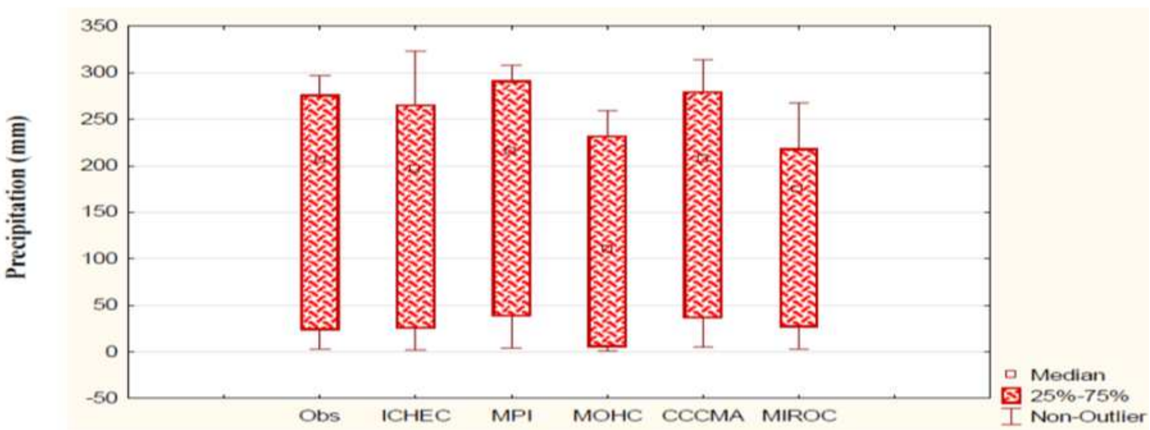
	General Circulation Models(GCMs)					
Month	ICHEC	MPI	MOHC	CCCMA	MIROC	CNRM
Jan	-71.4	-86.2	-77.2	-95.8	-47.1	-97.4
Feb	33.2	-39.2	-44.4	-66.8	28.0	-18.2
Mar	54.4	73.9	-8.5	17.9	77.3	73.4
April	47.2	46.7	49.3	46.7	64.8	31.0
May	50.4	44.6	60.3	66.6	66.8	52.2
June	45.4	37.0	61.3	23.9	32.3	19.2
July	23.0	29.4	36.1	14.0	36.0	4.7
August	43.1	51.8	23.9	27.6	53.8	22.5
Sept	17.2	30.5	21.4	4.1	39.9	15.5
Oct	-12.0	32.9	36.4	-57.3	46.7	5.7
Nov	-36.5	-19.0	79.5	-86.1	19.6	-49.0
Dec	27.8	16.7	45.7	-64.6	61.3	-79.0

Table 6: Changes in monthly precipitation(%) using six GCMs-4.5 for 2070-2100

	General Circulation Models (GCMs)					
Month	ICHEC	MPI	MOHC	CCCMA	MIROC	CNRM
Jan	-81.0	-86.2	-77.2	-96.8	-75.1	-70.4
Feb	-23.1	-39.2	-44.4	-79.7	16.8	4.2
Mar	55.3	36.9	-8.5	2.8	50.7	54.8
April	50.1	40.7	49.3	49.1	54.8	28.1
May	48.0	40.6	50.3	2.8	51.2	47.6
June	44.1	37.0	30.8	11.8	15.8	13.3
July	25.9	29.4	36.1	18.4	27.9	2.0
August	49.7	25.5	23.9	31.0	57.1	21.2
Sept	16.4	30.5	21.4	6.0	32.9	13.0
Oct	-16.2	32.9	36.4	-56.2	16.4	4.7
Nov	-45.6	-19.0	79.5	-89.1	-17.3	-49.0
Dec	-50.0	16.7	19.8	-87.0	-13.0	-42.6



(a)



(b)

Fig.5. Box plots of observed and SDSM based downscaling model for projected precipitation distribution (maximum, third quartile, median, first quartile and minimum) for ONAEZ for the periods 2035-2065 (a) and 2070-2100 (b).

4. Conclusion

In order to create future precipitation (2035-2065 and 2070-2100) from the predictors of six chosen climate models under greenhouse gas emission of RCP 4.5 over Ondo North District of Ondo State, Nigeria, a hybrid statistical downscaling model (SDSM) was utilized. The results of simulations using SDSM demonstrate that all GCMs successfully replicated the referenced precipitation over the research area. The predicted precipitation from the GCMs was compared to the baseline, and changes and the patterns of precipitation distribution were assessed. The overall finding indicates that while MIROC and CNRM projected a drop in the 2050s, four GCMs (ICHEC, MPI, MOHC, and CCCMA) revealed an overall annual mean rise in precipitation during the 2050s and 2080s. Therefore, to simulate and forecast precipitation over Ondo North District, these models showed great competence, but most of the models overestimated expected precipitation. This is the significance of employing different GCMs for climate studies from a practical standpoint. Thus, some crops that require a lot of effective rainfall, like plantains and bananas, may benefit from the expected shift in peak precipitation time, whereas crops like maize may suffer greatly. In the investigated region, there is a very high possibility that anticipated precipitation would result in flooding.

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DEVELOPMENT OF PSYCHRO-AUTOMATED DATA ACQUISITION SYSTEM FOR ENVIRONMENTAL MONITORING IN BUILT ENVIRONMENTS

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Abstract

This work involved the design and construction of psychrometric automated data acquisition system which was deployed in a built environment to carry out performance test and assessment. Psychrometric chart represents the physical and thermodynamic behavioral properties of gas-vapour mixture (moist-air) at a defined pressure. The system processes were primary data collection by data acquisition system (DAQ), data transfer, data synthesis/management and presentation. Read off data from the sensors (DHT22 sensor) were integrated into the sets of programs calling from the Arduino library (Arduino Uno as the microcontroller unit (MCU), written in C++ language). The microcontroller also calculates the psychrometric data of the environment from the readings taken off the sensors. The algorithms basically utilize the available data from the sensors (dry-bulb temperature and relative humidity) to numerically determine the psychrometric parameters through the psychrometric equations. The data was transmitted and presented over a serial communication channel between the Arduino microcontroller and a serial monitor software via the ports. The system was calibrated and validated using real data gotten from standard measured environmental parameters. Economic analysis was also carried out to determine the cost-benefit analysis of the automated environmental monitoring system as compared with the conventional method of environmental monitoring and control. The result showed that the Mean Error Percent Rate of the developed DAQ system's measured values compared to ASHRAE'S reference values were: enthalpy – 0.53%, dew-point temperature – 2.16%, Specific volume – 0.13%. The Mean Error Percent Rate of the developed DAQ system's measured values compared to LINRIC PsyCalc's measured values were enthalpy – 0.19%, dew-point temperature – 3.67%, specific volume – 0.26%, wet-bulb temperature – 3.97%. However, the developed DAQ system had comparative economic advantage over manual parametric instruments based on time value of money, security of data as well as relative cost of procurements.

Keywords: Psychrometry, Automation, Data acquisition system, Built environment, Real-time.

1 Introduction

Built environment monitoring involves measuring microclimatic parameters repetitively so that the structure and functional use can be deduced for observation, analysis and control (Acevedo, 2016). It is the continuous observation and study of the ambient environs for the purpose of data collection from which decision can be made (Artiola et al., 2004). Psychrometry involves the study of the observed heat exchange and kinetic properties of moist-air (ASHRAE, 2017). In addition to collection of data, the psychrometric properties of indoor air are essential to the design and operation of environmental control systems such as ventilation, refrigeration, heating and cooling, air conditioning, and modified environments. Calculation of energy demand in modified atmosphere storage, drying and cooling of agricultural products processing and storage, design of animal rearing house, humidity and temperature control in built structural units are paramount (Lindley et al., 1996). Environmental monitoring assists in the design of structure adapted to environmental changes and improved agricultural production systems as well as decision making (Acevedo, 2016). However, psychrometric variables are related to a number of physical laws. (ASHRAE, 2017). These laws are imperative in built environmental conditions. Some of the important psychrometric properties include dry-bulb temperature, wet bulb temperature, dew point temperature, relative humidity, humidity ratio, enthalpy and specific volume etc. With physical equations and relationships (ASHRAE, 2017), other respective psychrometric properties of moist air can be evaluated where two available psychrometric parameters are ascertained. Technology has evolved to the point of continuous insitu measurement of environmental parameter (real-time) for a given period of time. These technologies allow for measurement, evaluation, storage, transmission and display of environmental data in a variety of ways as against read off instrument like thermometer, anemometer or even with the use of psychrometric chart etc. Over the last few years, recent advances in the field of computation – hardware and software development has made psychrometric calculations and estimations more convenient and robust. Beltran-Prieto *et al*., (2015) developed a Visual Basic program describing the set of equations required to determine the value of seven different psychrometric properties – partial pressure of water vapor, absolute humidity, percentage humidity, relative humidity, dew point temperature, humid heat, humid volume or adiabatic saturation temperature – for mixtures of water vapor in air given the dry bulb temperature, the total atmospheric pressure and one additional parameter. Similarly, Psycalculator: an automatic system for psychrometric calculations, registered at the National Institute of Industrial Property (INPI, 2018) was designed and developed by Corraide *et al*., (2018). The software under review presented data from sensors and displayed their respective psychrometric properties in graph and tables. Commercially, PsyCalc, a desktop psychrometric calculator was designed and developed by LINRIC – and has been in use for more than 20 years. Also, a digital psychrometric device was developed for the determination of the psychrometric properties of moist air by Kizil *et al*, (2019). While some of these developed devices and programs had varying degrees of accuracy, others were not fully automated to function as data acquisition systems – DAQ. This paper presents the development of an automatic psychrometric data acquisition system for measurement of built environmental parameters. This device is expected to be deployed in multi built systems but was applied in a poultry rearing house to monitor the environmental variables as well as also estimate the cost benefit of developing the system relative to conventional use of psychrometric chart. It is expected to be portable, user-friendly, and cost-effective for low income farmers. Therefore, the system was developed to measure environmental parameters, calculate and display the corresponding psychrometric properties. In addition, cost-benefit analysis was also carried out to estimate the value of the innovations relative to conventional means of environmental measurement practices in built environment.

2.0 Materials and methods

2.1 Conceptual Design and Development of DAQ

For the purpose of this project, the methodology applied was data collection, data management, data synthesis/transfer and presentation. The data collection involved the design and development of the

DAQ – Data Acquisition System which primarily involved integrating the sensors to the microcontroller. Reading off data from the sensors with the use of the microcontroller involved writing sets of programs and calling from the Arduino library in C/C++ language. The data management involved the evaluation and determination of other psychrometric data using the measured temperature and relative humidity data gotten from the sensor environment. This is achieved by performing low-level function calls at the hardware level for increased optimization and efficiency in the operations. The data transmission process involved the serial communication channel between the Arduino microcontroller and a serial monitor software. For the exchange of information between the DAQ and the software, a serial communication channel was used. The necessary settings for the serial communication protocol were the predetermined baud rate, parity and the specific port. To view the output data, the microcontroller sends the processed data – measured and evaluated data to the serial monitor software. The serial monitor used was QTSerialMonitor, an open-source software. The serial monitor is a graphical user interphase (GUI) software that displays the output data both in logs and graphs. It also enables the user to save, export and print the data in various file formats such as clx, jpeg, txt etc.

2.2 Electrical components used in the device

i. Arduino UNO R3

Arduino Uno R3 is a microcontroller board with an AT mega328 microprocessor, serial ports, USB ports, AC/DC adapter.

Table 1: Specifications of Arduino Uno R3 microcontroller (ARDUINO, 2019)

Microprocessor	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7–12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Figure 1: Picture of Arduino Uno R3 microcontroller

ii. DHT22 sensor

The DHT22 sensor is a sensor that utilizes digital signal collecting-technique and humidity sensing technology. It is small size in nature, has a low power consumption and a single wire protocol for transferring data which enabled precise timing and easy, simple and fast integration with the Arduino UNO R3 microcontroller.

Table 2: Specifications of DHT22 (Aosong, 2021)

Sensing Period	**2s**
Sensing Element	Polymer capacitor
Operating Voltage	5V
Input Voltage Range	3.3 – 6V DC
Humidity Operating Range	0-100% RH
Temperature Range	-40 – 80^{O}C
Dimensions	14x18x5.5mm
Accuracy levels	Relative Humidity +-2% RH (Max +-5% RH)
	Temperature +-0.5^{O}C
Transmission Distance	20m

Figure 2: Picture of DHT22 sensor

2.3 Psychrometry parametric determination and evaluation

Psychrometry properties include, parameters like the air's dew point temperature, its wet bulb temperature, relative humidity, humidity ratio, enthalpy etc. The use of equations to calculate and determine the psychrometric properties of moist air requires at least two parameters and a measured altitude (Albright, 1990). The following are outlines as referencing equations for calculating moist air properties using perfect gas relations. For the scope of this paper, dry-bulb temperature, relative humidity and atmospheric pressure (derived from the determined altitude) will be the given parameters. Therefore, air parameters can be gotten as follows:

i. Atmospheric Pressure

The barometric pressure of atmospheric air varies considerably with altitude as well as with local geographic and weather conditions. The standard atmosphere gives a standard of reference for estimating properties at various altitudes. At sea level, standard temperature is 15°C; standard barometric pressure is 101.325 kPa. Temperature is assumed to decrease linearly with increasing altitude throughout the troposphere (lower atmosphere), and to be constant in the lower reaches of the stratosphere. The lower atmosphere is assumed to consist of dry air that behaves as a perfect gas. Gravity is also assumed constant at the standard value, 9.806 65 ms^{-2}. (ASHRAE, 2017). Pressure is calculated from the equation (1) (ASHRAE, 2017)

$$p = 101.325(1 - 2.25577 \times 10^{-5} Z)^{5.2559} \quad (1)$$

$where$
$Z = altitude, m$
$p = barometric\ pressure, kPa$

ii. Saturated Water Vapour

The water vapour saturation pressure is required to determine a number of moist air properties, principally the saturation humidity ratio. The saturation (sublimation) pressure for the temperature range of -100 to 0°C as given seen in equation (2) (ASHRAE (2017)

$$\ln p_{ws} = C_1/T + C_2/T + C_3/T + C_4/T^2 + C_5/T^3 + C_6/T^4 + C_7 \ln T \quad (2)$$

$where$
$C_1 = -5.6745359e^3$
$C_2 = 6.3925247$
$C_3 = -9.6778430e^{-3}$
$C_4 = 6.2215701e^{-7}$
$C_5 = 2.0747825e^{-9}$
$C_6 = -9.4840240e^{-13}$
$C_7 = 4.1635019e^0$

The saturation pressure over liquid water for the temperature range of 0 to 200°C is given as written in equation (3) (ASHRAE (2017)

$$\ln p_{ws} = C_8/T + C_9/T + C_{10}/T + C_{11}/T^2 + C_{12}/T^3 + C_{13} \ln T \quad (3)$$

$where$
$C_8 = -5.8002206e^3$
$C_9 = 1.3914993$
$C_{10} = -4.8640239e^{-2}$
$C_{11} = 4.1764768e^{-5}$
$C_{12} = -1.4452093e^{-8}$
$C_{13} = 6.5459673e^0$
$p_{ws} = saturation\ pressure, Pa$
$T = absolute\ temperature, T(K) = t(C) + 273.15$

iii. Humidity ratio (W)

The humidity ratio (W) is given as written in equation (4)

$$W = 0.621945 \frac{P_w}{p - P_w} \quad (4)$$

$where$
$P_w = partial\ pressure\ of\ water\ vapour$
$p = total\ mixture\ pressure$

iv. Saturation humidity ratio (W_s)

The saturation humidity ratio (W_s) is given as written in equation (5)

$$W_s = 0.621945 \frac{P_{ws}}{p - P_{ws}} \quad (5)$$

Specific volume v

Specific volume (v) of a moist air mixture is expressed as in equation (6)

$$v = \frac{0.287042(t + 273.15)(1 + 1.607858W)}{p} \quad (6)$$

$where$
$v = specific\ volume, \frac{m^3}{kg_{da}}$
$t = dry - bulb\ temperature, C$
$W = humidty\ ratio, \frac{kg_w}{kg_{da}}$
$p = total\ pressure, kPa$

v. Enthalpy h

Enthalpy (h) of a mixture of perfect gases equals the sum of the individual partial enthalpies of the components. Therefore, the specific enthalpy of moist air can be expressed as written in equation (7) (ASHRAE, 2017)

$$h = 1.006t + W(2501 + 1.86t) \quad (7)$$

$where$
$t = dry - bulb\ temperature, C$
$W = humidty\ ratio, \frac{kg_w}{kg_{da}}$

vi. Dew-point temperature

The **dew-point temperature (t_d)** of moist air with humidity ratio W and pressure p was expresses as the solution of $t_d(p,W)$ of $W_s(p, td)$. For perfect gases, this is reduced to the equation (8) given below (ASHRAE (2017).

$$p_{ws}(t_d) = p_w = \frac{pW}{0.621945 + W} \quad (8)$$

$where$
$t_d = dew\ point\ temperature, C$
$p_w = water\ vapour\ partial\ pressure, kPa$
$W = humidty\ ratio, \frac{kg_w}{kg_{da}}$

vii. Wet-bulb temperature t*

When the wet bulb is placed in an airstream, water evaporates from the wick, eventually reaching an equilibrium temperature called the wet-bulb temperature. As defined, thermodynamic wet-bulb temperature is a unique property of a given moist air sample independent of measurement techniques.

$$W = \frac{(2830 - 0.24t^*)W_s^* - 1.006(t - t^*)}{2830 + 1.86t - 2.1t^*} \quad (9)$$

$where$
$W_s^*\ is\ a\ function\ of\ temperature\ t^*\ for\ a\ fixed\ value\ of\ pressure$
$t^* = wet\ bulb\ temperature$

2.4 Numerical calculation of the psychrometric properties of moist air

The numerical calculation of the psychrometric properties of moist air could be approached using the several methods namely:

Method 1: When given the dry-bulb temperature t, wet-bulb temperature t* and pressure p.

Method 2: When given the dry-bulb temperature, dew-point temperature t_d, and pressure p.

Method 3: When given the dry-bulb temperature, relative humidity ϕ, pressure p.

This study was an approach using Method 3, given dry-bulb temperature, relative humidity ϕ, pressure p , other properties were determined. Therefore, for analysis of Method 3: we have:

1. To obtain the saturation pressure of water vapourp ws(t), we referred to equation (2) or (3) for temp. t between -100 to 0°C and temperature between 0 – 200°C.
2. To obtain the humidity ratio W, equation (4) was applied.
3. To obtain the saturated humidity ratio W_s, equation (5) was applied.
4. To obtain the specific volume v, equation (6) was applied.
5. To obtain the enthalpy H, equation (7) was applied.
6. To obtain the dew-point temperature t_d, equation (8) was applied.
7. To obtain the wet-bulb temperature t*, equation (9) was applied.

For the development of the automatic data acquisition system, the two environmental variables – dry-bulb temperature and relative air humidity were measured with sensors and stored in a microcontroller. The variables measured were transmitted from the microcontroller to the software program over a serial communication channel. DHT22 sensors which were used to measure the dry bulb temperature and the relative humidity and Arduino Uno R3 served as the microcontroller unit for the purpose of the study.

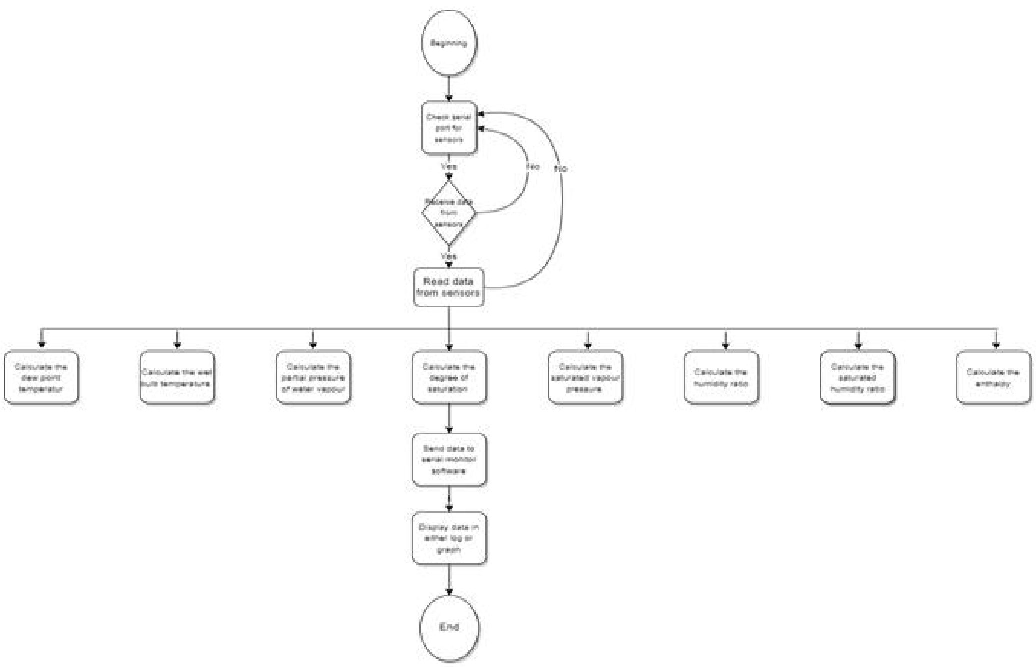

Figure 3: Flowchart of the entire DAQ system

3. Results and Discussion

The developed automated Data Acquisition system (DAQ) for the monitoring, evaluating and display of the psychrometric properties was actualized using Arduino Uno as the microcontroller unit (MCU), DHT22 sensor for measuring the dry-bulb temperature and relative humidity and a software program for the calculation, evaluation and display of the other psychrometric properties. The developed hardware of Psychro-automated data acquisition system. is shown in figure 4.

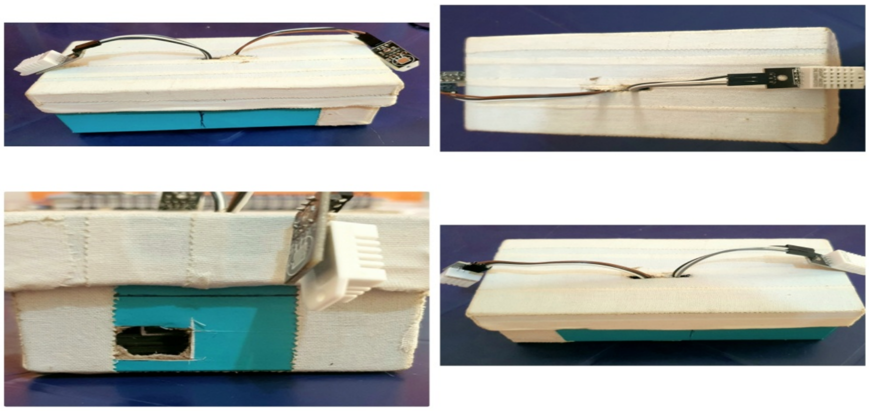

Figure 4: The developed hardware of Psychro-automated data acquisition system.

The software program simply evaluates nine other psychrometric properties of moist air and displays

them alongside the two measured parameters for reading and understanding as shown in figure 5. The data is displayed in logs and graphs for ease of processing and in-situ reading which ultimately guide in decision making and supports.

3.1 Cost structure of Psychro-automated data acquisition system.

The costs of the component parts of the automated data acquisition system have been detailed in table 3. These parts were: – microcontroller, sensors, and cables. The material costs used were primarily for prototyping and as such the cost can further reduce during mass production/deployment. Some additional costs not added were the software and hardware development costs, server costs, licensing software fee for additional features such as data processing, storage and analysis, predictive analytics. For the economics of this study, an exchange rate of N570 to $1 was adopted.

Table 3: Total cost of the developed automated Psychro-DAQ system

Equipment	Piece	Unit Price (N)	Total Cost (N)
Arduino UNO REV3 (Microcontroller)	1	17,160	17,160
USB 2.0 Cable Type A/B	1	500	500
Aosong DHT22 AM2302 Temperature and Humidity Sensor	1	6,240	6,240
ELEGOO 120PCS multicolored Dupont Wire	1	5,460	5,460
ELEGOO 3PCS 400 tie-points breadboard	1	6,240	6,240

Total Amount (N)	35,600
Total Amount ($)	62.46

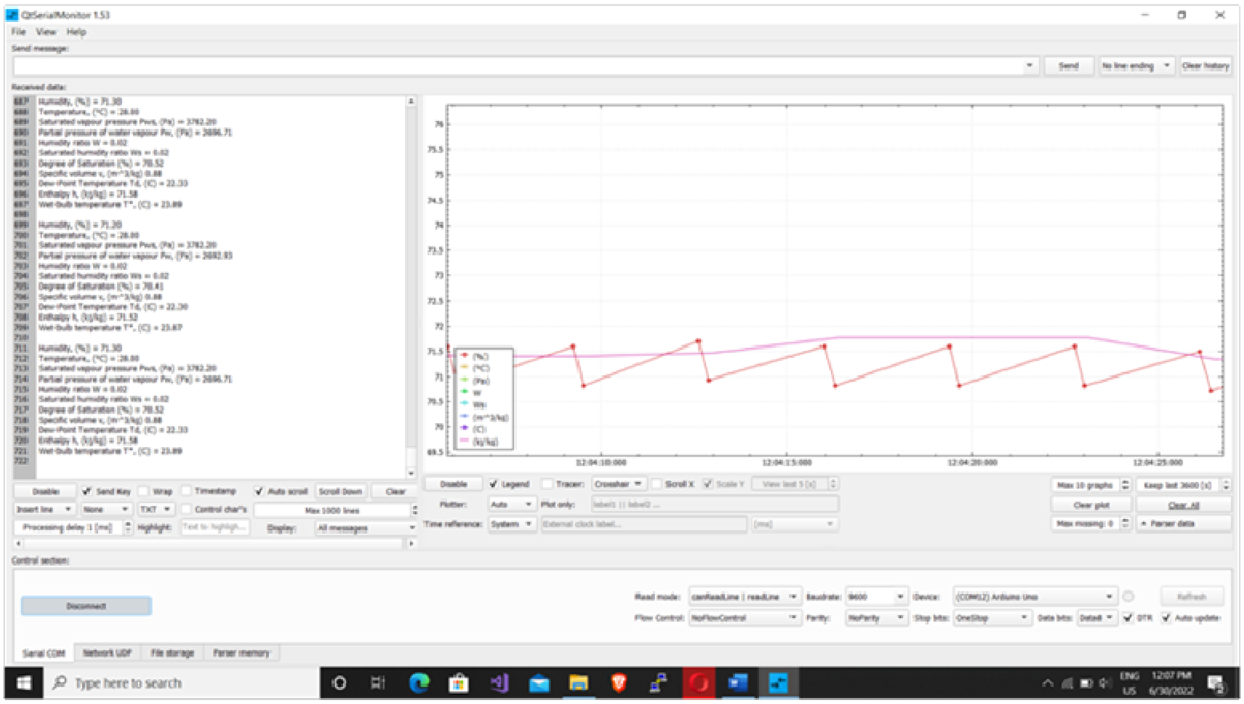

Figure 5: *Software program showing results of measured and calculated psychrometric data*

3.1.1 Cost and performance comparison between the psychrometric charts and the automated DAQ environmental monitoring system

For cost comparison, the system developed relative to the psychrometric chart is shown in table 3 where the total cost of producing Psychro-automated DAQ was N35, 600 or $62.46 while that of the psychrometric charts for research purpose was N10, 000 or $17.54. However, the use of psychrometric chart to determine the psychrometric properties of air has been subsisting and as such required read-offs which is usually cumbersome and time wasting given the time it takes to trace virtually all the air properties due to drudgery and human inefficiencies of the user. The average time it took to determine the temperature and relative humidity of the study environment and read off other psychrometric parameters of air from the psychrometric chart was 283 seconds while the developed automated system displays results at an average time of 7 seconds as shown in table 4. The chart plotted of the time taken for the various methods of measurements, significant time could be observed. The average amount of time saved for each data collection and evaluation for every period of collection was determined as 276 seconds. Similarly, it was also illustrated in figure 6 showing that of manual and figures 7 showing for developed automated system given the simulation as well as figure 8 showing the compares.

Table 4: showed the time taken to measure the psychrometric properties of air using the psychrometric chart and the developed automated DAQ system.

No of simulations	Time taken in seconds (s) to read data off sensors and psychrometric chart	Time taken in seconds (s) to read data off the automated system
1	320	5
2	322	6
3	335	8
4	250	8
5	279	7
6	255	9
7	280	6
8	290	8
9	260	7
10	265	6
11	254	8
Average time	282.7273	7.090909

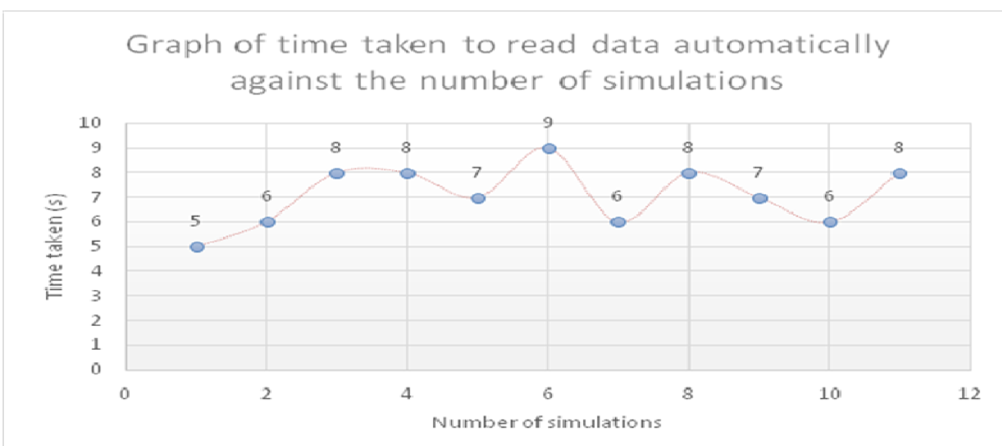

Figure 6: Graph of time taken to read data manually against the number of simulations

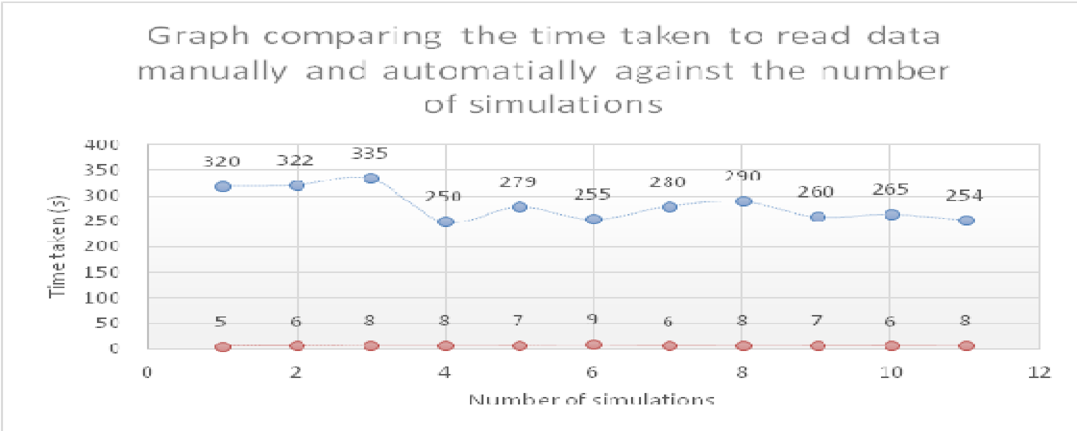

Figure 7: Graph of time taken to read data using the automated DAQ system against the number of simulations

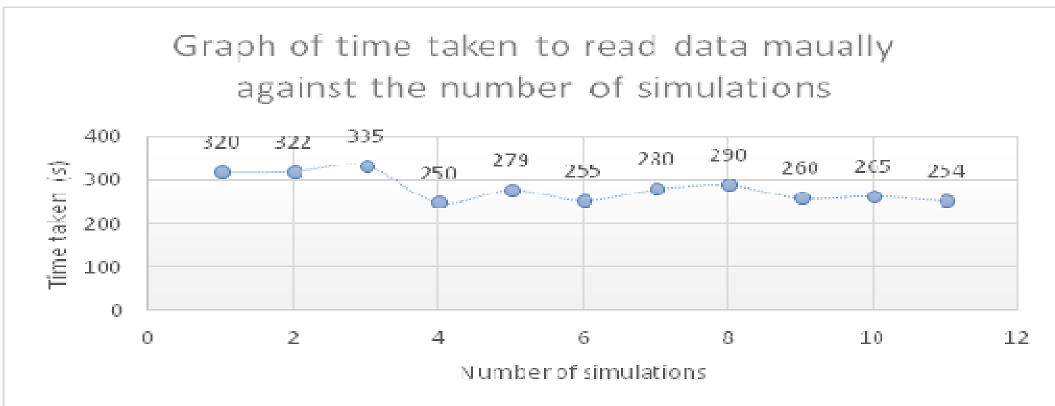

Figure 8: Graph comparing the time taken to read data manually and automatically against the number of simulations.

Therefore, time, convenience, effectiveness, accuracy and in-situ deployment facilitated in the use of developed Psychro-automated DAQ system over manual psychrometric chart vis-à-vis the cost out-weigh the burdensome, ineffectiveness, sometimes inaccuracy of the user as well as back and forth drudgery associated with manual read off.

3.1.2 Comparative analysis and validation of results.

The developed Psychro-automated DAQ system was calibrated using data gotten from the PsyCalc® software – version 5.2.2, developed by Linricand compared with ASHRAE's psychrometric table. The performance of the developed Psychro-automated DAQ system was carried out in a poultry rearing house to monitor environmental parameters. These parametric results were compared with results from other psychrometric software's as well as validated to determine the standard error mean.

For comparison and validation, readings were taken from the automated psychrometric software developed, the PsyCalc® software – version 5.2.2, developed by Linricand compared with ASHRAE's psychrometric table. Statistical tests were carried out to determine the validity of the results of the DAQ system when compared to other methods. Errors in the results derived from the various methods were computed. Also validation tests were carried out to determine the level of accuracy with the values compared. The validation test used was the Mean Error Percent Rate and is given as:

Mean Error Percent Rate was computed using the following – (experimental value – theoretical value)/experimental value x 100.

The Mean Error Percent Rate of the Automated DAQ system's measured values when compared to ASHRAE'S reference values gave: enthalpy – 0.53%, Dew-point temperature – 2.16%, Specific volume – -0.13%, The Mean Error Percent Rate of the Automated DAQ system's when compared to LINRIC's PsyCalc measured values gave :Enthalpy – 0.19%, Dew-point temperature – 3.67%, Specific volume – -0.26%, Wet-bulb temperature – 3.97% as seen in table 5,6,and 7 respectively.

Table 5: ASHRAE reference values

Number of simulations	Dry-bulb temperature (°C)	Relative humidity (%)	Enthalpy (kJ/kg)	Dew-point temperature (°C)	Specific Volume (m^3/kg)
1	-30	0.338	-30	-40	0.698
2	-10	0.492	-8.1	-17.75	0.746
3	0	0.885	8.38	-1.47	0.777
4	20	0.116	24.4	-9.5	0.832
5	20	0.884	53.1	18.03	0.848
6	35	0.106	44.6	-0.35	0.878
7	35	0.893	111.8	32.97	0.918
8	70	0.133	140.4	29.59	1.01
9	70	0.951	752.8	68.85	1.38
10	100	0.100	288.2	46	1.17
11	110	0.489	3871	90	3.6

6: Developed psychro-automated DAQ system measured values

Number of simulations	Dry-bulb temperature (°C)	Relative humidity (%)	Enthalpy (kJ/kg)	Dew-point temperature (°C)	Specific Volume (m^3/kg)	Wet-bulb temperature (°C)
1	-30	0.338	-29.9871	-39.4082	0.688	-30.4084

2	-10	0.492	-8.10911	-17.7435	0.746415	-11.6646
3	0	0.885	8.34852	-1.47009	0.777955	-0.659026
4	20	0.116	24.3582	-11.01	0.83269	7.87428
5	20	0.884	53.0022	18.0447	0.847758	18.6783
6	35	0.106	44.6619	-0.367543	0.878123	16.1121
7	35	0.893	118.5	32.9478	0.918511	33.3451
8	70	0.133	140.296	29.585	1.01361	50
9	70	0.951	748	68.8679	1.37461	68.8873
10	100	0.100	286.476	46.0606	1.17467	120
11	110	0.489	3890.94	89.969	3.52383	130

Table 7: Linric'sPsyCalc measured values

Number of simulations	Dry-bulb temperature (°C)	Relative humidity (%)	Enthalpy (kJ/kg)	Dew-point temperature (°C)	Specific Volume (m^3/kg)	Wet-bulb temperature (°C)
1	-30	0.338	-29.96	-40	0.69	-30.41
2	-10	0.492	-8.1	-17.75	0.75	-11.67
3	0	0.885	8.37	-1.48	0.78	-0.66
4	20	0.116	24.36	-9.52	0.83	7.85
5	20	0.884	53.12	18.03	0.85	18.68
6	35	0.106	44.71	-0.29	0.88	16.08
7	35	0.893	118.89	32.97	0.92	33.34
8	70	0.133	140.93	29.63	1.01	36.94
9	70	0.951	753.96	68.84	1.38	68.84
10	100	0.100	287.07	45.99	1.17	51.1
11	110	0.489	3891.47	89.87	3.52	90.05

4. Conclusion and Recommendation

This study resulted in the design and development of psychro-automated real-time environmental monitoring system using multi-disciplinary approach. The system can be used to automatically measure, transmit, evaluate, record, and present the psychrometric properties of moist air of any built environment. The advantages of the psychro-automated environmental monitoring system over manual read off of psychrometric chart can never be over emphasized for use in built environments in diverse agricultural applications given the low-cost of the components, the ease of assembly and operation, and most especially, the relative accuracy of measured data. The costs-benefits determined shows that considerable amount of time spent in reading off psychrometric data from the chart can be offset with the use of such automated system. The system is robust, economical, user friendly and in-situ deplorable. The integration of graphic user interface (GUI) with WIFI communication channels, internet connectivity, blue-tooth and cellular network connectivity, etc with machine learning, data processing and prediction and cloud storage of data was considered in the design model of the software to facilitate ease of upgrade and updates. Limitation to the automated DAQ system was that displaying results was only possible on installation of the QTserialmonitor software program on a personal computer (PC). Therefore, there is need to advance this study to become standalone data acquisition, monitoring and decision support system which will snowball into an expert systems.

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EVALUATION OF THE IMPACTS OF CLIMATE CHANGE ON CASSAVA WATER REQUIREMENTS IN EDO STATE, NIGERIA

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Abstract

General circulation models (GCMs) were used in the climate change (CC) study to examine the impacts of predicted climate on the crop water requirement (CWR) of cassava (Manihot esculenta Crantz) for the reference period (1980–2010) and for 2030–2060 (the 2040s) and 207–21100 (2080s). Hence, MOHC and CCCMA anticipated maximum temperature (Tmax) rises of 1.8°C-5.5°C and 1.1°C-2.2°C for the 2040s and 2080s relative to baseline, all the chosen GCMs revealed varying degrees of temperature increases of 2.5°C-5.2°C by MPI. To calculate reference evapotranspiration (ETo) and crop water needs for the study region, CROPWAT 8.1 software was used with historical and future climate records. Therefore, greater ETo values of 122.5 mm, 130.4 mm, and 119.6 mm in March were predicted by MPI and MOHC models for the 2040s and 2080s. However, the anticipated rise in temperature may be responsible for the forecasted rise in ETo. As a result, the simulation revealed that the CCCMA and MOHC models predicted increases in cassava CWR of 15.1%, 17.6%, 14.8%, and 18.1% in response to the baseline for 2030-2060 and 2071-2100, respectively. In order to supplement effective rainfall, supplemental irrigation is required based on the anticipated increase in CWR from March to April (Eff. Rain). On the other hand, during the near future (the 2040s) and long term (2080s), respectively, crop water requirements are projected to fall from April to May, increase from June to July, and then decrease from August through September. In conclusion, it is obvious that rising temperatures have a big effect on CWR. Shift cropping, the sowing of drought-resistant cassava varieties, water conservation, and the holistic application of climate-smart agriculture (CSA) are therefore essential.

Keywords: Climate change, Crop water requirements, General circulation models, Manihot esculenta Crantz, CROPWAT Software

1. Introduction

Water is the most important natural resource for humans, plants, and animals which its shortage could cause negative reversible and irreversible effects. Hence, excessive precipitation on the other hand could be more catastrophic than agricultural and meteorological drought events due to reduced and high rainfall variability. Additionally, increases in temperature are the key driver for high evapotranspiration (ETo) and consequently lead to distortion in the hydrological cycle. Manasa and Shivapour (2016) indicated that climate change (cc) is likely to have serious impacts on the hydrological cycle, water accessibility, and crop water requirements (CWRs). Rao *et al*. (2010) revealed that climate warming has been attributed to the fluctuation of many components of the hydrological cycle such as changes in precipitation occurrence, distribution, intensity and increases in evaporative demand, and changes in surface runoff.

The climate condition of Edo State is tropical with the average precipitation of 1206.4 mm. The region has two climatic classifications as the rainy and dry seasons. The onset to cessation to rainfall occurs from May to October, while the dry period lasts from April to November with average maximum and air temperatures of 31.2°C and 26.4°C. Maize, cassava, groundnut, and rice are some of the important crops cultivated in the agro-ecological zones (AEZs) in Edo State, while cassava is the most cultivated crop with cultivated land increases of 36%, 40%, and 47% in 2010, 2015, 2018, and 2020 respectively. Agriculture in Edo State is predominantly rainfed and this makes it to be highly susceptible to changes in climate. Several studies have shown that CC is likely to further stress water availability, and agricultural production (Chowdhury *et al.*, 2013; Manasa and Shivapur, 2016; Alkolibi, 2002).

An average cassava water requirement (CWRs) is about 400 mm to 600 mm and the temperature requirement is between 25-29°C. At the initial-establishment stage (the first three months) the crop is highly sensitive to water deficit, while at the development and maturity cassava can withstand mild periods of drought (Alkolibi, 2002). Temperature an essential agrometeorological variable that determines crop phenological development. An increase in air temperature shortens crop growing length and consequently leads to low yield. [3] reported that a temperature increase of 1oC could change a crop's thermal limit and this is likely to decrease agricultural production between 5-25%. The finding of Mall *et al*. (2006). indicated that global surface temperature (GST) is expected to increase by 1.4-3.0°C from 1990 to 2100 for low greenhouse emission scenario, whereas for high emission scenario, the temperature is projected to increase from 2.5-5.8°C. Conversely, projected temperature changes will affect crop sap flow, thermal limit, phenology, and crop yield. The effect of temperature increase is not limited to evapotranspiration, but also affects irrigation water requirement (IWRs) and crop water requirements (CWRs).

The climate study of (Shahid, 2011) showed a rise in temperature leads to an increase in evapotranspiration. Hence, temperature increase, rise in reference evapotranspiration, wind speed, and sunshine hour in combination with crop coefficient (Kc) determines CWR. Several climate studies have shown that CC will negatively affect global future crop water requirements (Shahid, 2011; Durand, 2005; Chowdhury *et al.*, 2013). However, studies on CC effects on cassava water requirements over Edo State and Nigeria are generally limited, while many climate change studies on CWRs have been recorded on maize, groundnut, and rice over the study region. The standard and well-accepted procedure for estimating CWR are through the application of CROPWAT software. The software uses robust meteorological variables (minimum and maximum temperature, sunshine hours, wind speed, relative humidity, precipitation) as inputs in combination with crop coefficient (Kc) to generate outputs such as reference evapotranspiration (ETo), CWR, solar radiation (Rs), IWRs, and actual crop evapotranspiration. CROPWAT software has globally been chosen over other process-based crop models due to its ability to simulate, estimate and predict CWR, IWR, ETo, and Rs under various climate change scenarios with reliable outputs. Chowdhury *et al.* (2013) revealed that the software performed very well in estimating CWR, irrigation planning, and scheduling from the past studies. Conversely, for effective water management and planning, it is essential to have good knowledge of CWR and changes in crop water requirements in response to CC. Therefore, in this study, baseline and projected cassava CWRs are computed using CROPWAT software version 8.1 for the short term (2040-2069) and long term (2070-2099) under three (3) general circulation models (GCMs) and two (2) representative concentration pathways (RCP 4.5 and RCP 8.5) in response to the baseline (1980-2010) over Edo State.

2. Materials and Methods

2.1 Study area

The study covers Edo State located in the South-South region of Nigeria. The State lies at the latitude of 6.6342°N and longitude of 5.930°E at an elevation of 122 m above sea level and a total land square area of 17,802 km². The State has three distinct agro-ecological zones which comprise the rain forest and mangrove swamp in the South, a combination of little savannah and rainforest in the Central, and large Savannah and low rainforest in the North. Edo State shares boundaries with Kogi State to the north-east, Ondo State to the West, Delta State to the Southeast, and Anambra State to the east (Opera-News, 2009). The State is a tropical climate with two distinct classifications as the rainy and wet seasons. The mean annual rainfall is about 1800 mm and the monthly air temperature of 27°C. The annual relative humidity ranges between 80% and 85% from the northern to the southern part of the of the study area. Fig.1 shows the map of the study area.

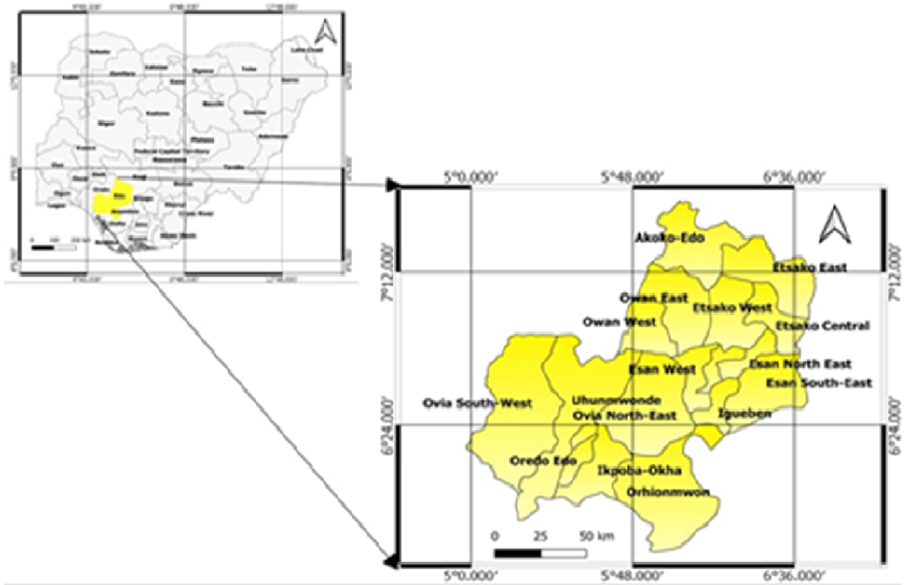


Fig.1: Location map of Edo State

2.2 GCMs simulation dataset

GCMs are typically run with various changes to forcing conditions, such as increased greenhouse gas concentrations in the atmosphere. According to (Tubiello *et al.* (2012), it is very important not to depend on one GCM alone, but several climate models predictions when developing assessment studies climate studies. Based on this, an ensemble of three (3) GCMs selected from the 5th Coupled Model Intercomparison Project (CMIP5) was used for this study. Statistical downscaling model (SDSM) which is a hybrid between a stochastic weather generator and a multilinear regression method, forcing synoptic-scale weather variables to local meteorological variables using statistical relationships of Pervez and

Henebry, (2014) was used for the simulation. Historical monthly climate datasets for 1980-2010 were taken from the CRU TS2.1 database through the Department of Agro-climatological, Ministry of Agriculture & Natural Resources, Edo-State, Nigeria with a spatial resolution of 30 arc-minute. Future climate datasets (minimum temperature, maximum temperature, and precipitation) for the near (2030-2060) and long term (2071-2100) will be simulated from the six selected GCMs under the climate change scenario-Representative Concentrations Pathway (RCP 4.5). Table 1 shows the description of selected general circulation models, their spatial resolutions, and representative concentration pathways for the research study.

Table 1: Properties of selected CMIP5 climate models used in this study

Model Name	Abbreviations	Spatial resolution
Canadian Centre for Climate Modeling & Analysis	CCCMA	48×96 cells, 3.750 ×3.750
Max Planck Institute for Meteorology	MPI	96×192 cells, 1.90 ×1.90
Met Office Hadley Centre	MOHC	88×176 cells, 2.00 × 2.00

2.3 CROPWAT Software

CROPWAT Irrigation model was used to compute the reference (ETo) and Cassava crop water requirement (CWR) under baseline (1980-2010) and future periods (2030-2060) and (2071-2100). The model, developed by FAO, is an irrigation management model to evaluate crop water requirements and irrigation needs (Clarke *et al.*, 1998). The CROPWAT model was selected based on its ability to simulate the impact of various climate change scenarios on crop water requirement; and also, on the basis of previous successful studies and satisfactory performance in a number of worldwide locations under varying climate circumstances (Hegde and Srivinas, 2008). Table 2 shows the input and output parameters of the CROPWAT model. cassava–crop water requirements were predicted using CROPWAT software as shown in equation (1). The model also uses the in-built Pen-Monteith method to compute reference evapotranspiration (ET_o) (2):

$$CWR = ET_o * Kc \quad (1)$$

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \quad (2)$$

CWR is crop water requirement in mm/day, Kc is crop coefficient and ET_o is reference evapotranspiration in mm/day. R_n is net radiation at the crop surface (MJ/m^2/day), G = soil heat flux density (MJ/m^2/day), T = mean daily air temperature at 2 m height (^{0}C), u_2 = wind speed at 2 m height (m/s); e_s= saturation vapor pressure (kPa/^{o}C); e_a = actual vapor pressure (kPa/^{o}C); e_s–e_a = saturation vapor pressure deficit (kpa); Δ = slope of vapor pressure curve (kPa/^{o}C) and γ = psychrometric constant (kPa/^{o}C).

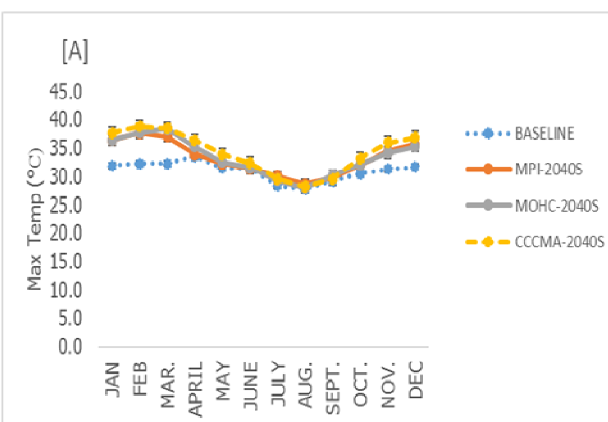
Table 2: Baseline and projected cassava water requirements (mm) under RCP 4.5 in Edo State

	Baseline	MPI		MOHC		CCCMA	
Month	1980-2010	2030-2060	2071-2100	2030-2060	2071-2100	2030-2060	2071-2100
MAR	47.6	59.1	59.4	88.2	60.5	90.4	61.8
APR	88.7	99.8	95.0	99.5	96.7	98.8	104.2
MAY	143.6	149.6	151.1	147.3	150.9	154.7	155.4
JUN	140.8	151.1	151.6	147.4	151.4	155.5	155.6
JUL	133.1	150.1	151.2	147.6	148.8	150.7	151.4
AUG	124.1	142.9	139.6	127.0	137.0	137.5	138.3
SEP.	73.3	96.5	97.1	94.6	95.9	94.4	95.0

3. Results and discussion.

3.1 Temperature projection

The output of temperature projection showed increases in Tmax and Tmin for the 2040s and 2080s relative to the referenced period (1980-2100) by the selected GCMs over Edo State as shown in Fig 1a-b. However, the estimated annual Tmax was projected to increase by 2.5-5.2^{o}C in MPI, 1.8-5.2^{o}C (MOHC), and 1.1-2.2^{o}C (CCCMA) for the 2040s and 2080s under the climate change scenario (RCP 4.5). The simulation runs indicated increases in annual changes for both minimum and maximum temperatures over the study region. The results of the projection showed very good agreement with the climate change studies in the literature (McCarthy *et al*., 2014; Osborn *et al*., 2014; Rosenzweig and Neofotis, 2013). Fig 2a-b shows the temperature projection for 2040s and 2080s respectively.



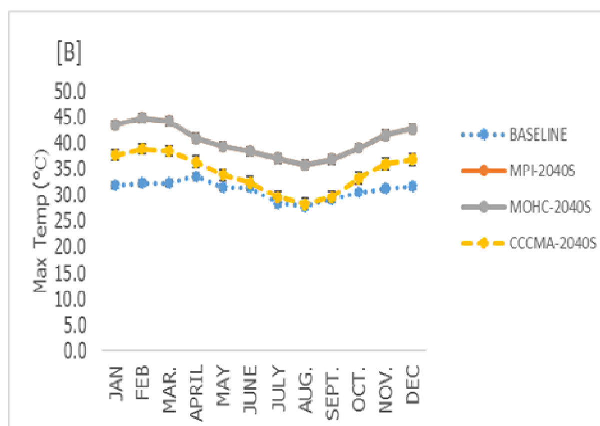


Fig. 2: Temperature projection for 2030-2060 (a), and 2071-2100 (b)

3.2 Reference evapotranspiration

Historical and projected input variables (minimum and maximum temperature, wind speed, sunshine hour e.t.c) were run with CROPWAT software to compute reference evapotranspiration (ETo) and solar radiation (Rs) over the study region. Accurate estimation of ETo in combination with a crop factor (Kc) are essential input parameters to compute realistic crop water requirements (CWRs). Overall simulation indicated that October and March are the months with the lowest and highest estimated ETo by all selected GCMs (Fig 3. Ai and Aii). Reference evapotranspiration increased from October through March, and the period represents the dry season. Again, it decreased from April to October which corresponds to the wet season. The finding is in agreement with the projections of reference evapotranspiration calculated using the Food and Agriculture Organization of the United Nations (FAO) 56 Penman-Monteith (Yip *et al.*, 2011). The observation shows that the regions are likely to experience a warmer climate with projected increases in temperature during the wet and dry periods as shown in (Fig. Ai and Aii). It is worthy of note that the predicted increase in temperature is responsible for the projected increase in reference evapotranspiration (ETo) since the temperature is the major driver of evapotranspiration. Fig 3ai and aii shows the projected ETo from the selected GCMs

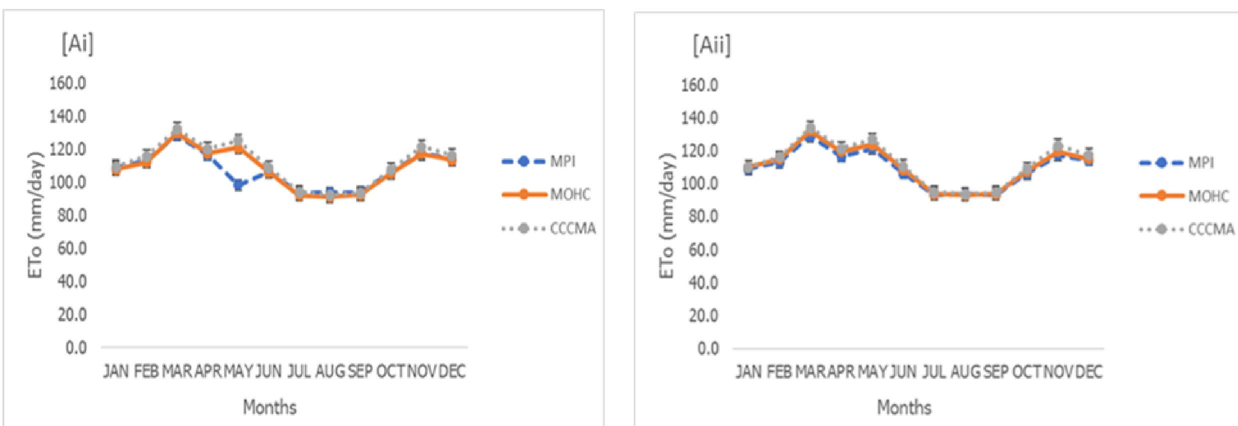


Fig. 3: Reference evapotranspiration projections for 2030-2060 (ai), and 2071-2100 (aii)

3.3 Crop water requirements (CWR)

CROPWAT Software uses estimated reference evapotranspiration (ETo) computed using the in-built Pen-Monteith equation embedded in the software in combination with cassava crop coefficient at various stages (initial, development, and maturity) to compute baseline and future CWRs and irrigation water requirements (IWR) under various climate change scenarios. All the selected GCMs projected higher CWR by 2030-2060 than 2071-2100 in the month of March as shown in Table 2. Also, in April, MPI and MOHC predicted higher CWRs during the short term (the 2040s) than the long term (2080s), whereas the CCCMA model projected a higher CWR of 104.2 mm by 2080s than the estimated CWR value of 98.8 mm during the 2040s. Hence, CWR increased from March to July and reduced from August to September. The period of March to April is the initial stage, this is the period of crop germination and establishment and at this stage, the crop needs some moisture, and irrigation is required to supplement effective rainfall (EffRain). However, from May to July, the crop is at the developmental stages. During this stage, CWR is high, and as such irrigation is needed to supplement the gap between the CWR and EffRain. Conversely, from August to September, this period falls at maturity and harvesting stages where the effective rainfall is large enough to satisfy the CWR, and irrigation is not required.

Table 3: Changes in cassava water requirements for periods under RCP 4.5

	MPI				MOHC				CCCMA			
	2040s		2080s		2040s		2080s		2040s		2080s	
Month	Mm	%	mm	%	Mm	%	mm	%	mm	%	Mm	%
MAR	11.5	12.9	11.8	13.1	13.1	14.8	15.9	18.1	13.5	15.1	15.2	17.6
APR	11.1	12.5	6.3	7.1	10.8	12.2	8.0	9.1	10.1	11.3	15.0	17.4
MAY	6.0	4.2	7.5	5.2	3.7	2.6	7.3	5.1	11.1	7.7	11.8	8.2
JUN	10.3	7.5	10.8	7.6	6.6	4.7	10.6	7.5	14.7	10.4	14.8	10.5
JUL	17.0	12.7	18.1	13.5	14.5	10.9	15.7	11.7	17.6	13.2	18.3	13.7
AUG	18.8	10.1	15.5	12.4	10.7	4.3	12.9	6.2	13.4	10.8	14.2	11.4
SEP.	23.2	6.2	23.8	8.4	12.1	4.6	14.2	6.7	21.1	7.2	21.7	7.6

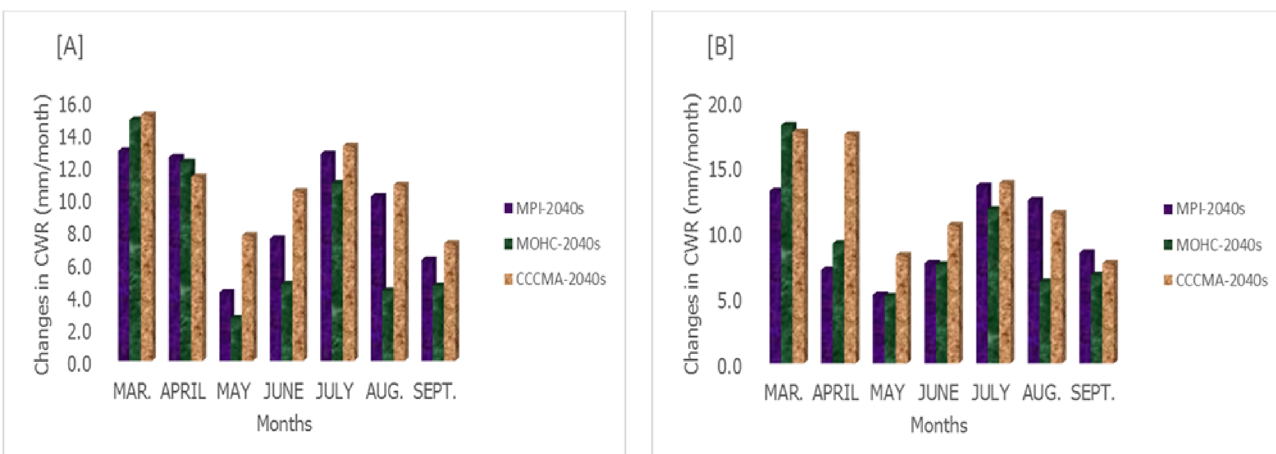


Fig. 4: Changes in crop water requirements by 2030-2060 (a) and 2071-2100 (b

Despite that cassava is a drought-resistant crop, the projected climate has a significant effect on cassava CWR, IWR, and yield. The changes in CWR were based on different GCMs simulations for a future period relative to the baseline as shown in Table 3. CCCMA and MOHC models estimated the highest CWRs in March with increases of 15.1 %; 17.6 % and 14.8%; 18.1% for the 2040s and 2080s in comparison to the baseline. respectively. However, there exists a reduction in a projected increase in changes in CWR from April to May and picked from June to July and finally dropped from August to September (Fig.4ab). The observation can be attributed to projected temperature patterns. The overall result of the study indicates that the effects of CC will increase future cassava CWR and this will affect crop growth, development, and yield if supplementary water application is not carried out. However, irrigation schemes could be very difficult since CC will have serious impacts on river basins, surface, and groundwater which could further complicate the availability of irrigation water. Hence a shift in the growing period of cassava to April-May indicated a reduction in CWR by all the selected GCMs, which implies that there will be enough effective rainfall to meet up with CWR at the crop development stages. Chowdhury *et al.* (2013) revealed that a shift of growing period of wheat to November-October indicated an increase of CWR by 50 MCM/year, showing that shift cultivation is not advisable. Fig. 4a-b shows the predicted changes in CWR for short and long term.

4. Conclusion

The climatic study examined the effects of climate change on the water needs of Manihot esculenta Crantz in Edo State, Nigeria. In comparison to the baseline, the maximum temperature rose for the 2040s and 2080s. However, the temperature has a considerable impact on crop water needs and reference evapotranspiration (ETo) (CWRs). As a result, the output of the analysis showed that, according to the selected GCMs for the 2040s, the percentage increase in CWR is at its highest during germination and establishment (March and April), whereas in the 2080s, all climate models followed the same pattern in March and showed decreases in CWR for MPI and MOHC while increasing changes for CCCMA. The predicted decline in CWR changes in May and June during the 2040s and 2080s, on the other hand, corresponds to the early stages of development and might be explained by a potential rise in precipitation and effective rainfall. Because of this, cassava leaves have a huge canopy cover during their complete development and early maturation stages, which results in significant transpiration as a result of the anticipated rise in temperature. The study's findings make it clear that CC has a big impact on how much water cassava needs. Therefore, it is crucial to implement some mitigation techniques, including integrated water conservation and irrigation systems, the use of holistic climate-smart agriculture (CSA), shifting farming, and the planting of more productive drought-resistant cassava varieties.

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PRODUCTION AND CHARACTERIZATION OF BIOMASS BRIQUETTE FROM NEEM-LEAVES AND PAPER-WASTE BLENDS: AN ALTERNATIVE TO COOKING FIREWOOD

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Abstract

Briquetting is one of the promising cooking energy sources tipped to replace firewood in Maiduguri. Agricultural and biological wastes are constantly degrading the environment due to improper management. In this study neem leaves, waste and paper waste was used for the production and characterization of briquettes, The briquettes were produced using a fabricated manual compression machine, and the produced briquettes and firewood sampled were characterized for physical properties, proximate and ultimate analysis, from the results the produced briquettes have the highest moisture content, volatile matter and calorific value of 13%, 52% and 25338.51 Kcal/kg respectively and lowest ash content of 12.5%. and shows a lower boiling time than firewood under similar conditions with little generation of smoke and harmful gases. The manual operation has significantly affected some properties such as density. The study concludes that Neem tree leaves and paper waste briquette can efficiently replace firewood for cooking in Maiduguri and Nigeria at large, towards reducing the ill effects of burning fossils and other uneconomic challenges relating to alternative cooking energy sources.

Keywords: Neem leaves waste; paper waste; Firewood; Maiduguri; briquettes.

1. Introduction

Traditionally firewood has been the major cooking fuel in developing countries, particularly in rural settlements, However, the ill effects of using wood-burning stoves on humans, the environment and deforestation need not be emphasized. Exposure to smoke from wood-burning fuels household residents is the greatest environmental health risk for humans; it is known to cause affect the eyes, lungs, and heart leading to diseases such as Cancer, Bronchitis Pneumonia and triggers diseases such as Asthma, (Riddervold et al., 2012). Children and elderly people with heart and lungs ailment are the most vulnerable group, moreover, besides the indoor air impact on the health of residents, it also contributes largely to global warming and the greenhouse effect. However, In the last decades, several renewable and environmentally friendly energy source alternatives have been developed and adopted, such as solar powered, and electric powered, these alternatives are effective, but uneconomic to the average household in developing countries, where the majority of citizens live on a low income. On the other hand, agricultural and bio-materials being generated as waste in cities such as sawdust, rice husk, plant leaves, papers, groundnut shells etc. are constantly degrading the environment in developing countries due to poor management, these materials however have the potential for energy source such as making for briquettes as a cost-effective and efficient fuel for cooking (Umesh et al., 2018, Tayade et al., 2017), they possess high calorific values and fewer emissions of gaseous pollutants. In addition, they are easy to process, create employment under commercial production and reduce deforestation and over-dependence on crude oil (Karunanithy et al. 2012).

Agricultural and biological waste produced in large tones in developing nations pollutes the environment significantly, hence their management becomes imperative to ensure quality livelihood, nonetheless, utilizing this important resource material for making briquettes for cooking helps to ensure environmental sustainability (Suhartini, et al., 2011, Maia et al. 2014) and contributes immensely to the socio-economic development of local communities (Syed et al. 2021). However, literature is replete with many studies reported on briquetting of paper waste blend with different biomaterials (Olorunnisola, 2007; Odusote et al. 2016), and no known published work on the blend of paper waste and Neem leaves). Neem tree leaves possess low moisture content and are available in large quantities, making them an excellent characteristic to be used for briquetting**.** Paper waste briquettes are excellent means of recycling papers as they are cheaply available and cooking with paper briquettes as fuel generates a lower level of particulate matter, carbon monoxide (CO) and Nitrogen oxides (NOx) pollutants (Xiu et al. 2018**)**. The Neem tree is locally known as *Dogon Yaro,* commonly found in northeast parts of Nigeria, it is mostly used as firewood, shelter belt and to control desertification. The tree remains leafy except during extreme drought when the leaves fall, being a major source of waste. Paper waste on the other hand mostly ends at dumpsites, when paper rots it emits methane gas which is 25 times more toxic than CO_2 to the environment. This waste can be utilized to reduce the environmental consequence by converting them into high density through briquetting. This research aims to produce and characterize biomass briquettes using Neem tree leaves and paper waste as a cost-effective and environmentally friendly fuel material.

This research work was intended for Maiduguri, the capital city of Borno State, Nigeria, where firewood is the dominant source of cooking fuel. However, Maiduguri has been facing insurgency security challenges for over a decade. Consequently, firewood scarcity has been growing daily as a result of forest being inaccessible due to fear of exposure to enemies of attack, many unsuspecting firewood vendors had lost their lives and properties from elements of insurgence while attempting to source firewood from particularly Sambisa forest, this has led to firewood vendors travelling over 200 kilometres neighbouring states importing firewood, and some resort to the breakdown of trees around residentials leading to desertification and bridging deforestation laws in the state. This menace resulted in firewood becoming costly and unaffordable to the general public. There is a dire need to develop a cost-effective and environmentally sustainable fuel alternative to replace firewood towards improving the standard of living of residents like briquetting; is comparatively the cheapest alternative that can be adopted by the people at the household level.

Biomass briquettes have been in use for years (Tayade et al., 2017), briquettes can be produced briefly through densification/compression of biomass materials using a fibrous material as a binding agent, and compression can be either manual or motorized. The combination of different materials and binders contributes to a difference in combustion properties such as calorific value and ash content. For briquette making, locally available biomass materials are usually used, which include biomass from coconut husk, wheat straws, rice husk, coffee husks and bagasse. And for binders, starch, clay, cow dung and gum Arabica are commonly used. In ratio, mixing depends on its ability to stick together. Fuel briquettes should have a good physical structure (rigid mixture, good density; strong) and combustion characteristics (high calorific value/heating value, low ash content, low volatile matter, low emission characteristics).

2. 0 Materials and Method

2.1 Preparation of Material Sample

3kg of waste Neem leaves (Figure 1 a) were collected, cleaned (to remove the impurities) and sun-dried, the dried sample was crushed to the required size using mortar and pestle for easy mixture, and 6kg of shredded waste paper (Figure 1 b) was immerged into 20litres of water to properly softened and makes it easier in rubbing between hands to makes it sticky. The crushed Neem leaves sample was added together with 1kg of starch (as a binder) into the bucket of soaked sticky paper and mixed thoroughly until a homogenous (uniform) mixture (Figure 1 c) was obtained.

(a) Neem

(b) Shredded Paper

(c) Mixture of Neem and Paper

(d) Briquettes

Figure 1: Briquette formulation

2.2 Biomass Briquette Formulation

Biomass briquettes materials were formulated using different percentages, the quantity of paper is 60%, the neem leaves30%, and starch is10% of the whole briquette ratio of the 6:3:1

2.3 Procedure of Briquetting

A hand-operated briquette press was used to produce the briquettes. A cylindrical metallic mould with 6 cm diameter and 22 cm height was used to shape the briquette during the pressing process. A metal press tip of 5.5 cm in diameter and 25 cm in height connected to the press lever was used as the press element. The lever of the briquette press was exerted around pressure when pushed downward, although a variety of forces may be observed due to the user's power inconsistency.

The briquetting moulds of the manual press briquette were filled with the same measured mixture of 400g, making sure that the moulder plates were inserted first. The lid of the moulder was closed and the mixture was densified by applying pressure on the manual handle. This action moves the movable part of the mould up to the immovable part (the lid), causing the mixture in the mould to be compressed, and it agglomerate to form a briquette (Figure 1 d), and during the compaction, it was observed that if the compression piston was held stationary at this point, the resultant force on the piston (equal to the force applied by the piston and therefore proportional to the pressure) would reduce as water flowed out of the pulp.

2.4 Drying Briquettes

After the briquettes have been ejected from the mould, they need to be dried. After drying the weight reduce to 217g.

2.5 Determination of Density Of The Samples

Density is a physical property of briquettes. It is defined as the structural packing of the molecules of the substance in a given volume. Since the briquettes are cylindrical of equal diameters, the various diameter of each was measured using veneer callipers. The volume was evaluated using $\pi r^2 h$. The density was computed as the ratio of mass to the volume of the briquette.

$$\text{Density (g/cm3)} = \text{mass/volume} \quad (1)$$

2.6 Proximate Analysis

The proximate analysis is the physical properties of the fuel and it consists of the moisture content, ash content, volatile matter as well fixed carbon.

2.6.1 Determination of moisture content

An aluminium pan of known weight was put in a drying oven for 3hrs at 105^{o}C. The aluminium pan was put in a desiccator to cool down. The aluminium pan was reweighed and the weight was noted. Then 50g of the sample was measured out. The sample and aluminium pan was put in a drying oven set at 105^{o}C and left for 4hrs. The pan and its contents were removed and put in a desiccator, allowed to cool to room temperature and reweighed. This was repeated until the weight after cooling was constant.

$$m.c = \frac{w_1 - w_2}{w_1} X\ 100 \quad (2)$$

Weight. Where W1 is the Initial weight of the sample and W2 is the final weight of the sample

2.6.2 Determination of volatile matter

The volatile matter of the sample was determined using the Meynell method. 20g of the dried sample from moisture content determination was preheated at 200°C in a furnace for 2hrs to drive off the volatiles. The resulting sample was further heated at 250°C for hrs (just before the materials turns black i.e. before it ashes)

Volatile matter = weight of residual dry sample – the weight of the dry sample after heating

$$\text{Volatile matter (\%)} = \frac{\text{loss in weight due to removal of volatile matter}}{\text{Weight of sample taken}} X\ 100 \quad (3)$$

2.6.3. Determination ash content

A portion of 10g was placed in a pre-weighed crucible and transferred into a preheated oven set at a temperature of 200°C for 6 hours after which the crucible and its content were transferred to a desiccator and allowed to cool. The crucible and its content were reweighed and the new weight noted. The percentage ash content was calculated thus:

$$\text{Ash content (\%)} = \frac{\text{weight of ash}}{\text{initial weight of dried sample}} X\ 100 \quad (4)$$

2.6.4 Determination of fixed carbon

Fixed carbon represents the quantity of carbon that can be burnt by a primary current of air drawn through the hotbed of a fuel (Moore and Johnson, 1999). The fixed carbon content of the samples was calculated using the following.

Fixed carbon content (%) = 100 – (moisture content (%) + volatile matter (%) + Ash content (%). (5)

2.7 Ultimate Analysis

The main purpose of the ultimate analysis is to determine the elemental composition of solid biomass fuel. The main elements of solid biomass fuels include carbon (C), hydrogen (H), nitrogen (N), sulphur (S) and oxygen (O).

2.7.1 Determination of the carbon content.

Weigh out accurately 0.1g of sample into a 250ml conical flask. Add 20ml of 1 potassium dichromate. Add 20ml of concentrate sulphuric acid using a measuring cylinder and mixed it thoroughly. Allow the conical flask to cool on a sheet of asbestos with occasional swirling for half an hour. Add 100ml of D/H2O and 10ml of ortho-phosphorus acid H3PO4 and a pinch of NAF. Add 5 drops of diphenylamine indicator, then titrate with 0.5 ammonium ferrous sulphate on adding the indicator the colour of the contents in the flask will be black on titrating with (NH4) FeSO4 7H2O, it will change from black to dark blueish, the to deep green endpoint.

$$\%Carbon = \frac{(B-T)\times N}{W} \times 100 \quad (6)$$

Where B= Blank titration value, T=Sample titration value, N=Strength of acid used, W=Weight of sample

2.7.2 Determination of the hydrogen content.

Measure 10ml of digest sample into a 250ml conical flask. Add 100ml of distilled water and add 5 drops of phenolphthalin indicator and titrate the solution with 0.05 sodium hydroxide to a permanent pink endpoint with alternate stirring and standing. If needed add a few more drops of indicator to replace the absorbed by the precipitated to AL(OH)3. The amount of base used is equivalent to the total amount of (H) in the digest taken.

$$\%Hydrogen = \frac{(a-b)\times N\times V1}{W\times V2} \times 100 \quad (7)$$

Where a= titration value of the sample, b= titration value of blank, N= Normality of base used, V1= Total value of digest, V2= Volume of digest used for analysis, W=Weight of plant material

2.7.3 Determination of the Sulphur content.

25 ml of the weighed samples were dissolved in water and pipette into 50 ml standard flasks followed by 20 ml gelatine BaCl2 solution and made up to 50 ml mark. The solutions were allowed to stand for 30 minutes.

$$\%Sulphur = \frac{X\times 0.13473}{g} \times 100 \quad (8)$$

Where g= the weight of the sample, X= the weight of $Bacl_4$

2.7.4 Determination of the Nitrogen content.

To 2ml of filtrate, add a pinch of powered FeSO4 crystal and heat gently to boiling without cooling add a few drops of dil H2SO4 to make just acid. A Prussian blue or colouration precipitate indicates the presence of nitrogen

$$\%Nitrogen = \frac{T\times M\times 0.014\times DF}{g} \times 100 \quad (9)$$

Where M=morality of acid, T=titre value, g= weight of the sample, DF=Dilution factor

2.7.5 Determination of the Oxygen content.

As there is no satisfactory method for the direct determination of oxygen, it is calculated by difference, that is the total of carbon, hydrogen, nitrogen, and sulphur and deducted from 100 is taken as oxygen.

$$\%Oxygen = 100 - (C + H + N + S + Ash) \quad (10)$$

2.7.6 Determination of compressive strength of the briquette samples

The samples were then put on the movable bed, and the control lever was applied upward to bring contact between the upper fixed bed and the movable lower bed on which the samples were sitting. The reading was taken immediately crack was noticed in the specimen, an indication that the specimen has been compressed. The value of the reading recorded from the machine is the compressive force or test force. The compressive strength of the samples was calculated using the formula below. The unit is given by N/mm2

$$\text{Compressive strength} = \frac{compressive force/test force\ (FT)}{crosssectionalareaofthesample\ (Ac)} \quad (11)$$

Where: cross sectional area = length × width.

2.8.0 The Water boiling tests

The water boiling test is a well-known test, which has been used previously. It measures the time it takes a given quantity of fuel to heat and boils a given quantity of water. In this case, a known quantity of both briquette and firewood was measured. The neem leaves with paper briquette samples were stacked in a fabricated stove while the firewood was stacked on a different stove. Two aluminium pots containing 2 litres of water each were mounted on the stoves. The stoves were ignited and as soon as the flames were stabilized, a stopwatch was activated. The initial temperatures of the water were noted and thereafter readings were obtained at 3 minutes intervals using a digital thermometer. This was terminated after attaining boiling point.

2.9.0 Heating Value (Hv)

This was calculated using the formula: Hv = 2.326(147.6c + 144v). where c is the percentage of fixed carbon and v is the percentage of volatile matter (Bailey *et. al.*,1982).

3.0 Results and Discussion

3.1 Physical Properties of the samples

3.1.1 Physical structure

Table 1 below compares the physical properties of the Neem leaves/paper Briquette produced and firewood of equal length, diameter and volume of 0.22m, 0.06m and 4.147m^3 respectively. The briquettes obtained after drying were strong, stable and cylindrical in shape, however, cracks were observed on some of the few materials. This was due to low and unequal compressive force applied resulting from the manual compressive machine. This corresponds to findings by Suhartini et al (2011), where a significant relationship between pressure and physical structure of briquettes made was observed, in addition to effects on water content, combustion rate, compressive strength and yield (Suhartini et al., 2011). Their external surfaces were rough but the cross section was compact and homogenous having a brownish colour for the firewood and the briquette is brownish-white.

Table 1: Physical Properties of Biomass Briquette/ Firewood

PARAMETERS	BIOMASS BRIQUETTE	FIREWOOD (Azadirachta Indica)
Height (m)	0.22	0.22
Diameter (m)	0.66	0.66
Mass (kg)	0.22	0.31
Volume (m^3)	4.147	4.147
Density (kg/m^3)	0.05	0.07
Colour	Brown and white	Dark brown
Texture	Rough	Rough

3.1.2. Density

The density of the briquette and firewood were 0.05kg/m^3 and 0.07kg/m3 respectively, density influences the burning rate, and addresses issues relating to the handling, storage and transportation (Karunanithy et al. 2012). However, higher density briquettes tend to have a longer burning time and release more heat than lower density briquettes, The density is significantly affected by moisture content, particle size and raw material (Karunanithy et al. 2012), the smaller the particle size, the higher the density of the briquettes by compaction, and some other briquettes made from such as rice husk and agricultural materials were characterized to have a higher density than the produced briquette from Neem leaves and paper mixture which are relatively lighter low moisture content materials (Suryaningsih et al. 2018; Kpalo et al. 2022). In addition, the use of manually operated briquetting machines has also contributed which gives poorer densification and compression, hence lower density (Akpan et al. 2019). Also, density, moisture content and water resistance were significantly affected by the variation in the mixing proportion and the quantity of the binder used (Umesh et al. 2018; Fadele et al. 2021, Syed et al. 2021). However, Firewood with high density has a better chance for storage and can burn for a long period, whereas for transportation, the briquette was easier for loading and unloading because it is lighter.

3.2. Proximate Analysis Properties

3.2.1 Moisture content

As shown in Figure 2, the average moisture content of the biomass briquette was 13% and that of firewood was 12%. The moisture content affects the combustion process where the heat produced will be used to evaporate the water first (Suryaningsih et al. 2018) and sometimes tears the briquettes into pieces with a low burning rate and excessive smoke emission, furthermore, it helps control deterioration and decomposition during storage, and determines the ease of ignition of briquettes (Supatata et al. 2013). However, the optimum moisture content of briquettes ranges from 10% - 18%. In this condition therefore high calorific value is expected since the moisture content is within range.

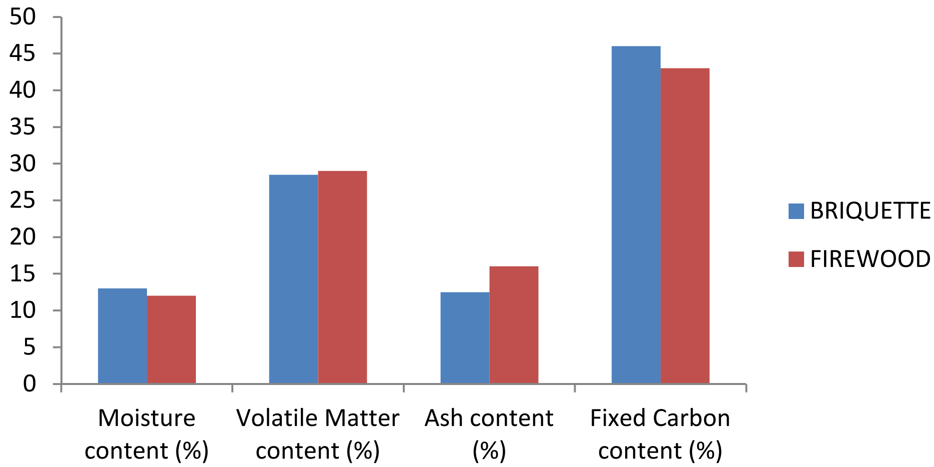

Figure 2: Proximate analysis.

3.2.2 Volatile matter

The biomass briquette has a volatile matter of 28.5% as against 29% for firewood. The volatile matter contains hydrocarbon compounds such as combustible or incombustible gas or a combination of both that is released while briquette when it is burnt. (Suryaningsih et al. 2018). However, high volatile matter indicates easy ignition of the briquette and a proportionate increase in flame length. The high volatile matter content indicates that during combustion, most of the formed volatiles will burn as gas in combustion chambers. The sample with the least volatile matter is expected to have the highest energy value, this implies that more energy will be required to burn off the volatile matter before the release of its heat energy, the Biomass briquette with the low volatile matter tends to give high calorific value.

3.2.3 Ash Content

This is simply the mass of incombustible material remaining after burning a given briquette sample expressed as a percentage (Suryaningsih et al. 2018). However, the ash content of the biomass briquette and firewood were 12.5% and 16% respectively. High ash content reduces the calorific value of the fuel () and is mostly composed of huge alkaline earth metals (Supatata et al. 2013). It creates cleaning and disposal problems and further disrupts the flow of heat and supply of air during burning. Ash content is affected by the type of binders, starch binder shows less ash content as observed in different studies (Ajimotokan et al., 2019 Sabo et al. 2022). Nonetheless, good fuel should have a low percentage of ash.

3.2.4 Fixed carbon

The fixed carbon for biomass briquette was 46% and 43% for firewood. Fixed carbon is the percentage of carbon (solid fuel) available for char combustion after the volatile matter is distilled off. Or it can also be stated as the result of a reduction of 100% sample with the volatile matter, moisture content and ash content. It gives a rough estimate of the heating value of fuel and acts as the main heat generator during burning. High fixed carbon implies a high calorific value (Bartocci et al. 2018). With the percentage obtained, biomass briquette can generate high calorific value than firewood.

3.3 Ultimate Analysis

3.3.1 Carbon and Hydrogen

From Figure 3, the carbon in briquette and firewood were 24% and 40.66% respectively, while the hydrogen content was 10% and 15%. However, hydrogen is mostly associated with volatile matter and hence it affects the burning rate. Hydrogen is mainly present in combination with oxygen as water, it lowers the calorific value of fuel, and so the lesser the percentage of hydrogen better the quality sample. Whilst higher carbon fuel releases carbon into the atmosphere during burning which ultimately results in such as acid rain, global warming and other environmental issues, therefore biomass briquette with less carbon and hydrogen should be maintained towards reducing the ill-effects of firewood on the environment.

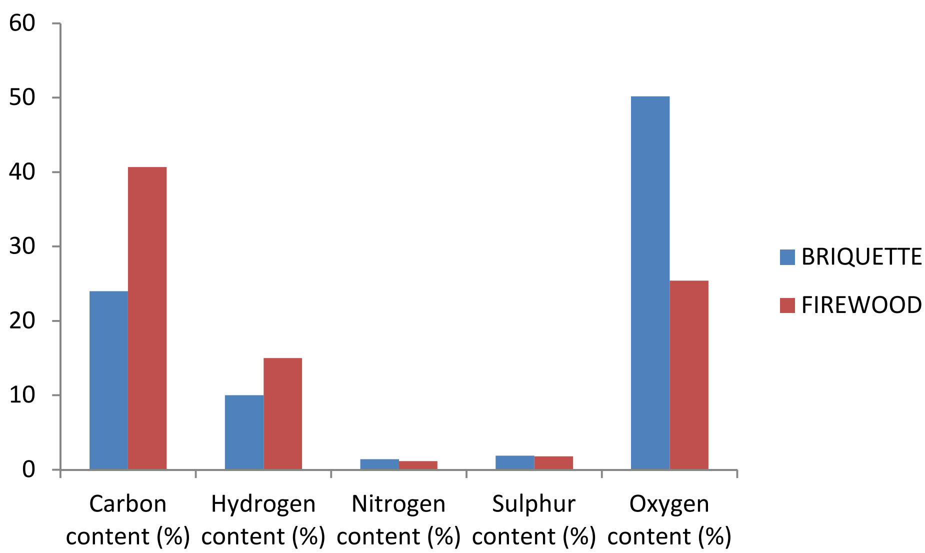

Figure 3: Ultimate analysis.

3.3.2. Sulphur and Nitrogen

An increase in Sulphur and Nitrogen content in biomass briquette is due to a mixture with starch. From Figure 3, the sulphur and nitrogen content is low in both briquette and firewood. The Sulphur contents were 1.90% and 1.78% while the nitrogen contents were 1.42% and 1.16% respectively. Nitrogen is an inert and incombustible gas but contributes a part to burning. The nitrogen content in fuels is a significant source of NO and NO2 pollutants released into the atmosphere. A high concentration in the fuel composition will lead to higher atmospheric Nitrogen Oxides pollution leading to global warming and other environmental issues. Similarly Sulphur is the source of SO_2 and SO3 pollutants. Also, Sulphur present in higher concentrations adversely affects the properties of soil water and air such as acid rain formation. Nevertheless, these percentages of sulphur and Nitrogen in the briquettes may release a lesser amount to the environment, thus creating less environmental pollution and health risk when used as fuel.

3.3.3 Oxygen content

Higher oxygen content decreases the calorific value. High Oxygen content is characterized by high inherent moisture. Moreover, oxygen is present in a combined form with hydrogen, thus hydrogen available for combustion is lesser than actual. An increase in oxygen content decreases the calorific value and hence high oxygen is undesirable.

3.4 Compressive Strength

The two compressive strengths measured were 141.14N/mm^2, and 263.67N/mm^2 for biomass briquette and firewood respectively. Firewood has a higher compressive strength due to high inter-particle bonding with nearly no inter-particle spacing. Compressive strength is one of the most important characteristics that determine the stability and durability of the samples. Biomass briquette has low compressive strength because is been compressed manually by manpower. In addition, compressive strength is influenced by the quantity and quality of the binder used (Syed et al. 2021).

3.5. Water Boiling Test

The result obtained from the water-boiling test for briquette and firewood are shown in table 2 below;

Table 2: Temperature variation during water boiling test

BRIQUETTE		FIREWOOD	
TIME (Min)	TEMPERATURE (^{O}C)	TIME (Min)	TEMPERATURE (^{O}C)
0	24	0	24
3	38	3	34
6	53	6	49
9	78	9	71
12	93	12	83
15	100	15	92
18		18	100

Table 2 above Shows the variation of temperature with time for both neem leaves/paper briquette and firewood. It is seen from this table that the briquette attained a temperature of 38^{0}C in 3 minutes while firewood attained 34^{0}C at the same interval of time (both from an initial temperature of 24^{0}C). In 6 minutes, the briquette rose to 530C followed by 78^{0}C in 9 minutes, 93^{0}C in 12 minutes and finally 100^{0}C in 15 minutes. This indicates that the briquette has better combustion characteristics compared to firewood, which burns slowly from 49^{0}C in 6 minutes through 71^{0}C, 83^{0}C,92^{0}C, to 100^{0}C in 9, 12, 15, and 18 minutes. The water heated by Neem leaves/paper briquette took 15 minutes to boil compared with that of firewood which took 18 minutes to boil the same quantity of water. This difference can also be observed from the graph of temperature versus time for both the briquette and firewood as shown in Figure 4. However, the rapid combustion observed could be due to the porous nature of the neem leaves and paper briquettes compared to the relatively dense firewood. The porosity in the briquettes enables the volatiles to leave more readily and be consumed rapidly in the flame. This explains the sharp temperature rise within the first 6 minutes. Moreover, the burnout time of the briquette was shorter and the overall burning rate became faster. In addition, the quality of air emissions (CO and CO2) was much improved.. similar to findings by

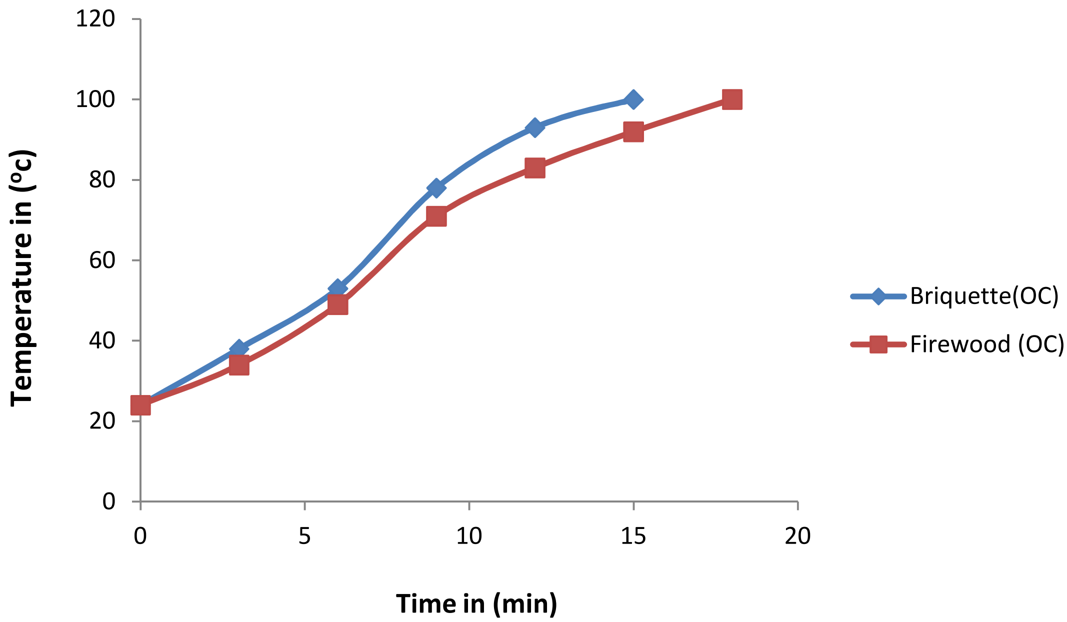

Figure 4: Water boiling test

4.0 Conclusion and Recommendation

Carbon monoxide and other harmful gaseous pollution from burning fossil fuels and crude oil have necessitated the need for alternative energy sources for cooking in households. This work produces and characterizes biomass briquettes from Neem leaves and paper waste admixture as an alternative to replace firewood in Maiduguri Based on the investigations, it was concluded that the produced briquettes of Neem leaves and Paper materials exhibit an excellent characteristic to be used for briquette making to replace firewood in Maiduguri, which causes desertification and poses residents to a security threat and with Neem Leaves being an abundant waste in Maiduguri, there is a continuous supply of raw materials. However, the biomass briquettes have lower density and compressive strength compared to the firewood making their storage and handling difficult, this was due to the limitation of manually operated briquetting machines given the poor densification of loose materials. This can be remedied by grinding the materials finely and increasing the quantity of binder to enhance densification efficiently.

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FARM POWER AND MACHINERY

EFFECTS OF TWO AGRICULTURAL BUSH CLEARING METHODS ON THE RATES OF TILLAGE

OPERATION IN THE DERIVED SAVANNAH ZONE OF NIGERIA

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Abstract

A research conducted to determine the rates of tillage operation under two agricultural bush clearing methods is reported. The two agricultural bush clearing methods are hand and mechanical. Three tillage operations were used. These were ploughing, harrowimg and ridging. Three bulldozers namely D6, D7 and D8 were employed for the bush clearing exercise. The experiments were carried out on the farm lands of Ukehe (Agu Ukehe) and Ako Nike communities all in Enugu state in the derived Savannah zone, Nigeria. For the tillage operation, one meter width disc plough, a 2 gang disc harrow measuring 3 m in width and a 3 m width disc ridger were used for the three operations (ploughing, harrowimg and ridging) respectively. The implements were operated using a 41kW two-wheel drive tractor, A digital stop watch was used to record the time taken to complete the operations in the plots Time obtained at the end of each operation in a plot was used to divide the size of the plot to get the rate of the operation. For the three operations higher values of rates of operation were obtained in areas cleared using hand method in both locations. For ploughing operation, the difference was between 0.01ha/hr and 0.02ha/hr at Agu Ukehe and 0.02ha/hr to 0.03ha/hr in Ako Nke. Also for the harrowing operation, areas cleared hand method recorded the higher rate in both sites. The rates of harrowing in areas cleared mechanical means has values between 1.5% and 3% lower than the areas cleared using manual method. For ridging operation, the same trend followed. It is concluded that rates of tilage operation were higher in areas cleared hand methos than in the areas cleared using mechanical method.

In the two locations, results indicated no significant difference between the treatments ($p < 0.05$).

Key words: Tillage, Agriculture, Bush Clearing, Mechanization, Rate

1. Introduction

The first major operation in crop production enterprise is bush clearing. This is followed by tillage. For large and medium scale crop production, use of machinery for field operations is imperative. Machinery for agricultural bush clearing include: tree pusher, the clearing rake, clearing chains, crawler tractor bulldozer etc. And machinery for tillage operations include the conventional tractor, plough (disc, chisel, mouldboard), harrow, ridger, sub-soiler and rotavator, In developing countries, the commonest bush clearing machinery is the crawler tractor bulldozer which ranges from models D5 to D9. Agricultural bush clearing methods include manual, burning, explosive blasting, chemical, and, mechanical. Tillage is one among other management practices that are significant to the soil quality, and it has important effects on many soil characteristics (Ahaneku and Dada, 2013).

For optimum performance of crops, the field operations must be done at appropriate time. Failing to carry out an operation at the required or appropriate time leads to reduction in both quality and output (yield) of the crop. Many farmers have suffered big losses in crop production due to inability to complete operations within the required time. This required time is called optimum time of the operation. These losses have discouraged many farmers from going into crop production business. In some cases, the losses could be regarded as an hourly charge against the machinery. Ability to carry out an operation within the required time is known as timeliness of operation. Timeliness of field operations is one of the benefits of agricultural mechanization. Timeliness and precision in performing agricultural operations have therefore discouraged the primitive use of hand tools and manual laboure in performing the operations (Afolabi *et al*; 2012).

Several tillage studies in Nigeria such as Onwualu and Anazodo, (1988); Adama and Onwualu, (2008); Ajav and Adeyoyin, (2012); Abubarkar, *et al*; 2012; Afolabi, *et al*; (2012); Abubarkar and Sittu, (2012) Ahaneku and Dada, (2013); etc. were carried out on post bush clearing soils. Such studies were silent on the method and/or machinery used in clearing the area. This is a fundamental gap.

This study is aimed at determining the effects of agricultural bush clearing methods on rates of tillage operations in the derived Savannah zone of Nigeria. The two agricultural bush clearing methods are hand (manual) and mechanical.

2. **Materials and Method**s

Two un-cleared areas were selected and each demarcated into four blocks. The locations are Agu Ukehe in Igbo Etiti Local Government Area and Ako Nike in Enugu East Local Government Area all in Enugu state, Nigeria. The machines used for the mechanized bush clearing operations were tractor bulldozers models D6, D7 and D8 described elsewhere (Adama, 2014a and b; Adama and Akubuo, 2017). Details of the experimental design, field layout, bush clearing operation have been given elsewhere (Adama, 2014a and b; Adama and Akubuo, 2017; Adama et al 2020 and 2021) For the tillage operation, one meter width disc plough, a two gang offset disc harrow of width 3 m and a 3 m width disc ridger were used for the ploughing harrowing, and ridging operations respectively. The implements were operated using a 41kW-two-wheel drive tractor,

The time taken to complete the operations in each plot was obtained using a digital stopwatch. The size of the plot which is 0l01 ha was divided by the time it took to complete the operation to get the rate of the particular operation.

The objective of conducting the experiments in two locations in the same ecological zone was to replicate with respect to location and reduce over generalization. This is important because noticeable variations occur in climate and soil properties as you move from one location to the other within agro-ecological zones in the tropics. Such variations are also noticed down the depth.

3. Results and Discussion

3. 1 Rates of ploughing operation

The average rates of ploughing operation in the study area were shown in **Tables 1 and 2.** The rate of ploughing in Agu Ukehe in areas cleared using manual method (Table 1) was obtained to be 0.47ha/hr and rates for areas cleared using mechanical methods were 0.45 ha/hr for D7 and D8, and 0.46 ha/hr for D6. At Ako Nike (Table 2) the rates were 0.48 ha/hr for areas cleared manually, 0.46 ha/hr for areas cleared using D7 and 0.45 for areas cleared using D8. These values are higher than average values of 0.44 ha/hr for mechanized ploughing in five states of the old Anambra, Imo, Cross River, Rivers and Bendel obtained by Anazodo (1987). The higher results recorded in this study when compared with those of Anazodo could be due to inclusive of soils in the Rainforest zone in Anazodo's study. Soils of the Rainforest zone are heavier and could result into slower rate of work In the two locations, the rates of operation are higher for the areas cleared manually than other areas cleared mechanically. These are followed by results from areas cleared using D6. The lowest rates in the two locations were recorded for the areas cleared using D7 and D8 which showed differences of 0.02ha/hr in Agu Ukehe and 0.03 ha/hr in Ako Nike when compared with the results from the areas cleared using hand. The lower rates recorded on the areas cleared using mechanical means could be attributable to compaction and creation of sink holes by the machinery which affected tractor maneuverability. At 0.05 level of significant, there was no significant difference among the treatments.

Table 1: Average Rates of Ploughing (ha/hr) in Areas Cleared Using Hand Slashing and Mechanical (Tractor Bulldozing) at Agu Ukehe.

		Blocks				
S/N	Treatments	I	II	III	IV	Treatment mean
1	Manual method, H	0.49	0.47	0.45	0.47	0.47
2	Bulldozer, D6	0.45	0.43	0.46	0.44	0.46
3	Bulldozer, D7	0.46	0.45	0.44	0.46	0.45
4	Bulldozer. D8	0.46	0.45	0.44	0.47	0.45
	Grand mean				0.45	

Table 2: Average Rates of Ploughing (ha/hr) in Areas Cleared Using Hand Slashing and Mechanical (Tractor Bulldozing) Methods at Ako Nike

		Blocks					
S/N	Treatment	I	II	III	IV	Treatment total	Treatment mean
1	Manual method, H	0.47	0.48	0.48	0.49	1.92	0.48
2	Bulldozer, D6	0.45	0.44	0.46	0.45	1.80	0.46
3	Bulldozer, D7	0.46	0.46	0.44	0.45	1.81	0.46
4	Bulldozer. D8	0.45	0.44	0.46	0.45	1.80	0.45
	Grand mean						0.46

3. 2 Rates of harrowing operation

The rates of harrowing operation as affected by bush clearing methods in Agu Ukehe and Ako Nike were presented on **Tables 3** and 4 respectively. Areas cleared manually recorded the highest rate in both sites.

At Agu Ukehe site (Table 3), areas cleared using mechanical method lower rates of operation when compared with the result for area cleared using manual method. Areas cleared using crawler tractors D6 and D7 recorded 1.5% deviation from the rate in the area cleared using manual method. The area cleared using crawler tractor D8 recorded 3% deviation from the rate in the area cleared using manual method

At Ako Nike site (Table 4), equal rates of operation were achieved in areas cleared using machines. A difference of 0.01 ha/hr (1.5%) between the areas cleared using manual method and areas cleared mechanically was recorded

In the two locations, results indicated no significant difference between the treatments ($p< 0.05$).

Table 3: Average Rates of Harrowing (ha/hr) in Areas Cleared Using Hand Slashing and Mechanical (Tractor Bulldozing) Methods at Agu Ukehe

		Blocks					
S/N	Treatments	I	II	III	IV	Treatment total	Treatment mean
1	Manual method, H	0.67	0.66	0.65	0.66	2.64	0.66
2	Bulldozer, D6	0.64	0.64	0.65	0.66	2.61	0.65
3	Bulldozer, D7	0.65	0.66	0.64	0.65	2.60	0.65
4	Bulldozer. D8	0.66	0.64	0.63	0.65	2.57	0.64
	Grand mean						0.65

Table 4: Average Rates of Harrowing (ha/hr) in Areas Cleared Using Hand Slashing and Mechanical (Tractor Bulldozing) Methods at Ako Nike

		Blocks					
No	Treatments	I	II	III	IV	Treatment total	Treatment mean
1	Manual method, H	0.66	0.65	0.64	0.66	2.61	0.65
2	Bulldozer, D6	0.65	0.64	0.63	0.64	2.56	0.64
3	Bulldozer, D7	0.64	0.65	0.64	0.65	2.58	0.64
4	Bulldozer. D8	0.63	0.64	0.65	0.62	2.54	0.64
	Grand mean						0.64

3.3 Rates of Ridging operation

Areas cleared using manual methods recorded highest rates of ridging operation than areas cleared using mechanical method in both sites (Agu Ukehe and Ako Nike).

At Agu Ukehe site (Table 5), the least rates of ridging in the sites were obtained in areas cleared mechanically. The result showed a deviation of 3.45% from the area cleared using manual method. Areas cleared using crawler tractors D6 and D7 recorded 1.72% deviation from the rate in the area cleared using manual method.

At Ako Nike site (Table 6) areas cleared using manual method recorded the highest rate of ridging operation. This was followed by the areas cleared using crawler tractors D6 and D7 which had equal rates of 0.57 ha/lit each.

The field results were further analyzed statistically using ANOVA. There was no significant difference ($p<0.05$) in the rates of ridging operation between areas cleared using manual and mechanized methods of bush clearing in the study area.

Table 5: Average Rates of Ridging (ha/hr) in Areas Cleared Using Hand Method and Mechanical Methods at Ukehe

		Block					
No	Treatments	I	II	III	IV	Treatment total	Treatment mean
1	Manual method, H	0.57	0.58	0.58	0.57	2.30	0.58
2	Bulldozer, D6	0.56	0.57	0.57	0.56	2.26	0.57
3	Bulldozer, D7	0.56	0.56	0.57	0.57	2.26	0.57
4	Bulldozer. D8	0.54	0.56	0.55	0.57	2.22	0.56
	Grand mean						0.57

Table 6: Average Rates of Ridging (ha/hr) in Areas Cleared Using Hand Slashing and Mechanical Tractor Bulldozing at Ako Nike (Site B)

		Block					
No	Treatments	I	II	III	IV	Treatment total	Treatment mean
1	Manual method, H	0.56	0.57	0.56	0.57	2.26	0.57
2	Bulldozer, D6	0.56	0.55	0.56	0.56	2.23	0.56
3	Bulldozer, D7	0.56	0.55	0.56	0.56	2.23	0.56
4	Bulldozer. D8	0.54	0.56	0.55	0.54	2.19	0.55
	Grand mean						0.56

4. Conclusions and Recommendations.

The effects of agricultural bush clearing methods (manual and mechanized) on rates of mechanical tillage system in the derived Savannah zone of Nigeria have been determined.

For the three tillage systems considered (ploughing, harrowing and ridging), the rate of tillage operations are higher in the areas cleared manually than in areas cleared mechanically.

Rates of tillage varied slightly between locations within the same agro ecological zone.

There were no significant difference ($p<0.05$) in the rates of ploughing, harrowing and ridging between areas cleared using manual and mechanized methods of bush clearing in the study area.

It is recommended that further analysis of the data be carried done to;

Compare the rates of tillage operation on the area cleared using machinery. In this case, the effect of size and model of the machine used to carry out bush clearing operation on the rates of tillage operation will be determined.

Determine if there are variations in the rates of the operations in two locations within the same agro-ecological zones

Determine the level of variations of rates operation between the different models and sized of the bush clearing machinery and manual bush clearing.

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AQUACULTURAL MECHANIZATION IN NIGERIA: A REVIEW

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Abstract

Aquacultural mechanization demand in Nigeria is growing in a fairly consistent way as the cultivation of desirable aquatic organisms is becoming increasingly important as one of the fastest-growing agro-industrial activities in the world. Demand side factors considerably explain the low adoptions of aquacultural equipments in Nigeria. It is possible to increase the efficiency of pond farms by introducing new digital technologies into the technological processes of fish cultivation. Mechanization of a fish farm reduces labor and management cost and increases the productivity along with reducing the water pollution through effective fish feed and power management. Mechanization levels of some selected fish farms in some states in Nigeria, were considered. The information was gathered using structured questionnaire to establish the socio – economic characteristics, educational level, and technical know-how of the fish farmers set. The inventory of the farm machinery was also established at each of the farms visited. Agricultural mechanization index was used to evaluate the level of aquaculture mechanization. The results of the farm mechanization index study revealed that the average level of aquaculture mechanization in the States in Nigeria is low. However, improving the situation still remains, training through inclusion in the curricular of the institute, access to funds and technology are suggested.

Keywords: Aquaculture, fishery, mechanization.

1. Introduction

Fish is an important source of nutrients such as vitamins A, B and D, calcium, iron and iodine. Fish also provides vital amino acids that areoften lacking in staple foods such as rice or cassava (Okwuosa, 2011). The demand for fish in Nigeria mostly outstrips the local production. Nigeria is the largest fish consumer in Africa and among the largest fish consumers in the world with over 1.5 million tons of fish consumed annually. Yet, Nigeria imports over 900,000 metric tons of fish while its domestic catch is estimated at 450,000metric tons/year (Ozigbo *et al.,* 2013). Aquaculture represents an opportunity to increase seafood consumption worldwide and is currently one of the fastest growing industries all over the world. This industry has the potential to become a major source of affordable, sustainable and healthy nourishment for a growing human population in Nigeria. Fish being a good rich source of some amino- acids, vitamins, minerals and poly-unsaturated fatty acids not found in other sources of fat from aquatic environment. Its harvesting, handling, processing, storage and distribution provide livelihood for millions of people as well as providing valuable foreign exchange earnings to many countries (Al-Jufaili and Opara, 2006). These potentials can only be achieved if farmers and fishermen are provided with production and processing technologies that increase production and add value to their crops. The development of fishing machinery and techniques that can be employed for effective fish, handling, harvesting, processing and storage can never be over-emphasized especially in this age when aquaculture development is fast gathering momentum in Nigeria (Akinneye *et al*., 2007).

Agricultural Mechanization in Nigeria can be classified into the hand tool technology, animal-draught and engine power technology. Hand tool technology is the lowest level of mechanization. It refers to tools and implements that rely on human muscles as the prime mover. Such tools in aquaculture include hook and line, dragnets, fish nets, fishing baskets and fishing traps. Engine powered machinery technology consists of a range boat used as mobile power for aquacultural operation. It also includes all those machines that use power source for its operation in feeding, harvesting, processing, storage and preservation of aquatic animals. More than 90% of farm operations in Nigeria are carried out using farm tools (Anazodo *et al*., 1987). Takeshima (2017a) finds that mechanization adoption rates are higher in areas that share similar agro climatic conditions with the areas where major plant breeding is conducted and thus have high spillover potentials. However, in aquaculture, mechanization can be classified into two broad areas; namely manual powered and engine powered. The major operations undertaken in a fish farm include hatchery and grow out, fish feed production and post-harvest processing.

Presently in Nigeria, the mechanization level of fish processing is low which results from the overall limited production, seasonal availability of fish, poor information dissemination of the available improved technology to processors, and lackof inexpensive equipment adaptable for processing (Davies *et al.,* 2009). The need for mechanized fish farming, feed productions and post-harvest processing has drawn the attention of National Agricultural Research to devote utmost interest and resources to engineering research in operations to minimize the drudgery, reduce labor intensities and unsanitary and inherent unhygienic handling that are involved in the traditional manual operations (Davies, 2006).

Aquacultural mechanization is the development, introduction and use of mechanized assistance of all forms and at any level of technological sophistication in aquacultural production. It involves the design, development, operation and maintenance of prime movers and devices for aquatic environment development, crop and aquatic animal production, processing and storage. Aquaculture activities in Nigeria started about 65 years ago (Olagunju *et al.,* 2007). Lack of adequate fish handling, processing techniques and storage facilities contribute significantly to the low supply of fish to poor rural dwellers that form three quarters of the population in developing countries (Ayuba and Omeji, 2006). The need for the development of fish preservation and processing machinery and techniques for effective fish handling, harvesting, processing and storage can never be over- emphasized especially now that aquaculture production is on the increase in Nigeria (Davies *et al.,* 2008).

The purpose of this study is to demonstrate the possibilities of introducing digital technologies into fish farms. Automated control of all processes in pond fish farming starting from pond preparation for stocking of fish to placement and production of commercial fish will significantlyincrease the efficiency of fish farming, reduce costs and lower fish production costs.

2. Materials and methods

In the Nigerian Federation, those involved in pond aquaculture has increased in the last decade. The countryis split into six geopolitical zones: the semi-arid North East and North West zones and the higher rainfall and cooler North Central, South West, South South and South East zones, which are clustered around the equator (CIA 2018). This makes it possible to implement modern innovative digital technologies due to autonomous equipment that use solar energy.

Such systems include autonomous, integrated into the common control system (Figure 1) of feeders and aerators (Figure 2, 3), the latter can be implemented in its stationary or mobile version.

Figure 1: Autonomous Feed

Figure 2: Stationary Aerator

Figure 3. Mobile Autonomous Aerator

The data analysis presented in (Daus *et al.,* 2019; Nagayo *et al.,* 2017) shows that the highest intensity of solar radiation for the fish- growing zone occurs during the period from May to August, which corresponds to the period of intensive feeding and other technological operations, including those related to water quality control. The potential of solar energy in summer months is quite sufficient not only for autonomous operation of feeding and aeration devices, but also for sustainable operation of control and measurement systems and data transmission systems. Fish nutrition is the most important factor affecting metabolism, formation of fish organism, their growth and reproduction functions. Feeding in general has a much greater effect on the fish body and their productivity than breed or origin. The need for feeding is caused by the fact that it allows realizing the natural potency of fish growth in the shortest time and growing them at higher planting densities than at cultivation on a natural fodder base. This, in turn, significantly increases fish productivity of water reservoirs: lakes up to 400-500 kg/ha, ponds up to 2.5-5 t/ha, etc. About 85-95% of fish products are produced in pond farms due to artificial feeding.
For properly organized feeding of fish, it is necessary to take into account many factors such as: fish-holding density, water and air temperature, content of oxygen dissolved in water, water level and feed intake. (Liu *et al.,* 2014; Wahid *et al.,* 2017).

At present, the system of complex automation of any production enterprise shall take into account the technologies of the fourth industrial revolution – Industry 4.0. This will make it possible to achieve higher profit and success of the enterprise in general (Romli *et al.,* 2017; Luna *et al.,* 2017; Martinez *et al.,* 2003).

3. Results

The study proposes the intelligent process control system of pond farm, which is logically divided intothree levels: field level, control level, cloud storage of information.
The automated floating feeder with autonomous power supply from solar panels is the main field level unit. The work (Deroy *et al.,* 2017; Menicou and Vassiliou 2010) proves the efficiency of such solutions. The design and functional features of the feeder will determine the functionality of the entire automation system: automatic feeding, monitoring of water and environment parameters, deoxidation of water reservoir, supplementary feeding with insects, frightening of fish-eating birds.

Automatic feeding provides for feed distribution process performed in automatic mode via a screw doser depending on ambient parameters and a feeding plan. Monitoring of water and environment parameters is designed to measure such parameters as water and air temperature, concentration of oxygen dissolved in water, air speed, water level and others. Wiora and wiora (2017) considers the analogue of such system to measure water body parameters using catamaran.
Deoxidation of the water body is carried out by replacing fodder in the feeder with special technological mixtures, which are also introduced into the pond. The supplementary feeding with insects is carried out by attracting flying insects at night and their electric shock.
The frightening of fish-eating birds is carried out via acoustic signals.

The most important condition for increasing the production of fish products is technical re-equipment, creation of new technologies, acquisition and introduction of modern technical equipment and mechanization tools, as well as innovative approaches to aquaculture management in pond farms.

The innovative approach proposed is that if the pond is equipped with several floating feeders, it is necessary to connect them to each other in a single information system, which functions through wireless radio communication.
As a result of the proposed innovative approach, the pond farm aquaculture management system will include the following blocks: Purchase or Feed Preparation Unit, Central Warehouse Unit, Feeding Plan Unit, Automated Feed Control Unit, Central Control Unit.

The Purchase or Feed Preparation Unit. Depending on the fodder used and the presence of a shop for its preparation, this module can serve as an application for accounting and forecasting fodder consumption or a complex separate automated fodder production line taking into account its consumption.

The Central Warehouse Unit performs automated recording and storage of feed from the central warehouse. The unit represents an automated product accounting application and can be expanded to an automated feed storage control system taking into account climatic conditions.

The Feeding Plan Unit, In this unit the information is processed from the monitoring unit of water and environment parameters, which controls temperature and composition of water, and on the basisof the obtained data the number of fodders for the introduction into the water body during the current day is determined. The feeding plan also takes into account the type of fish, the time of the year and the prevention of diseases. It is proposed to implement the unit as an application.

The Automated Feed Control Unit takes into account the amount of feed delivered from the central warehouse to a tank installed on the pond and the distribution of food from this tank to automated feeders. It is proposed to implement it in the form of a robotic complex with a feed tracking system from the central warehouse to automated feeders.

The Central Control Unit coordinates the operation of all units on the basis of received information. It also allows storing the received data on a cloud server and accessing the system remotely.

4. Discussion

The increase of economic efficiency of fish breeding and fishing directly depends on the reduction of costs per unit of fish production and the growth of its cost. Recently, there has been an increase in fish consumption. According to medical standards, 18.2 kg of fish products per year is necessary for normal development of the human body. In the future this requires measures mainly aimed at conditions to increase the production volume of commercial fish, expand its range, improve the qualityand competitiveness of products. The ability to manage the living conditions of bred fish, improve their breed qualities and aquaculture in general allows achieving high productivity of fish farming, which is many times higher than the fish productivity of natural water bodies.

The efficiency of automation within the framework of digitalization allows increasing fish production in pond farms by 70-80%, which entails profit increase by 30-40%. On average fish productivity of used water bodies is as follows: lakes up to 400-500 kg/ha, ponds up to 2.5-5 t/ha. Today the average cost of fish is 800 naira/kg, then per 1 ha the fish productivity will make 5 t and accordingly the revenue is 4,000,000 naira, and per 10 ha the profit will increase by 8,000,000 naira, which will provide for 40% of net profit to be allocated for the purchase of modern technical equipment, mechanical equipment, automation and intelligent aquaculture management systems of pond farms.

5. Conclusion

Thus, it has been proved that the development of aquaculture is impossible using current material and technical base of pond farms. There is a need for a new approach to the automation of management system of fish farming enterprises taking into account advanced digital technologies such as the Industrial Internet, large data banks and a unified system of data storage and processing. The implementation of all these technologies in a single automation system can only ensure the competitiveness of domestic enterprises compared to foreign fish producers thus making fish farms attractive for investment.

It is proposed to create robotic aquaculture control systems, the basis of which will include automated floating feeders ensuring optimal feeding of fish in pond farms. All these measures will help to achieve the main goal of the strategy for the development of aquaculture in Nigeria.

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FAILURE ASSESSMENT OF SELECTED TILLAGE IMPLEMENTS IN SURROUNDING FARMS OF BAUCHI METROPOLIS

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Abstract

This study was carried out to assess the failure of disc plough, disc harrow and mouldboard plough in surrounding farms of Bauchi metropolis. 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 analyzed 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 fail 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: assessment, disc plough, disc harrow, mouldboard plough

1.0 Introduction

Tillage operation is an agricultural preparation of the soil by mechanical agitation of various types to provide most effective condition for crop production (Awulu and Enokela, 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 (Awulu and Enokela, 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).. 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 etc. (*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) define 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 was aimed to assess the failure of disc plough, disc harrow and mouldboard plough and then 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 was 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 which lies on latitude **10.314159 and** longitude **9.846282 with the GPS coordinates of** 10° 18' 50.9724'' N and 9° 50' 46.6152'' E (*Bauchi, Nigeria lat long coordinates info*, n.d) in the savanna region of the country which has an average annual rainfall of 1009 mm (*Bauchi climate summary*, n.d)

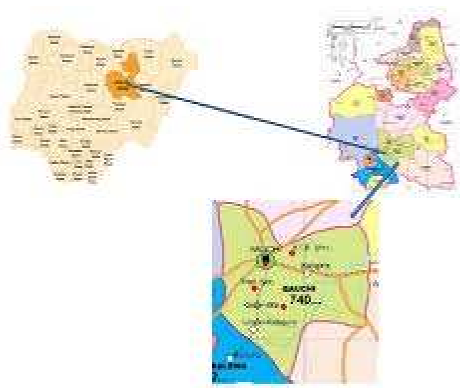

Figure 1: Map of the study area
Source: Bauchi state Ministry of Land and Survey, 2015

2.3 Methods

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 by the researchers and retrieved during scheduled visits to the respondents that were randomly selected from the target population. 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 Tables and Pareto diagrams were plotted for the implements' component failure.

3.0 Results and Discussion

3.1 Availability of the Selected Tillage Implements

Table 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, disc harrow which is 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 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 is 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 as observed by 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. It works well in sticky soil in which a mouldboard plough does not scour. Additionally, it can be used in stony and stumpy soil without much breakage.

3.2 Components Failure of the Implements

Figure 2 and Figure 3 show the Pareto charts for the components failure of disc plough and disc harrow respectively. It is observed from these figures that bearing, bolt and Shaft are the components that have the 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 subjected to which is beyond its bearing capacity. This finding is in agreement with the findings of Falau *et al*., (2014). More so, it can be attributed to poor routine maintenance (lubrication and improper adjustment) as indicated by the respondents in Table 2 that lubrication poor adjustment are some of the causes of implement component failure. This coincides with what was reported by (Radu, 2010). 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 of 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).

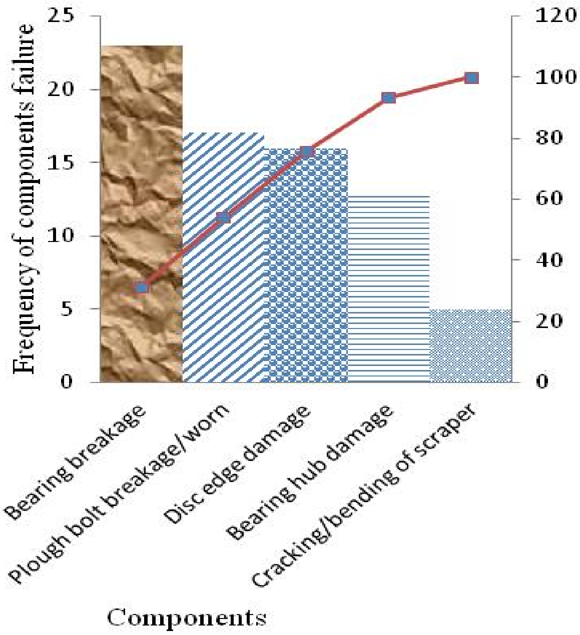

Figure 2: Pareto Chart Showing the Components Failure for Disc Plough

The incidence of shaft failure in Figure 3 can be seen to have a frequency of 21.

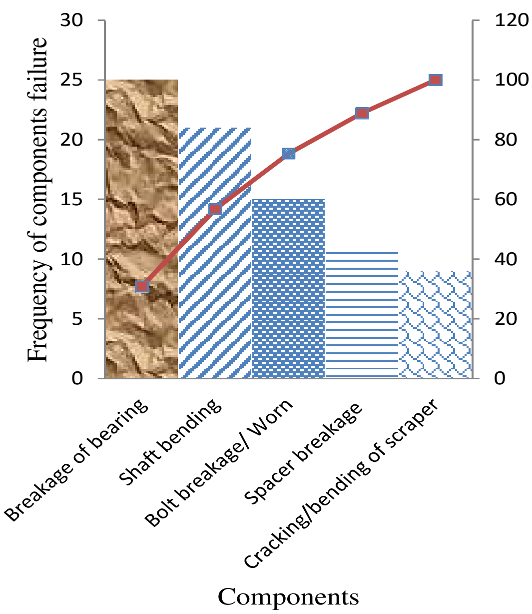

Figure 3: Pareto Chart Showing the Components Failure for Disc Harrow

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 experiences extreme overload, it twist and distort. Additionally, incessant bearing failure may keep the shaft away from position and consequently causes shaft bent (SFM, 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. This failure is usually due to improper attachment in line with the report of Kaul and Egbo, (1985) as cited by Falalu, *et al*., (2014).
Figure 4 shows components failure for mouldboard plough. It can be observed from the Figure that the total frequency of failure for the entire components is 9.

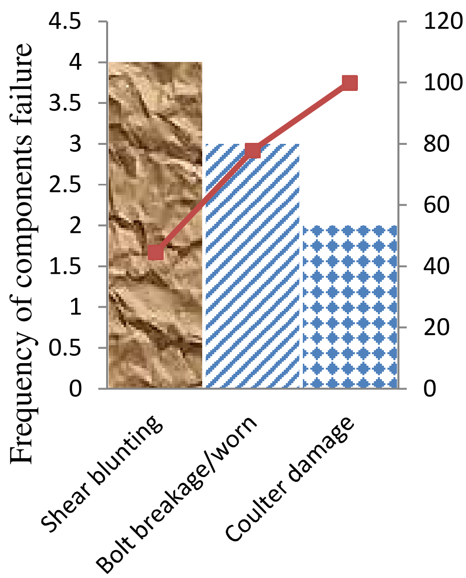

Figure 4: Pareto Chart Showing the Components Failure for Mouldboard Plough

This is because mouldboard plough is not widely used in the study area as indicated by the respondent in Table 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).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 2 shows the possible causes of tillage implements failure as indicated by the respondents. It can be observed from the Table that poor land clearing accounts for the highest frequency of 26. It usually subjects 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 2: 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

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.

4.0 Conclusion

Failure assessments of selected tillage implements were carried out in surrounding farms of Bauchi metropolis. The results show that disc harrow has the highest components failure followed by disc plough and mouldboard. This was observed to be caused mostly by poor land clearing, poor lubrication and wrong implement selection. Thus, adhering to routine maintenance specifications as recommended by machinery/implements manufacturers, appropriate provision for personnel and quality spare parts for effective repair and maintenance when the need arises, knowledge of tillage operation(s) required for particular crop after considering the field conditions and matching the implement with the field conditions would reduce the rate of failure.

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DETERMINATION OF A WHEEL SLIPPAGE OF MF 375E TRACTOR DURING PLOUGHING AND HARROWING OPERATIONS AT THE AGRICULTURAL AND ENVIRONMENTAL ENGINEERING DEPARTMENTAL FARM OF BAYERO UNIVERSITY, KANO-NIGERIA

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Abstract

Tillage is a very important practice in agriculture and is one of the major energy consumers in agricultural production; its efficiency is measured by power consumption. Several attempts have been made to study the wheel slippage of the agricultural tractor in order to minimize it to acceptable levels during tillage operations. There are many methods to decrease tractor fuel consumption during tillage. One of them is the wheel slippage reduction to the minimum. Tractor wheel slippage is a critical parameter for fuel consumption and field performance and should not exceed 15%. The aim of this study was to determine the wheel slippage of MF375Etractor during ploughing and harrowing operations at four different soil moisture contents on two different soil types at the departmental research farm of the agricultural and environmental engineering, Bayero University, Kano, Nigeria. The soil type, soil texture and wheel slippage were determined using ASAE standards. The soil type and soil texture of plot 'A' were found to be sandy and sandy loam respectively while those of plot 'B' were found to be clay and clay loam respectively. The soil moisture contents used on both plots 'A' and 'B' were 10.25%, 15.15%. 20.05% and 25.10%. Also, the mean percentages of MF375E tractor wheel slippages on plot 'A' were found to be 9.1%, 12.4%, 15.2% and 18.4; and 8.5%, 10.4%, 12.2%, and 15.4% for the ploughing and harrowing operations respectively. while on plot 'B', the mean percentages of wheel slippages were 13.6%, 17.2%, 21.7% and 26.8%; and 11.6%, 15.2%, 19.7% and 24.8% for the ploughing and harrowing operations respectively.

Keywords: Wheel slippage, harrow, plough, tillage operations, soil moisture content

1.0 Introduction

Wheel slip is known as the relative movement in travel direction between tyre and soil. According to the ASAE standard (Joseph, 2003), Slip is the ratio of the missing distance to the distance travelled by car. Wheel slip relates to travel ratio. Travel ratio is defined as the ratio of travel distance per revolution of the tyre under operating conditions, to travel distance per revolution under specified zero conditions. Wheel Slip can be also considered as a reduction in the actual forward speed of the vehicle versus theoretical forward speed. From the soil mechanics theory viewpoint, wheel slip occurs when the horizontal force acted by a tyre on the soil overcomes the internal shearing strength force of soil planes. This task leads to soil displacement in the opposite travel direction (Reed and Turner, 1993). Wheel slip is one of the important tractor performance parameters in the evaluation and optimization processes of farm machinery which must be accurately measured. Reduction and control of slippage of traction devices for agricultural machinery result in fuel consumption reduction, high attractive efficiency, and tyre wear decrement and eventually, reduction of repair and maintenance costs (Stuchly *et. al,* 1983). Tillage is a very important practice in agriculture and is one of the major energy consumers in agricultural production; its efficiency is measured by power consumption. Wheel slip is known as a relative movement in travel direction between tyre and soil. According to the ASAE standard (Joseph, 2003), Slip is the ratio of the missing distance to the distance traveled by the car. Wheel slip relates to travel ratio. Travel ratio is defined as the ratio of travel distance per revolution of the tyre under operating conditions, to travel distance per revolution under specified zero conditions. Wheel slip can be also considered as a reduction in the actual forward speed of the vehicle versus theoretical forward speed. From the soil mechanics theory viewpoint, wheel slip occurs when horizontal force acted by a tyre on the soil overcomes the internal shearing strength force of soil planes. This task leads to soil displacement in the opposite of travel direction (Reed and Turner, 1993). Tractor wheel slippage is a critical parameter for fuel consumption and field performance and should not exceed 15%. Several attempts have been made to study the wheel slippage of the agricultural tractor in order to minimize it to acceptable levels during the tillage operations. There are many different types of implements for soil tillage, and each one of them affects the wheel slippage differently. Moreover, several studies have found many operating conditions that can affect the wheel slippage significantly such as soil moisture content, tillage speed, ballast weights and the type of implement used for tillage. One of the major factors that affect fuel consumption is tillage depth. Increasing tillage depth also means more work which needs more fuel, therefore the issue of reducing the fuel consumption of the tractor during tillage has been investigated and reported by many researchers. There are many methods to decrease tractor fuel consumption during tillage. One of them is the wheel slippage reduction to the minimum. The wheel slippage is a critical parameter for fuel consumption and field performance.

A tractor working at its highest level of efficiency does not only cut down fuel cost but, generally, also makes maximum use of time and money. The concept of wheel slippage in tractors has always been one of the main efficiency factors affecting fuel consumption by tractors, for both on-field and off-field farm operations. Tractor performance is influenced by traction elements, soil conditions, implement type, and tractor configuration (Ani *et al*., 2004). The soil moisture content, bulk density, soil texture and shear strength contribute to tillage energy requirement. Operations that involve machinery traffic and soil engaging tools, such as tillage and planting, on agricultural soil, are considered tractable if they can develop adequate shear resistance to minimize tyre slip and soil damage and can as well produce soil tilt without the formation of clods (Olatunji and Davies, 2009).

By decreasing soil moisture content, net traction of the tractor decreased and resulted in reduced rolling resistance. Also, the rolling resistance of the wheel will increase with the reduction of some key soil parameters (Fenyency *et al.,* 2002). The mean value of wheel slip increased from 11.91 to 29.47% just by increasing ploughing depth from 10 to 20 cm. An increase in ploughing depth resulted in more engagement of the soil by the rear tyres. Furthermore, increasing the ploughing depth also increases the friction between the tyre and soil interface which, changes the slicing forms of soil that, in turn, causes the percentage increase in rolling resistance (Zoz and Grisso, 2003). The traction forces (also called driving forces), generated by tyre-road interaction, are expressed as a function of the wheel slip ratio, the normal force acting on each wheel, and of the friction coefficient which depends on soil conditions. Since the wheel slip ratio directly affects the generation of the traction forces, the wheel slip ratio can be a control variable in the traction control system (Deur *et al.,* 2011).

Wheel slippage is known to cause rapid frequent replacement of lubricant and fuel consumption of tractors. Also, the work of a tractor and trailer in cultivated soil and stubble is always affected by the slippage of a driving wheel. Furthermore, wheel slippage can determine the wear and expected lifetime of a tractor's drive train and tyres. A wheel slip that is too low may be a sign that the drive train is being strained and excessive weight is being hauled. Conversely, a very high wheel slip suggests that the tyres are wearing excessively and wasted rotations are likely wasting fuel (Vantsevich, 2007). Moreover, from preliminary investigation, the MF375E tractor is regularly used for ploughing operations in the study area (Abdulqaniyu, 2019). Understanding wheel slippage and learning how to measure it is an essential skill in tractor operation, maintenance and cutting down on cost. In addition, wheel slippage is one of the most important variables in assessing the efficiency of traction and correct operation of the machine. It is therefore important to determine the wheel slippage of the MF375E tractor during ploughing and harrowing operations at the departmental research farm of agricultural and environmental engineering in Bayero University Kano to ascertain the tractor performance and fuel consumption. The following specific objectives were determined

i. The soil type, soil texture and soil bulk density at the Agricultural and Environmental Engineering Departmental farm.
ii. Wheel slippage of MF375E tractor at four (4) different soil moisture contents (10.25%, 15.15%, 20.05% and 25.10%) during ploughing and harrowing operations at loading and unloading conditions on two different soil types at the Agricultural and Environmental Engineering Departmental farm.
iii. Statistical analyses of the result obtained at the loading and unloading conditions on different types of soil.

2.0 Materials and Methods

2.1 Study Location

The experiment was carried out at the departmental research farm of Agricultural and Environmental Engineering, Faculty of Engineering, Bayero University, Kano-Nigeria.

Plate 1.0: Experimental site.

2.2 Materials

The following materials were used in the study:

1. Spray paint/chalk
2. Measuring tape (Steel tape 50 m)

3. Disc plough (disc diameter 0.6 m, weight 50 kg)
4. Disc harrow (disc diameter 0.58, weight 14.75 kg)
5. MF 375E Tractor (45 Hp)
6. Jar
7. Drying oven (SM-9023)
8. Weight balance (capacity 300 g, d=0.1 g)
9. Moisture can (24.7 g)
10. Hand gloves
11. Spatula
12. KCL Solution (50 ml)
13. Oscillator (KJ-201BS)
14. Thermometer (VC-230)
15. Hydrometer (ASTM E100)

2.3 Methods

The procedure followed by Adewunmi and Joshua (2015) was followed to determine the soil types of the study location.

2.3.1 Determination of soil texture

Particle size analysis was performed by using the Bouyoucos hydrometer method (Gee and Dr, 2002). The percentage of sand, silt and clay particles in the samples was determined from Equations (1) – (4);

$$\%(S_i + C) = \frac{\mathrm{CHR_1}}{W_s} \times 100 \quad (1)$$

$$\%C = \frac{\mathrm{CHR_2}}{W_s} \times 100 \quad (2)$$

$$\%S_i = \%(S_i + C) - \%C \quad (3)$$

$$\%S = 100 - \%(S_i + C) \quad (4)$$

Where Si = silt, C = clay, S = sand, CHR_1= First corrected Hydrometer Reading and CHR_2 = Second corrected hydrometer reading, Ws = Weight of sample.

2.3.2 Determination of soil moisture content

The gravimetric method as described by SAA (1977) was adopted in determining soil moisture content. Formula 5 below was used to calculate soil moisture content.

$$\mathrm{MC} = \frac{M_W - M_S}{M_S} \times 100 \quad (5)$$

Where MC = moisture content in %, (dry basis)
M_W= mass of wet soil, (g)
M_S = mass of oven-dried soil, (g)

2.3.3 Determination of soil bulk density

Bulk density was evaluated using the core sampler method (the method used for moisture content) (SAA, 1977) in equation 6.

$$\rho b = \frac{M_S}{V_S} \quad (6)$$

Where, ρb is the soil bulk density in g/cm^3, M_S is the mass of oven dried soil, in g, and V_S is the volume of the core sampler in cm^3.

2.3.4 Determination of tractor wheel slippage

Chalk was used to mark the rear tractor tyre. Then with the tractor loaded, the beginning was marked off and the end of five complete revolutions of the tyre. The linear distance travelled was measured. Without the implement, the beginning and the end of five complete revolutions of the tyre were marked off. And the liner distance traveled was measured. Finally, the per cent slip was calculated using the following formula 7 (Davies, 2009).

$$\%Slip = \frac{N-L}{N} \times 100 \quad (7)$$

Where:

% Slip = percentage of slippage

N = No load distance

L = Load distance

An implementation of this way of measuring wheel slip is known as the'10-turn method.

2.3.5 Statistical analysis

The wheel slippage results obtained on the two different plots and two different tillage implements at different soil moisture contents were subjected to statistical analysis using an MS Excel spreadsheet.

3.0 Result and Discussions

3.1 Soil properties

3.1.1 Soil type and soil texture

Table 1 presents the soil properties of the two plots. Plot 'A' was sandy and plot 'B' was clay. This was obtained from the soil analysis on texture from the soil samples on plots 'A' and 'B'. The soil texture was obtained from the USDA textural classification chart (1986).

Table 1 – Soil properties of plots 'A' and 'B'

S/N	Properties	Plot 'A'	Plot 'B'
1	Soil type	Sandy	Clay
2	Soil texture	Sandy loam	Clay loam

3.1.2 Result of the soil moisture content and soil bulk density

Table 2 – Mean values of soil moisture content and soil bulk density of plots 'A' and 'B'

S/N	Plot	Soil Moisture content (%)	Soil bulk density (g/cm^3)
	Plot 'A'		
1		10.25	1.69
2		15.15	1.68
3		20.05	1.53
4		25.10	1.55
	Plot 'B'		
1		10.25	1.57
2		15.15	1.59
3		20.05	1.46
4		25.10	1.47

Table 2 shows that the mean soil moisture contents of plot 'A' as 10.25%, 15.15%, 20.05% and 25.10% with soil bulk density of 1.69 g/cm^3, 1.68 g/cm^3, 1.53 g/cm^3 and 1.55 g/cm^3 while the mean soil moisture contents of plot 'B' were 10.25%, 15.15%, 20.05% and 25.10% with soil bulk density of 1.57 g/cm^3, 1.59 g/cm^3, 1.46 g/cm^3, 1.47 g/cm^3. This is in accordance with Jebur and Alsayyah's (2017) result, who reported that an increase in soil moisture content decreases the soil bulk density and also increasing soil moisture content from 12% to 22% led to an increase in wheel slippage from 10% to 20%. Also, reducing soil moisture content from 18% - 20% to 14% - 16% led to a decrease in slippage percentage by 31.34% and force pull by 26.14%.

3.1.2 Effect of the wheel slippage at different soil moisture content for the different plots during ploughing and harrowing operations

Figures 1-5 present the graphs of the wheel slippage at different soil moisture content for the different plots during ploughing and harrowing operations. This is in agreement with the work of Amponsah *et al.*, (2014) that says a linear correlation relationship exists between tractor wheel slippage and soil moisture content.

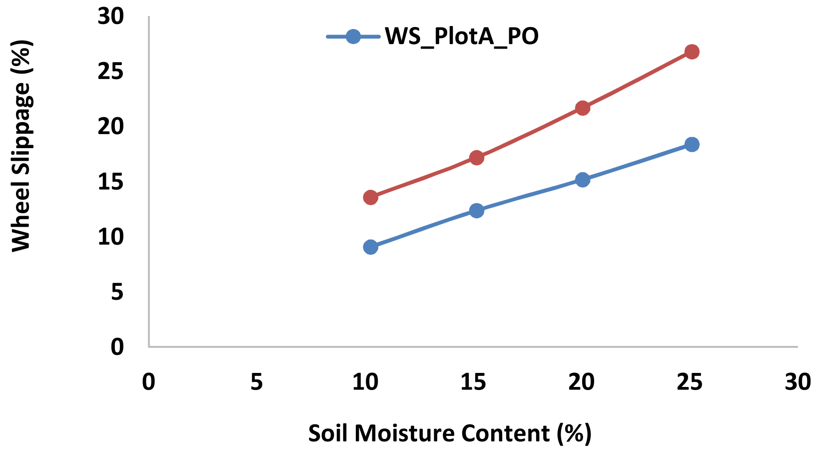

Figure 1 – Wheel slippage at different soil moisture content for the plots 'A' and 'B' during ploughing operation

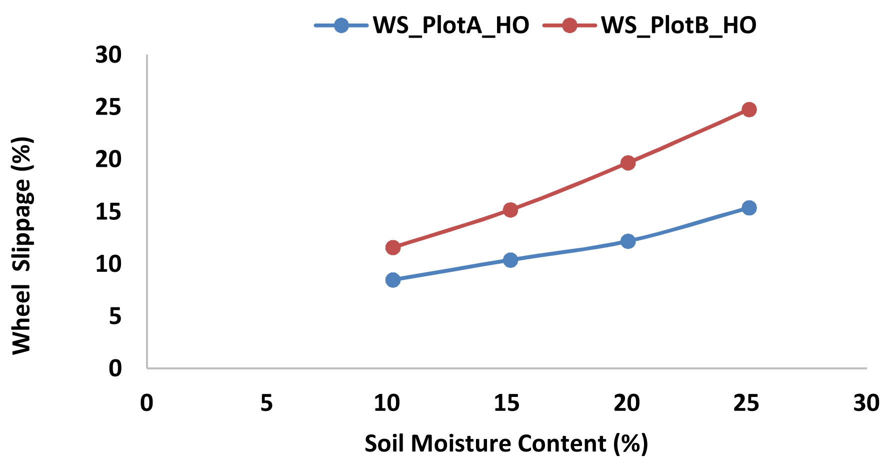

Figure 2 – Wheel slippage at different soil moisture content for the plots 'A' and 'B' during harrowing operation

Figures 1 and 2 present the graphs of the wheel slippage at different soil moisture content for the plots 'A' and 'B' during ploughing and harrowing operations. According to Lee *et al.*, (2016), tractors and tyres should be maintained to optimize wheel slippage at 10% to 15%. Low slippage (less than 9%) leads to the expenditure of too much fuel energy to move the wheels, whereas too much slippage (greater than 15%) can result in excessive tyre spin and energy loss through the tyre, which is nonproductive. The less wheel slippage result obtained on plot 'A' was close to the minimum slippage (10%) reported by Lee *et al.*, (2016) while the minimum wheel slippage result obtained on plot 'B' was within the acceptable range. In the case of moist clay and loamy (unsaturated), the surface tension causes an aberrant consistency. Thisconsistency disappears in both dried and saturated loamy soil. The increase in tractor speed decreases the time of wheel contact with the soil. Although the increase in tractor speed increases the field capacity, fuel consumption and wheel slippage, it decreases soil deformation and rupture. The in increased harrowing depth increases both wheel slippage and fuel consumption may attribute to the overburden pressure of the topsoil layers on the subsoil ones and the decrease in soil organic matter content with depth.

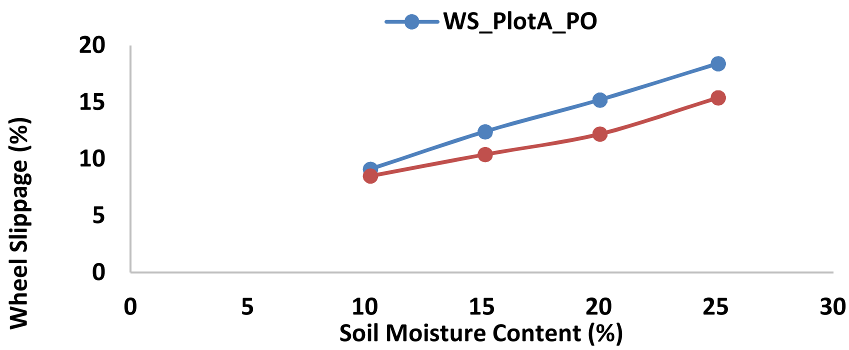

Figure 3 – Wheel slippage at different soil moisture content for plot 'A' during ploughing and harrowing operations

Figure 3 presents the graph of the wheel slippage at different soil moisture content for plot 'A' during both ploughing and harrowing operations. A higher graph slope of wheel slippage was shown during ploughing operation when compared with that of harrowing operation. Result from Tayel *et al.,* (2015), tillage depth increases wheel slippage increases. When the depth increased from 10 to 20 then to 30 cm the wheel slippage increased from 17% to 19% then to 21%. When Moitzi *et al.,* (2006) studied the effect of tillage systems and wheel slippage on fuel consumption they found a reduction in wheel slippage from 6% to 3% during ploughing and from 15% to 5% during cultivation with a heavy cultivator when the tractor was operated at four-wheel drive comparing to the two-wheel drive.

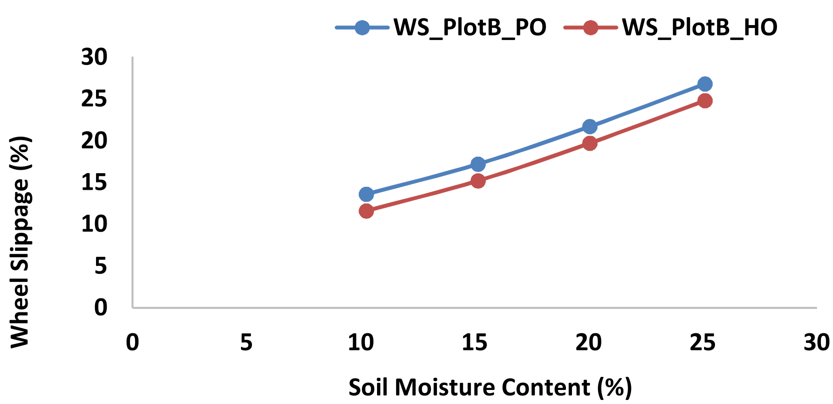

Figure 4 – Wheel slippage at different soil moisture content for the Plot 'B' during ploughing and harrowing operations

Figure 4 presents the graph of the wheel slippage at different soil moisture content for plot 'B' during both ploughing and harrowing operations. A higher graph slope of wheel slippage was shown during ploughing operation when compared with that of harrowing operation.

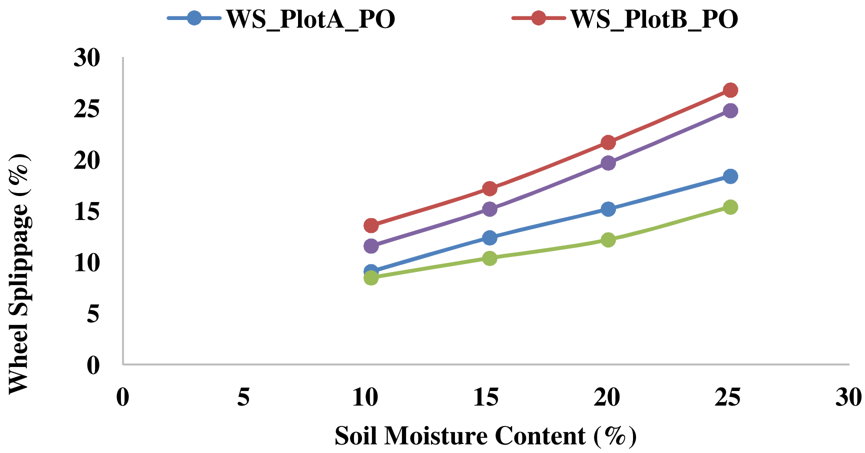

Figure 5 – Wheel slippage at different soil moisture content for the plots 'A' and 'B' during ploughing and harrowing operations

Figure 5 presents the graph of the wheel slippage at different soil moisture content for plots 'A' and 'B' during ploughing and harrowing operations. The wheel slippage in tillage operation is an important factor for analysis of fuel consumption, Fuel consumption and wheel slippage of tillage operation with a given implement are greatly affected by soil moisture. Wheel slippage and fuel consumption increase with increasing soil depth, Tractor speed, and soil moisture values under study. Wheel slippage occurs when the tyres are turning faster than the ground speed of the tractor. As a result, less than 60% to 70% of the power that a tractor engine develop is used to pull an implement through the soil, However, most of the power is lost in transmitting power from the tyres to the soil. The above results are similar to those found by Jebur and Alsayyah (2017) who found in their work that reducing soil moisture content caused decreasing wheel slippage percentage and force pull.

4.0 Conclusions

This research determination of an MF375E tractor wheel slippage during ploughing and harrowing operations was carried out at four (4) different soil moisture content on two different plots.

1. The soil type, soil texture and wheel slippage were determined using ASAE standards. The soil type and soil texture of plot 'A' were sandy and sandy loam while those of plot 'B' are clay and clay loam.
2. The mean soil moisture contents of plot 'A' as 10.25%, 15.15%, 20.05% and 25.10% with soil bulk density of 1.69 g/cm^3, 1.68 g/cm^3, 1.53 g/cm^3 and 1.55 g/cm^3 while the mean soil moisture contents of plot 'B' were 10.25%, 15.15%, 20.05% and 25.10% with soil bulk density of 1.57 g/cm^3, 1.59 g/cm^3, 1.46 g/cm^3, 1.47 g/cm^3.
3. Also, the mean percentage of MF375E tractor wheel slippage on plot 'A' was found to be 9.1%, 12.4%, 15.2% and 18.4; and 8.5%, 10.4%, 12.2%, and 15.4% for the ploughing and harrowing operations respectively. while on plot 'B', the mean percentages of wheel slippages were 13.6%, 17.2%, 21.7% and 26.8%; and 11.6%, 15.2%, 19.7% and 24.8% for the ploughing and harrowing operations respectively.

4.1 Recommendations

Based on the findings of the study, the following recommendations are made for further study:

1. Different types of tractors should be used to conduct a similar study.
2. Different types of implements should also be used to conduct a similar study.

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SOIL AND WATER ENGINERRING

THE USE OF REMOTE SENSING IMAGERIES IN ASSESSING VULNERABILITY OF LAND TO EROSION

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Abstract

The concept of remote sensing imageries has been useful in land degradation study and evaluation. Land cover and density has been known to reduce the impact of raindrops on the soil and the resulting runoff that aids the transportation of detached soil particles thereby causing soil erosion. The Landsat Thematic Mapper (TM)/Enhanced Thematic Mapper Plus (ETM^+)/Operational Land Imager (OLI) image data for 1986, 2003 and 2020 respectively were obtained from the United States Geological Survey. The imageries were downloaded, processed and classified according to the various land use pattern using the ERDAS IMAGINE version 15. The different land uses identified within the study area were grouped according to their rate of vulnerability. The results obtained were Completely Dense (Class I), Mostly Dense (Class II), Moderately Dense (Class III), Poorly Dense (Class IV) and Scantly Dense (Class V). The change detection of the land cover from 1986 to 2020 indicates that there is an increase in the vulnerability of soil to erosion within the study area. The data obtained in this research showcased the vulnerability of lands to erosion which can serve as a guide to concerned individuals on management of fragile soils for environmental sustainability and agricultural productivity.

Keyword: Land cover, Remote Sensing, Land vulnerability, Satellite Imageries and GIS.

1. Introduction

Geospastial technology has been found to be useful in environmental studies, through the retrieval and processing of environmental related data (Ekpo *et al*., 2020). Remote sensing imageries have been found to be useful in studying the vulnerability of land to erosion, based on the land use/land cover (Orakwe *et al*., 2021). Land cover has been known to decrease the susceptibility of land to erosion, through the binding of the soil particles through the rooting system and interception of the raindrop impact on the soil surface (Mahmoudzadeh, 2007). Land cover represents the physical pattern of the earth's surface, which represents the vegetation, soil, water bodies and other physical characteristics of the land (Karar *et al*., 2020). Population growth and technological advancement has continued to impact the earth due to the excessive activities of man and the extent of his exploration. This has resulted to the changes in the environment. These changes have affected the land use/land cover of the environment, which has affected other parts of the environment simultaneously, such as water cycle, soil loss and sedimentation of nearby water bodies, carbon cycle, reservoir problem, fertility decimation and the activities of the ecosystem (Turner *et al*., 2007; Eyoh and Eboh, 2015; Karar *et al*., 2020). For soil erosion to occur, several factors are combined together to cause soil loss, such as rainfall erosivity, soil erodibility, land cover, topography and anthropogenic activities (Wischmeier and Smith, 1978; Orakwe *et al*., 2021). Soil erosion has been considered as a global menace that needs urgent attention due to its impact on the environment. Anthropogenic activities has resulted to land use/land cover changes, which have resulted to a changing environment, as a result of the high rate of population growth and improper use of land, thereby contributing significantly to soil erosion.

Geospatial technology, such as remote sensing satellite imageries has been found to be an essential tool in observing environmental changes such as the land use/ land cover changes (Ekpo *et al*., 2020). The use of satellite remote sensing imageries has become important in monitoring the susceptibility of lands to soil loss for proper environmental study and sustainability (Karar *et al.*, 2020). Satellite imageries have been found to be useful due to its ability to be retrieved for past years, processed and stored for easy usage over a vast area (Eyoh and Eboh, 2015; Ekpo *et al*., 2020), however, the land use/land cover pattern can be observed through the processed imageries.

Monitoring of the environment becomes necessary as a result of the population growth and overexploitation, in order to understand the level of impact and ensure adequate environmental sustainability. Therefore, the objective of this work is to apply the geospatial technique in assessing the vulnerability of land to erosion in a changing environment, using the vulnerability class obtained from the land use/and cover changes of the study area.

2. Materials and Methods

2.1 Study Area

The location of the study is Akwa Ibom state, Nigeria. It has trigonometric boundaries of 4°32′ and 5°33′ north latitude and 7°25′ and 8°25′east longitude and a landmass of 7081km^2 and a population of about seven million. The climate season comprises of two distinct seasons, the wet and dry season. The study area experiences an annual total rainfall ranging from 1875mm to 2500mm with a mean annual temperature that varies between 21°c and 29°c and a relative humidity of 60% to 85% (Isaiah *et al*., 2020). The map of the study area is given as shown on Figure 1.

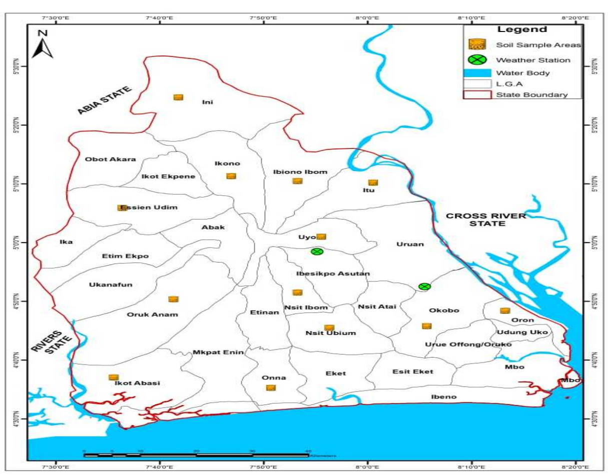


Figure 1: Map of the Study Area

2.2 Data Acquisition

30m x 30m resolution satellite imageries were obtained from the United State Geological Surveys (USGS). The satellite imageries were obtained from the Landsat Thematic Mapper (TM)/Enhanced Thematic Mapper Plus (ETM+)/Operational Land Imager (OLI) for 1986, 2003 and 2020 respectively and used for the soil erosion vulnerability assessment, based on the vegetation cover of the study area.

2.3 Image Processing and Data Preparation

30m x 30m remote sensing satellite imageries were processed using ERDAS IMAGINE (Version 15) software. To eliminate the changes caused by atmospheric conditions during image capturing, radiometric calibration and corrections were carried out to eliminate such differences. Similar method has been carried out by (Eyoh and Uboh, 2015; Essien and Cyrus, 2019; Karar *et al*., 2020; Ekpo *et al*., 2020).

2.4 Classification of the Vulnerability of Land to Erosion

The concept used in the classification of the vulnerability land to erosion is based on the land cover, which is a function of the land use pattern. The degree of vulnerability is reflected on the land cover as a function of the density of the land cover, which affects the rooting system. Based on the land cover classification of the study area, the vulnerability classes are given as shown on Table 1.

Table 1: Degree of Vulnerability to Erosion

Land Cover	Vulnerability Class	Degree of vulnerability
Completely Dense	I	Slight
Mostly Dense	II	Moderate
Moderately Dense	III	High
Poorly Dense	IV	Very high
Scantly Dense	V	Severe

3. Results

3.1 Classification of Vulnerability of Land to Soil Erosion in Akwa Ibom State

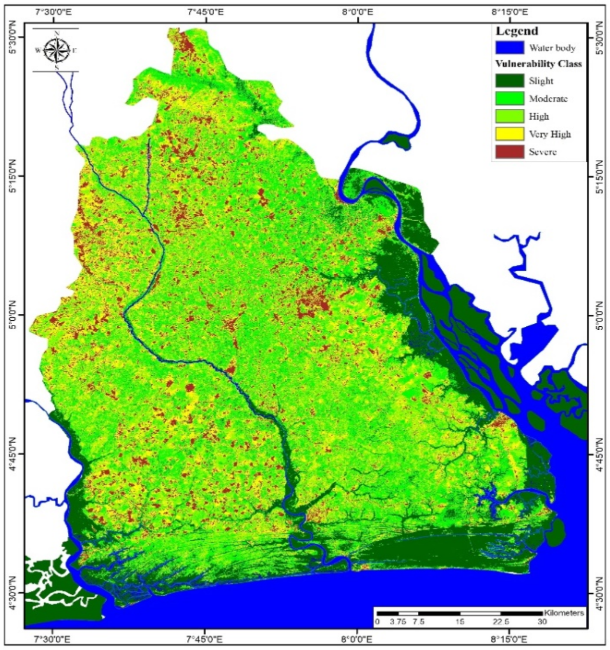
Table 2 show the areas in hectares and percentages covered by the different vulnerability classes of land to soil erosion in Akwa Ibom state for 17 years intervals representing 1986, 2003 and 2020.

Table 2: Vulnerability Class of Land to Erosion for 1986, 2003 and 2020

SN	Vulnerability class	1986 Area (Ha)	1986 Area %	2003 Area (Ha)	2003 Area %	2020 Area (Ha)	2020 Area %
1	I	168413.05	23.9	195272.75	27.7	95046.10	13.5

2	II	180529.71	25.6	180059.25	25.5	212025.80	30.1
3	III	143048.61	20.3	103812.59	14.7	77847.44	11.0
4	IV	141142.90	20	136425.30	19.4	159515.17	22.6
5	V	50149.71	7.1	63819.76	9.0	140531.51	19.9
6	Water Body	21951.38	3.1	25845.72	3.7	20269.35	2.9
	TOTAL	**705235.37**	**100**	**705235.37**	**100**	**705235.37**	**100**

Five classes of vulnerability of land to erosion were identified within the study area, which include; class I, II, III, IV and V representing the different degree of vulnerability as shown on Table 1. The total area of land occupied by the study area is given as 705235.37ha. In 1986, vulnerability class of I covered 168413.05 ha (23.9%), vulnerability class of II covered 180529.71ha (25.6%), vulnerability class of III covered 143048.61 ha (20.3%) and vulnerability class of IV covered 141142.90 ha (20%) while vulnerability class of V occupied 50149.71ha (7.1%), while the area covered by water was given as 21951.38 ha (3.1%). In 2003, vulnerability class of I occupied 195272.75 ha (27.7%), vulnerability class of II occupied 180059.25 ha (25.5%), vulnerability class of III covered 103812.59 ha (14.7%), vulnerability class of IV occupied 136425.30 ha (19.4%), vulnerability class of V occupied 63819.76 ha (9.0%) and water occupied 25845.72 ha (3.7%). In 2020, vulnerability class of I covered 95046.10ha (13.5%), vulnerability class of II covered 212025.80ha (30.1%), vulnerability class of III covered 77847.44ha (11.0%), vulnerability class of IV covered 159515.17 ha (22.6%) and vulnerability class of V occupied 140531.51ha (19.9%), while water body was given as 20269.35ha (2.9%). The final classified map of the vulnerability of land to erosion for 1986, 2003 and 2020 across the study area are shown on Figures 2, 3 and 4.



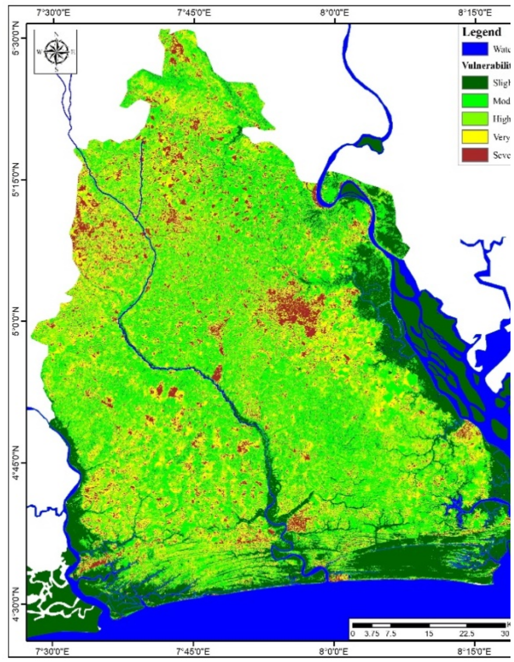
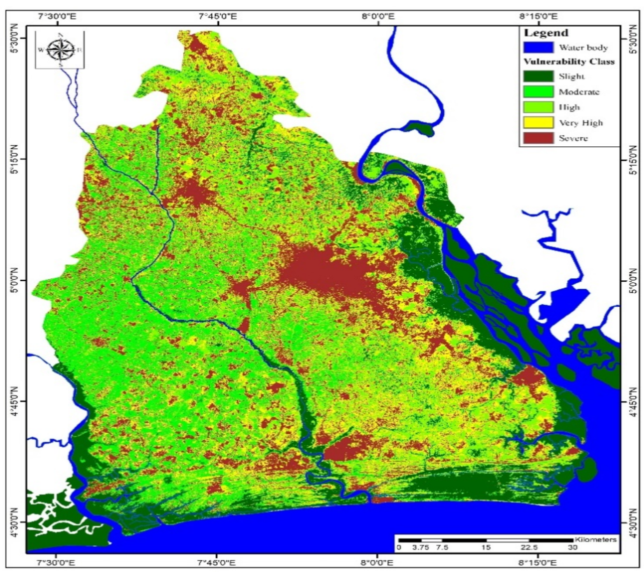


Figure 2: Soil Vulnerability Map for 1986



3.2 Changes in the Vulnerability Class of Land to Erosion in Akwa Ibom State

The changes in the vulnerability class of land to erosion within the study area from 1986 to 2020 are given as presented in Table 3. From 1986 to 2003, vulnerability class of I had an increase of 26859.7 ha, vulnerability class of II had a decrease of 470.46 ha, vulnerability class of III had a decrease of 39236.02 ha in 2003, vulnerability class of IV had a decrease of 4717.6 ha and vulnerability class of V had an increase of 13670.05 ha. From 2003 to 2020, vulnerability class of I decreased by 100226.65 ha, vulnerability class of

II had an increase of 31966.55 ha, vulnerability class of III had a decrease of 25965.15 ha, vulnerability class of IV had an increase of 23089.87 ha and vulnerability class of V had an increase of 76711.75 ha.

Table 3: Changes in the Vulnerability Class of Land to Erosion in Akwa Ibom State

SN	Vulnerability class	Area Change 1986	Area Change 2003	Area Change 1986-2003 (Ha)	Area Change 2003	Area Change 2020	Area Change 2003-2020 (Ha)
1	I	168413.05	195272.75	26859.7	195272.75	95046.10	-100226.65
2	II	180529.71	180059.25	-470.46	180059.25	212025.80	31966.55
3	III	143048.61	103812.59	-39236.02	103812.59	77847.44	-25965.15
4	IV	141142.90	136425.30	-4717.6	136425.30	159515.17	23089.87
5	V	50149.71	63819.76	13670.05	63819.76	140531.51	76711.75
6	Water Body	21951.38	25845.72	3894.34	25845.72	20269.35	-5576.37

4. Discussion

The changes of vulnerability classes within the study area for 1986, 2003 and 2020 has been identified, using the satellite remote sensing imageries as a rapid means of identifying the vulnerability of land to erosion, according to land cover and vegetation index of the study area (Mahmoudzadeh, 2007). However, there has been a rapid increase in the rate of vulnerability class of V, IV, III and a decrease of class I and II across the years. This can be linked to the increase in population of the study area, which have impacted the land cover pattern of the study area, as the population of the study area was found to be 4 million in 2006 (NPC, 2006), with an annual growth rate of 3.46% (NBS, 2021). Population growth has affected class IV and V, as most lands are being cleared for agricultural activities, in order to meet up with the food demand of the populace (Eyoh and Eboh, 2015). However, this has resulted to a decrease in class I, II and III. Developmental projects and built up has increased within the study area, as shown by the continuous increase in area coverage by class V for 1986, 2003 and 2020. Therefore, the increase in population continues to impact the vulnerability of land to erosion (Karat et al., 2020; Essien and Cyrus, 2019; Mahmoudzadeh, 2007).

5. Conclusion

Land cover has been found to be useful in the soil erosion control; however, population growth has affected the land use/land cover pattern, which has affected the vulnerability of land to erosion. Remote sensing imageries have been found to be relevant in the rapid study of vulnerability of soil to erosion, using the land cover of the study area. Five vulnerability classes were identified within the study area and they are grouped as class I, II, III, IV and V. it can be seen that population growth affects the different groups as shown on the map. This study shows the changes of the vulnerability classes of soil to erosion for 1986, 2003 and 2020 within the study area. This can give an insight into the rate of depletion of soils within the study area, considering its land cover. It can also serve as a guide to soil conservationists on the pattern of soil vulnerability and create a road map for soil conservation activities in order to stop the depletion of soil resources from further degradation, for proper soil utilization.

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DEVELOPMENT AND TESTING OF SENSOR-BASED DRIP IRRIGATION TO IMPROVE TOMATO PRODUCTION IN SEMI-ARID NIGERIA

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Abstract

The current trends in population growth posed a unique pressure on limited water resources, especially in arid and semi-arid regions of the world. In such water-stressed areas, irrigated agriculture requires efficient water application methods like the drip irrigation system. Sensor-based drip irrigation was developed by installing an automatic tensiometer in the experimental plot at 15 cm depth which was connected to an irrigation controller that was also connected to a solenoid valve installed at the main line of the drip. The tensiometer was set at -15 kPa and -10 kPa as the lower and upper limits of soil moisture respectively. The automatic tensiometer was designed to trigger irrigation when the soil moisture reached the lower limit and interrupts and stop the irrigation when the upper limit is attained. The manual tensiometer was also installed in the field to serve as the control. The developed sensor-based drip irrigation system was used to assess the average number of leaves per plant, the leaf area index, the yield and water productivity of the Roma VFN tomato variety. The average number of leaves per plant, the leaf area index, the average yield per hectare and water productivity of the tomato were found to be 218, 2.27, 12.44 $t\,ha^{-1}$ and 2.69 $kg\,m^{-3}$ respectively. The sensor-based automated drip irrigation system was able to save 5% of water when compared to conventional drip irrigation systems which can be used to irrigate other lands. In addition, the water productivity of tomato was also improved by 6% when compared to the conventional drip irrigation system. Thus, a sensor-based drip irrigation system has the power to not only reduce labour and maintain optimum soil moisture but also improve the yield and water productivity of the Roma VFN tomato variety.

Keywords: Drip irrigation, Semi-arid Nigeria, Soil-moisture sensors. Tomato yield, Water productivity

1. Introduction

The continuous increase in water demand for agricultural production has necessitated the use of water-saving methods and techniques in the irrigation sector. This is reportedly linked to the frightening rate of population growth and uncertainties due to climate change impacts (Lawal et al., 2022). According to the Population Reference Bureau, the world population is estimated to increase from 7.8 billion in 2020 to 9.9 billion by 2050 (PRB, 2020). This clearly, indicated that more food is required to feed the growing population and hence, more water demand by the agricultural sector. The agricultural sector is the major user of water resources accounting for about 70% of the global freshwater (FAO, 2017; Shanono & Abba, 2022). About 90% of the freshwater consumed by agriculture is applied through surface irrigation which is the most common and widely practised by farmers (Shanono et al., 2012; Akbari et al., 2018). Moreover, the surface irrigation method of water application is known to have the lowest water application efficiency (Shanono et al., 2020). Therefore, sustainable agricultural food production that can meet the ever-increasing population could be realized when more food is produced with less water through optimal irrigation water management which ensures high water productivity indices.

The drip irrigation system is known to save water without adversely affecting crop-water productivity (Zakari et al., 2012). In addition to improving crop water productivity, the drip irrigation system can also minimize costs, labour, and other inputs (Evans & Sadler, 2008). Drip irrigation uses a micro-device known as an emitter to deliver water slowly and directly to the roots of plants, either on the soil surface or buried below the surface thereby minimizing evaporation and runoff losses (Dubey & Dubey, 2018).

Sensor-based drip irrigation is an emerging agricultural technology that is key to sustainable agriculture. The system used a soil moisture sensor for irrigation scheduling and it is widely used for both full and deficit irrigation systems (Bello et al., 2014; Chen et al., 2019). The use of soil moisture sensors in irrigated agriculture can improve irrigation water management through proper irrigation scheduling by providing information about when and how much water to apply. The sensors will ensure the efficient use of water to meet crop needs without applying excess or too little water. Excessive irrigation increases the cost of production from additional pumping costs and fertilizer lost to runoff and leaching. It can also decrease yields from waterlogging and the leaching of soil nutrients (Maughan et al., 2015). The use of soil moisture sensors requires an understanding of soil moisture depletion, available soil water, and irrigation application. Research conducted by Yadav et al., (2020) to improve water use efficiency and irrigation scheduling in vegetable cropping systems using soil moisture sensor-based irrigation scheduling. The results indicated that soil sensor-based technology can improve water use efficiency and help farmers to improve their irrigation scheduling. Another study revealed that the water use efficiency of crops such as Onion, Spinach and other vegetables can be increased by about 16 to 25% when using irrigation scheduling controlled by sensors (Rekika et al., 2014). Irrigation systems are automated with the help of soil moisture sensors coupled with irrigation controllers and/or solenoid valves to minimize human intervention and reduce labour, time, energy, cost of operation, and the overall productivity of the system.

Tomato, *Solanum Lycopersicum* L., is the world's most highly consumed vegetable due to its status as a basic ingredient in a large variety of raw, cooked or processed foods (Nasidi et al., 2015). It belongs to the family *Solanaceae,* which includes several other commercially important species. Tomato is the major vegetable crop grown globally accounting for about 60% of the world's vegetable production at 177 million tons in 2016 (PWC, 2018). Nigeria is currently the second-largest producer of fresh tomatoes in Africa, producing 10.8% of fresh tomatoes in the region (Olanrewaju et al., 2017). Globally, Nigeria is ranked as the 14th largest tomato producer with 2.3 million tons in 2016 (PWC, 2018). Tomato is also the most common and popular vegetable produced in semi-arid Nigeria such as in Kano State. A baseline study of vegetable production in Kano State conducted by the Netherland Enterprise Agency across the Kano State revealed that tomato constitutes about 55% of the total vegetables produced (Netherland Enterprise Agency, 2021).

The sensor-based drip irrigation system is important for addressing water scarcity in the semi-arid region of Northern Nigeria which occasionally experiences climatic uncertainties such as drought and erratic rainfall. Thus, this study is aimed at developing a sensor-based drip irrigation system for the assessment of the average number of leaves per plant, leaf area index, water productivity and yield of Roma VFN tomato variety against the conventional drip irrigation system.

2. Material and Methods

The study was conducted at the training farm of the Department of Agricultural and Environmental Engineering, Bayero University, Kano. Kano is located in the northwestern part of Nigeria and lies between latitude 12° 0' 0.0000'' N and longitude 8° 31' 0.0012'' E and it is 472.45m above mean sea level. Kano is situated in a semi-arid zone with an average annual rainfall of 898 mm which is below average evaporation of 1560 mm. The average minimum and maximum temperatures are 26 °C to 32 °C respectively (Ahmad & Haie, 2018). The experiment was carried out on a $15\,m \times 3\,m$ field from 24th February to 31st May 2022. The drip system consists of the main pipeline connected to a water source which was also connected to the submain pipeline. The submain pipeline has 20 junctions and each junction was connected to a lateral and the laterals were spaced at 0.75 m apart as recommended row spacing of the tomato crop. Each lateral has a length of 3 m and 9 emitters that are spaced 0.3m apart based on the recommended crop spacing of the tomato crop. Figure 1 shows the layout of the experimental plot.

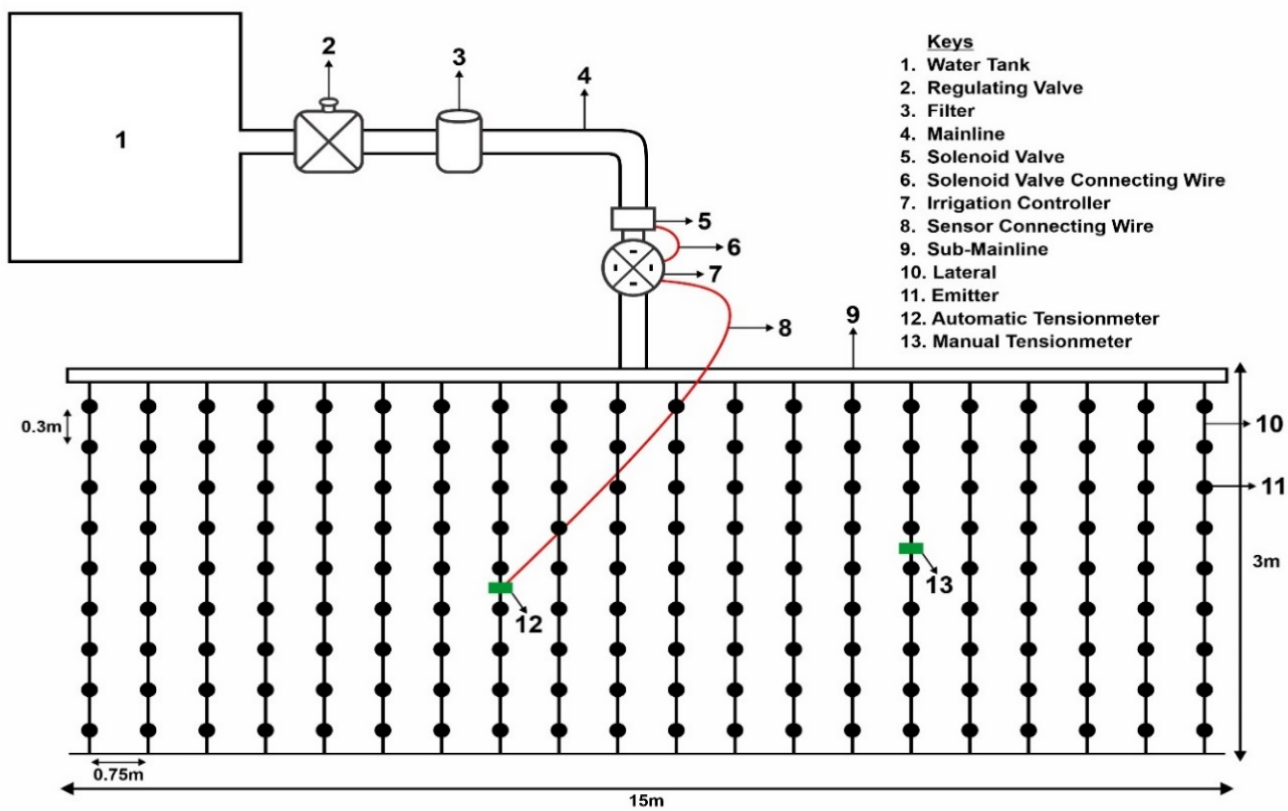

Figure 1: The layout of the experimental plot

The automatic tensiometer was installed in the experimental plot at a depth of 15 cm and set at -15 kPa and -10 kPa as the lower and upper soil moisture limits respectively for sandy loam soils (Smajstrla & Locascio, 1996; Thompson & Gallardo, 2005). The automatic tensiometer was connected to an irrigation controller that is also connected to the solenoid valve which was installed at the mainline of the experimental field. The manual tensiometer was also installed at depth of 15 cm in the field to serve as a control. Both automatic and manual tensiometers were calibrated by determining the soil moisture using a gravimetric method of the sample taken at the exact depth of the ceramic tips of the sensors and the results were related to the soil-water characteristic curve of the experimental site. The soil moisture characteristic curve of the experimental site is shown in Figure 2.

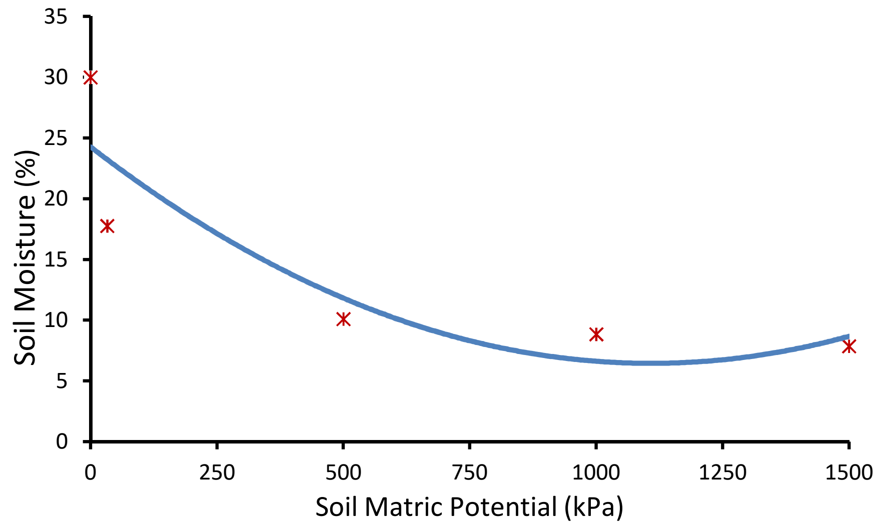

Figure 2: Soil water retention curves of the experimental site.

The laboratory tests of the soil of the experimental site show that the soil has an average bulk density of 1.65 $g\ cm^{-3}$ with a textural class of sandy loam (82.4% sand, 4 % silt and 13.76 % clay). The field capacity and permanent and wilting point of the soil were found to be 17.77 % and 7.48 % respectively.

The automatic tensiometer signals the irrigation controller to trigger or interrupt/stop irrigation events based on the set limits and the controller will either open or close the solenoid valve to initiate or suspend the irrigation events. Figures 3- 6 show the automatic sensor, irrigation controller, solenoid valve and manual tensiometer installed in the experimental plot.

Figure 3: Automatic Tensiometer

Figure 4: Irrigation Controller

Figure 5: Solenoid valve

Figure 6: Manual Tensiometer

3. Results and Discussions

The result of the study shows the average number of leaves per plant and the leaf area index of 218 and 2.27 respectively. The average number of leaves per plant obtained from the study (218) is high when compared with the work of Enujeke & Emuh, (2015), Abang & Iloba (2002) Falodun & Emede, (2019) who obtained 34, 55, 148 as an average number of leaves per plant for the same Roma VFN tomato variety. The leaf area index is also high when compared with the work of Muhammad et al., (2014) and Karaca & Buyuktas, (2021) who obtained 0.86 and 1.51 respectively as an average leaf area index for Roma VFN tomato variety. The leaf area index obtained from the study (2.27) is also low when compared with the work of Abang & Iloba, (2002) who obtained a leaf area index of 5.21 for the same variety.

The total marketable yield obtained from the study is 12.44 $t\ ha^{-1}$ which is high when compared to the average yield per hectare usually obtained by the farmers in the Nigeria of 3.91 $t\ ha^{-1}$ as reported by PWC (2018) and also 4.4 $t\ ha^{-1}$ as reported by FAOSTAT, (2020). The yield obtained from this study is also higher when compared with the works of Kabura et al., (2009), Afolayan et al., (2014), Falodun & Emede, (2019), Isah et al., (2014) and Tya & Othman, (2014) who obtained a yield of 6.1 $t\ ha^{-1}$, 7 $t\ ha^{-1}$, 8.28 $t\ ha^{-1}$, 11.2 $t\ ha^{-1}$, 11.7 $t\ ha^{-1}$respectively using the same variety of Roma VFN. In contrast to the above, the yield of the study is slightly lower when compare with the work of Enujeke & Emuh, (2015) who obtained 13 $t\ ha^{-1}$ using the same variety of tomato.

The total volume of water applied for the whole growing season of tomato is 20,847 litres ($20.847\ m^3$) as against 22,011 litres ($22.011\ m^3$) which would have been applied if the conventional drip irrigation system was used in the study. This shows that the system has saved 5% of water which would have been over-irrigated if the conventional drip irrigation system was used in the study. This is close to the water saved used of 13% and 2.9% as reported by Barkunan et al., (2019) and Mohammed et al., 2021 respectively when they compared sensor-based drip irrigation with conventional drip irrigation systems.

The water productivity computed from the study of $2.69\ kg\ m^{-3}$which is relatively higher when compared to what would have been obtained of $2.54\ kg\ m^{-3}$ if a conventional drip irrigation system was used in the study. The sensor-based drip irrigation system has therefore improved the water productivity of tomato by 6% when compared to the conventional drip irrigation system. The study agreed with the findings of Mohammed et al., (2021) whose studies achieved remarkable water productivity of 19% who used sensor-based drip irrigation when compared to the conventional drip irrigation system. Water productivity is a function of yield and the water applied in the production of a crop. Similar to the yield, the water productivity of tomato also varies across the world due to the differences in varieties, climatic conditions, soil properties, management practices and irrigation methods.

The results of this study have revealed the importance of a sensor-based drip irrigation system in terms of yield, the volume of water applied and water productivity for the crop tested. The sensor-based drip irrigation system has undeniably and unambiguously demonstrated superiority over conventional drip irrigation systems.

4. Conclusion

The results of this study have shown that sensor-based drip irrigation is key to improving the yield and water productivity of tomato crops in the semi-arid region of Nigeria. The average number of leaves per plant, the leaf area index, yield and the water productivity of the tomato were found to be, 218, 2.27, 12.44 $t\ ha^{-1}$ and $2.69\ kg\ m^{-3}$ respectively. The yield obtained is above the average of $4.4t\ ha^{-1}$usually obtained by farmers in semi-arid Nigeria. The system was also able to save 5% of water which can be used to irrigate more land and improved water productivity by 6% when compared to conventional drip irrigation systems. The study can be extended to other crops for more studies on yield and water productivity assessment. The sensor-based drip system is therefore recommended for irrigation particularly in water-stressed regions such as northern Nigeria as it allows efficient utilization of the limited water resources.

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EFFECT OF DEFICIT IRRIGATION ON THE PERFORMANCE OF WHEAT (*Triticum aestivum L.*) IN A SEMI-ARID REGION OF NORTH-EASTERN NIGERIA

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Abstract

Water stress is one of the major abiotic factors hindering wheat production in the semi-arid Lake Chad region of Northeastern Nigeria. Deficit irrigation (DI) has been reported to be a reliable water management strategy in coping with water scarcity situation. Moreover, it is crucial to understand the response of different growth stages of a specific crop to water deficit in every agro-ecological region. This research work investigated the effects of DI on the performance of an early maturing REYNA-28 wheat variety in Borno State, Nigeria. The field experiment consisted of ten (10) treatments replicated three (3) times in basins of 3 m x 4 m laid in a randomized complete block design (RCBD). The treatments comprised the application of 100 % gross irrigation depth (I_g) and DI of 80, 60 and 40 % I_g each, at the vegetative, flowering and yield formation growth stages. Polyvinyl chloride (PVC) pipes of 4.6 cm diameter were installed in each check basin as orifices to measure water application. At all the three levels of water deficits, highest water savings of 9.3, 18.6 and 28.0 % were achieved during the yield formation stage. DI, when imposed at any of the three growth stages was found to affect crop yield and productivity. The crop produced grain and biomass yields of 5.20 and 10.93 t/ha respectively under non-deficit condition. The yields dropped by 43 % due to 60 % water deficit during the vegetative stage only. Grain irrigation water use efficiencies of 13.09 and 12.45 t/ha-mm were achieved at the application of 40 and 60 % I_g respectively during the yield formation stage which were statistically higher than any other treatment. The vegetative stage was found to be more sensitive to water deficit, with K_y = 1.46, whereas, the flowering and yield formation stages were found to be tolerant to water deficit, with K_y values of 0.79 and 0.92, respectively. Hence, there is need for adequate irrigation at the vegetative stage of the wheat and thus, water and energy could be conserved by applying up to 40 % water deficit during the yield formation stage of the crop.

Keywords: Water scarcity, Semi-arid, Lake Chad, Wheat, Deficit irrigation.

1.0 Introduction

Water scarcity is a serious problem in many part of the world, with almost a billion people lacking safe drinking water and more than that lack proper sanitation (Chai *et al.*, 2016). The problem may worsen as the world population is growing exponentially coupled with the forecasted climate change. Located in west-central Africa, Lake Chad's dynamic nature has made its size, shape and depth continuously changing in response to variations in temperature and rainfall. In 2003, the lake region was classified among the ten most water-impoverished locations in the world (Okpara *et al.*, 2015).

While it is recognized as the major consumer of the fresh water, agriculture is the major source of livelihood of about 60 % of the people residing within and around the basin. Population growth necessitated agricultural expansion in the region and this has doubled the initial agricultural water demand from 1960 to 1990. Over the last 40 years, the inflow into the lake has reduced by 70-80 % and the lake has shrunk to only about 10 % of its original surface area (Mahmood and Jia, 2018).

Wheat (*Triticum aestivum L.*) is among the most important cereal crops in the world. It is anticipated that due to climate change, water and heat stress will be the major limitations for wheat production even in irrigated environments (Tadesse *et al.,* 2016). Water stress affects both the structure and the dynamic metabolism of plants. The degree of the effects is affected by crop variety, growth stage, duration and level of stress (Moghaddam *et al.,* 2012). Maintaining optimum water requirement at sensitive stage of crop would aid in achieving improved yield and water productivity.

Water has become the major challenge/constraint to agricultural production in the semi-arid Lake Chad region. In Borno state, farmers face challenges of water stress during crop cultivation more especially when dealing with wheat crop. This is due to drying of the surface water sources usually used for irrigation, therefore necessitates the use of groundwater which is costly for many farmers due to poverty. Hence, this in turn leads to insufficient water application into their farms. In some areas, the terrain of the land negates water application by gravity, water must be pumped to a height of about 16 m, and this involves enormous use of energy and its attendant cost. These challenges are some of the reasons that discourage wheat production in the region. Wheat farmers in Borno state need promising methods of cultivating wheat that consume less water and energy.

Many water-saving techniques have been developed. Deficit irrigation (DI) (irrigation below the optimum crop water requirement) is an energy and water-saving strategy that enables coping with water stress situation in which crops are subjected to a certain level of water deficit for a specific period or the entire growing season (Chai *et al.,* 2016). For many crops, researches on DI produced different outcomes from around the world. Therefore, effective implementation of this technique requires precise knowledge of the critical growth stages of a particular cultivar under local environmental condition.

Globally, deficit irrigation has been widely reported to be a promising adaptation measure to water scarcity situation for wheat crop. However, research outcomes documented on it are very few in the sub-Saharan African countries (Oiganji *et al.,* 2017) and more intense in Borno State, Nigeria. This work was designed to evaluate the effects of DI (imposed at different growth stages) on the productivity of an early maturing REYNA-28 wheat variety in the semi-arid region of Northeastern Nigeria. Information on the sensitive growth stages of the wheat variety will help wheat farmers to plan irrigation prudently. The work could also aid in reducing the wide knowledge gap that exists in the study area on the subject matter. The information generated from this work could also serve as basis for future researches targeting improvement of irrigation water productivity and adaptation to climate change in this agro-ecological region.

2.0 Materials And Method

2.1 Study Location

The experiment was conducted at the Research Farm of the Lake Chad Research Institute, Maiduguri, Borno state, Nigeria. The site is located between latitude 11^{o}51′40″ and longitude 13^{o}13′37″, on 341 m above mean sea level (Figure 1). The climate of Maiduguri is generally semi-arid with tropical grassland vegetation. The mean monthly minimum temperature is lowest (13.5^o C) during the period of strongest and most constant northeast winds (Harmattan) in December and January; and highest (24.7^o C) in April. The mean monthly maximum temperature is highest (40.3^o C) prior to and during the onset of the rains in April and the lowest (30.8^o C) during the peak rained period of August (Adeniji *et al.,* 2013). The area is characterized by short wet season (June-October) and long dry season (November-May) with mean annual rainfall of 625 mm. The major water source is the Ngadda River which is a tributary to the Lake Chad. The river flows through Maiduguri Metropolitan Council (MMC) and Jere local government area (LGA). The Alau dam that was built on the river has interfered with the seasonal over bank floods. The over flow from the river has resulted in the formation of Jere bowl and series of ponds and marsh complexes. Such environments are generally referred to as *Fadamas* or lowlands or flood plains where substantial irrigation farming is been practiced (Bukar, 2016).

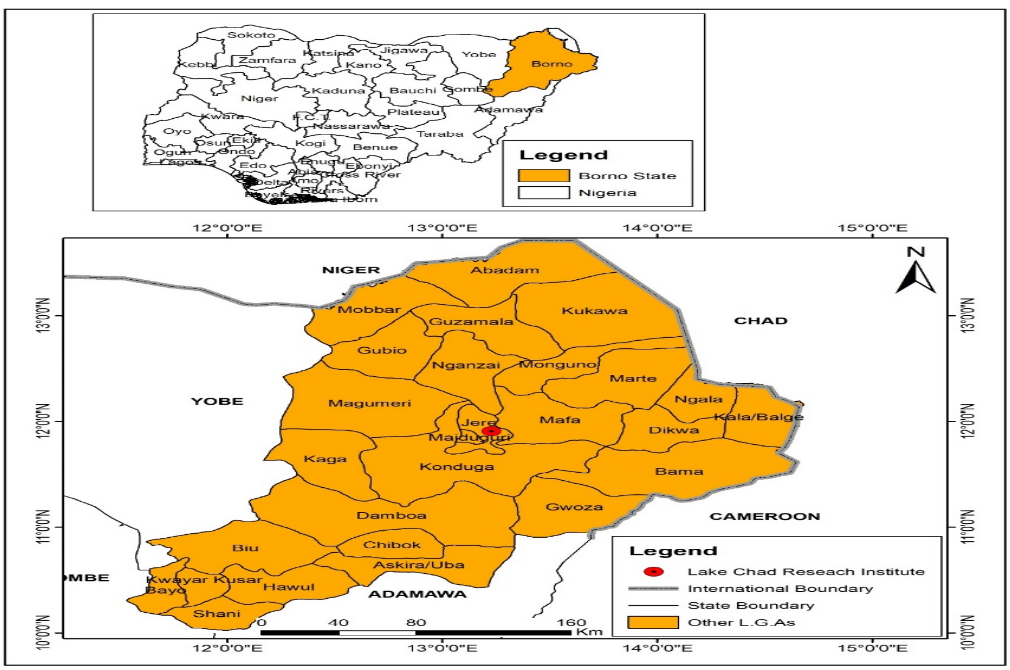

Figure 1: Study location

The soil physical properties of the experimental site, which include textural class, bulk density, saturated hydraulic conductivity and moisture content at saturation, field capacity and permanent wilting point were determined in a laboratory at the Department of Soil Science, University of Maiduguri. Soil samples were collected from the experimental field at an incremental depth of 30 cm from the soil surface to 150 cm depth. Particle size distribution was analyzed using hydrometer method and textural class was determined based on the percentage of sand, silt and clay. Soil bulk density of undisturbed sample was determined as the ratio of mass of oven dried soil to volume of core sampler. Soil moisture content at saturation, field capacity and permanent wilting point were determined using pressure plate at 0, 0.3 and 15 bars respectively.

Table 1 illustrates the average daily monthly climatic data of the location. Wheat is cultivated in the area between November and March during the dry seasons.

Table 1: Monthly average daily climatic variables of the study area

Months	Min. Temp. (°C)	Max. Temp. (°C)	Relative Humidity (%)	Wind Speed (m/s)	Sunshine Duration (Hours)
January	13.4	32.7	32.0	1.2	7.8
February	17.8	35.2	25.0	1.3	8.6
March	20.8	37.8	20.7	1.6	9.7
April	24.7	40.3	28.3	1.6	9.9
May	26.1	39.3	41.8	1.6	9.1
June	24.6	36.6	55.6	1.6	8.3
July	23.1	32.2	71.2	1.5	7.6
August	22.0	30.8	80.2	1.3	6.9
September	22.4	32.7	71.9	1.5	8.4
October	22.4	35.2	55.9	1.4	8.3
November	16.8	36.0	36.0	0.9	7.7
December	13.3	33.0	34.0	0.9	7.7

2.2 Treatments and Experimental Design

The experiment was based on irrigation treatment of 100 % gross irrigation requirement (I_g) as the control and deficit irrigation treatments of 80, 60 and 40 % I_g each only at vegetative, flowering or yield formation growth stages, making a total of ten (10) treatments as presented in Table 2. The treatments were laid in a randomized complete block design (RCBD) with three (3) replications, making a total of 30 plots.

Table 2: Description of treatments

Treatments	Description
Treatment 1	Full irrigation (FI); 100 % of I_g throughout the growing season
Treatment 2	Irrigation at 80 % I_g during vegetative stage only
Treatment 3	Irrigation at 60 % I_g during vegetative stage only
Treatment 4	Irrigation at 40 % I_g during vegetative stage only
Treatment 5	Irrigation at 80 % I_g during flowering only
Treatment 6	Irrigation at 60 % I_g during flowering only

Treatment 7	Irrigation at 40 % I_g during flowering only
Treatment 8	Irrigation at 80 % I_g during yield formation only
Treatment 9	Irrigation at 60 % I_g during yield formation only
Treatment 10	Irrigation at 40 % I_g during yield formation only

Levees were constructed surrounding each plot with 25 cm width and 20 cm in height. The plots were separated by space of 0.5 m while replications had buffer zones of 1 m between them.

2.3 Management Practices

REYNA 28 is a variety of wheat crop selected and adapted in the ecology by Lake Chad Research Institute (LCRI). The variety has outstanding characteristics of medium maturity (90-95 days), heat tolerant, good yielding (5-5.5 t/h) and baking quality. The lengths of the establishment, vegetative, flowering and yield formation stages of the crop were 14 days, 30 days, 14 days and 37 days respectively. The variety originated from the International Centre for Agricultural Research in Dry Areas (ICARDA), Sudan, and is well adapted to irrigated conditions of the entire Northern Nigeria (LCRI, 2017). The experimental treatments were imposed 2 weeks after planting to allow proper establishment. All other agronomic activities were kept same for all treatments. NPK (20:10:10) was applied in each plot at planting, at the rate of 400 kg/ha and at four (4) weeks after planting at the rate of 200 kg/ha as recommended by LCRI (2017). Weeding was done manually at two weeks interval and no incidence of birds, rodents, pest and disease was observed.

2.4 Irrigation Scheduling and Irrigation Water Application

Basin irrigation was adopted during the field experiment with basin size of 3 m by 4 m. Crop water requirement and irrigation requirement were determined using the FAO-CROPWAT 8.0 software based on climatic, environmental and crop characteristics. The soil and climate data used in the software are presented in Tables 1 and 3 respectively. For the crop input requirement, default crop parameters were adopted from the software except the crop growth stages. These were substituted with 15, 25, 35 and 20 days for initial, developmental, mid-season and late season growth stages respectively, as recommended by LCRI. The software generated net irrigation depths of the control treatment (100 % I_g) and then it calculated gross irrigation depths as the ratio of net irrigation to application efficiency (65 %). Weekly (7-days) irrigation interval as recommended by LCRI (2017) was used throughout the growing period which gave 100 % irrigation scheduling efficiency from the software. Irrigation depths of the DI treatments at each irrigation were calculated as percentage of the control treatment (T1).

Water was conveyed into the experimental plots from the field channels using pair of 4.6 cm diameter calibrated PVC pipes that were installed in each basin to give free orifice flow. The calibration result gave an average coefficient of discharge of the PVC pipe to be 0.68. Pairs of 30 cm meter rule were used as gauges at the pipes inlet to determine the height (head) of water above the inlet. The discharge of water through the pipe was calculated using the orifice equation as expressed in equation 1.

$$Q = AC_d \sqrt{2gH} \qquad (1)$$

C_d = coefficient of discharge = 0.68; A = cross sectional area of orifice (m^2); g = acceleration due to gravity (9.81 m/s^2); H = height of water above the orifice (m).

The time of flow into each plot was based on the depth of water applied into the plot at an irrigation requirement (i.e. I_g= gross irrigation depth). Having known the plot size (A) and the flow rate into the plot (Q), Irrigation time was calculated using equation 2. A stopwatch was used to monitor time of water application.

$$t = \frac{I_g * A}{Q} \quad (2)$$

Seasonal irrigation water applied (SIWA) in millimeter (mm) for each treatment was calculated as the summation of all the weekly irrigation water depth applied from the beginning to the end of the season. The amount of water saved (AWS) in % by each DI treatment was estimated as shown in equation 3.

$$AWS = \frac{\text{SIWA OF T1} - \text{SIWA OF DI}}{\text{SIWA OF T1}} * 100 \quad (3)$$

2.5 Determination of Grain Yield (GY) and Biomass Yield (BMY)

Harvesting was done manually when the crop reached maturity. An area of 1 m^2 from center of each plot was selected to represent the harvestable yields of each treatment as described by (Memon *et al.,* 2021). Samples were harvested from ground surface in each plot and tagged, and then sun-dried for one week. The dried samples were weighed using electric balance to record BMY (consisting both grain yield and straw yield). Samples were manually threshed, winnowed and cleaned, and then the GY was also weighed using electric balance at the standard gravimetric moisture content (13.5 %) (Memon *et al.,* 2021). Both grain yield and biomass yield were first recorded in gram per harvested area (1 m^2) and then converted to ton per hectare.

2.6 Determination of Harvest Index (HI)

HI in % was calculated using equation 4 (Khan *et al.,* 2021).

$$HI = \frac{GY\ (t/ha)}{BMY\ (t/\ ha)} * 100 \quad (4)$$

2.6 Determination of Irrigation Water Use Efficiency (IWUE)

Irrigation water use efficiency (IWUE) (in kg/ha-mm) with respect to GY (GIWUE) and BMY (BIWUE) were computed as the ratio of GY or BMY in kilogram per hectare to seasonal irrigation water applied (SIWA) in millimeter as shown in equations 5 and 6 respectively (Igbadun, 2012).

$$IWUE_{grain} = \frac{GY}{SIWA} \quad (5)$$

$$IWUE_{biomass} = \frac{BMY}{SIWA} \quad (6)$$

2.7 Determination of Actual Crop Evapotranspiration (ET_a) and Yield Response Factor (K_y)

The actual crop evapotranspiration (ET_a) was estimated using the soil moisture depletion method with the expression given as (Igbadun, 2012):

$$ET_a = \frac{\sum_{i=1}^{n}(GMC_{1i} - GMC_{2i}) * A_i * D_i}{t} \quad (7)$$

Where: ET_a = average daily evapotranspiration between successful soil moisture sampling periods (mm/day); (GMC_{1i}-GMC_{2i}) = soil moisture deficit between two measurement dates in ith soil layer; A_i = specific gravity of ith layer; D_i = depth of ith layer (mm); n = number of soil layer sampled; t = number of days between successful soil moisture content sampling.

Soil moisture content of each plot was monitored using calibrated gypsum blocks installed at 15 cm, 45 cm and 75 cm depths. Yield response factor (K_y) to DI for each treatment was computed using equation 8 (Steduto *et al.,* 2012).

$$\left(1 - \frac{Y_a}{Y_m}\right) = K_y\left(1 - \frac{ET_a}{ET_m}\right) \quad (8)$$

Where:

Y_m and ET_m were yield and actual evapotranspiration of the FI treatment while Y_a and ET_a were yield and actual evapotranspiration of the DI treatment.

2.8 Statistical Analysis

The data recorded on GY, BMY, GIWUE, BIWUE and HI were statistically analyzed using analysis of variance (ANOVA) with Statistics 8.0 software package. Differences between means were compared using least significant difference (LSD) at 5 % level of significance.

3.0 Results and Discussion

3.1 Physical Properties of the Soil in the Study Area

The analysis revealed that the texture of the soil is sandy loam to sandy clay loam which becomes more clayey towards the eastern direction. The gravimetric soil moisture content of the top most layer at saturation, field capacity and permanent wilting point were 0.325, 0.257 and 0.027 respectively. Likewise, the saturated hydraulic conductivity was found to be 1200 mm/day. The bulk densities of the sandy loam and sandy clay loam layers were averagely 1.67 and 1.50 g/m^3 respectively. Table 3 presents the physical properties of the soil for the site.

Table 3: Physical properties of the soil at the experimental site

Properties/Layers	0-30cm	30-60cm	60-90cm	90-120cm	120-150cm
Textural Class	Sandy loam	Sandy clay loam	Sandy loam	Sandy clay loam	Sandy clay loam

SAT (g/g)	0.325	0.428	0.394	0.444	0.444
FC (g/g)	0.257	0.104	0.085	0.104	0.118
PWP (g/g)	0.027	0.055	0.051	0.066	0.077
Bulk Density (g/cm^3)	1.63	1.46	1.70	1.56	1.52
Ksat (mm/day)	1200	269	1200	273	342

NB: SAT= gravimetric moisture content at saturation; FC= gravimetric moisture content at field capacity; PWP= gravimetric moisture content at permanent wilting point; Ksat= saturated hydraulic conductivity.

3.2 Gross Irrigation Water Applied

Table 4 presents weekly gross irrigation depths, SIWA and amount of water saved by DI treatments (in %). All treatments received the same amount of weekly gross irrigation depths of 33.7 and 12.1 mm at the first two irrigations respectively to allow proper establishment of the crop. The crop received four irrigations during the vegetative and yield formation stages and two irrigations during the flowering stage. The gross irrigation water depth of the crop under non-deficit condition increased towards the end of the season as a result of the crop growth and warmer climate. The seasonal depth of gross irrigation water applied for the crop in FI (non-deficit condition) was found to be 477.10 mm as presented in Table 4. Steduto *et al.* (2012) stated that seasonal water requirement for wheat crop ranges from 200-500 mm. The lowest seasonal depth of gross irrigation water applied was 343.72 mm and it corresponded to irrigation at 60 % I_g at the yield formation stage. This combination was found to have saved 28 % of gross irrigation water.

Table 4: Weekly gross irrigation depths, seasonal irrigation water applied (SIWA) and percentage saved by each treatment

Treatments	**Weekly Gross Irrigation Depths (mm)**											**SIWA (mm)**	**Water Saved (%)**
	Establishment		Vegetative				flowering		Yield Formation			Total	
	1	2	3	4	5	6	7	8	9	10	11	12		
T1	33.7	12.1	17.0	23.3	30.6	42.0	46.4	49.7	52.9	54.3	56.0	59.1	477.1	0
T2	33.7	12.1	13.6	18.6	24.5	33.6	46.4	49.7	52.9	54.3	56	59.1	454.5	4.7
T3	33.7	12.1	10.2	14.0	18.4	25.2	46.4	49.7	52.9	54.3	56	59.1	431.9	9.5
T4	33.7	12.1	6.8	9.3	12.2	16.8	46.4	49.7	52.9	54.3	56	59.1	409.4	14.2
T5	33.7	12.1	17.0	23.3	30.6	42.0	37.1	39.8	52.9	54.3	56	59.1	457.9	4.0
T6	33.7	12.1	17.0	23.3	30.6	42.0	27.8	29.8	52.9	54.3	56	59.1	438.7	8.1
T7	33.7	12.1	17.0	23.3	30.6	42.0	18.6	19.9	52.9	54.3	56	59.1	419.4	12.1
T8	33.7	12.1	17.0	23.3	30.6	42.0	46.4	49.7	42.3	43.4	44.8	47.3	432.6	9.3
T9	33.7	12.1	17.0	23.3	30.6	42.0	46.4	49.7	31.7	32.6	33.6	35.5	388.2	18.6
T10	33.7	12.1	17.0	23.3	30.6	42.0	46.4	49.7	21.2	21.7	22.4	23.6	343.7	28

At each level of the DI imposed, more water was saved during the yield formation stage followed by the irrigations at vegetative stage and lastly the flowering stage. This was because the wheat variety used has short flowering stage (14 days only) compared to the vegetative and yield formation stages. Also, atmospheric evapotranspiration demand increased during the later growth stage of the crop.

3.3 Effect of Deficit Irrigation on Yields of Wheat

The effect of the various irrigation applications on grain yield (GY), biomass yield (BMY), irrigation water use efficiencies (IWUE) and harvest index (HI) of wheat crop are presented in Table 5. The highest BMY observed was 10.93 t/ha at treatment T1 and the lowest observed was 6.12 t/ha at T4. The result showed insignificant difference (p= 0.05) between the control treatment (T1), T8, T2 and T9. The crop resisted 20 % water deficit at all the three growth stages studied. When the stress reached 40 % and beyond at the vegetative stage, the effect became significant. During the yield formation stage, when the water stress was increased to 40 %, the yield was still not significantly affected. At 60 % deficit, the yield reduction was significant but by just 12 %. This could be because water deficit was imposed when the crop almost reached its full vegetative growth. The highest GY observed was 5.20 t/ha in treatments T1 and T5 and the lowest yield achieved was 3.00 t/ha in treatment T4. Irrigation at 60 % I_g during yield formation stage had no significant effect on GY as it was observed in treatment T9. During the flowering stage, irrigating at 60 and 40 % I_g resulted in significant difference (p= 0.05) with only 8 and 9 % yield reduction respectively. Similarly, at the vegetative stage, the significant yield reductions were by 22 and 43 % (T3 and T4) respectively. The result indicated that BMY and GY were not significantly affected by mild stress as it was reported in many works (Chai *et al.*, 2016; Torrion and Stougaard, 2017; Fahad *et al.*, 2019; Guo *et al.*, 2020; Memon *et al.*, 2021). This could be because the rate of photosynthesis does not drop under such condition. On the other hand, the yields were found to be significantly affected by moderate and severe water stresses (such as irrigating at 60 % I_g and 40 % I_g, respectively) which is in line with Torrion and Stougaard (2017), Fahad *et al.* (2019) and Zhao *et al.* (2020). This could be attributed to intensive reduction in rate of photosynthesis, accelerated start of leaf senescence and affected transport of photosynthetic products to various parts of plant (Torrion and Stougaard, 2017). Soil water deficit also inhibits leaves development and extension (Zhao *et al.*, 2020); therefore the interception of photosynthetic effective radiation is decreased, resulting in a reduction in plant height and biomass accumulation which in turn affects GY.

The negative impact of water stress on BMY and GY was found to be higher during the vegetative stage than the flowering or the yield formation stages. The significant reduction in yields could be attributed to the reduction in tillering and number of panicles per hill. Higher sensitivity of the vegetative stage with regard to GY is corroborated by Ozturk and Aydin (2004) and Sarvestani *et al.* (2008), which attributed it to delayed flowering period. Conversely, Maqbool *et al.* (2015) reported that GY was most sensitive to water deficit at yield formation stage and this might be due to variation in crop variety and environmental condition.

Table 5: Mean comparison for grain yield, biomass yield, water use efficiency and harvest index of wheat under different deficit irrigation application

Treatments	Grain Yield (t/ha)	Biomass Yield (t/ha)	GIWUE (t/ha-mm)	BIWUE (t/ha-mm)	HI (%)
T1	5.20[a]	10.93[a]	10.90[c]	22.90[cde]	47.63[ab]
T2	4.90[abc]	10.74[a]	10.78[c]	23.64[bcd]	45.60[b]

T3	4.03^{d}	8.40^{c}	9.34^{d}	19.44^{f}	49.01^{ab}
T4	3.00^{e}	6.12^{d}	7.25^{e}	14.96^{g}	48.42^{ab}
T5	5.20^{a}	9.72^{b}	11.36^{c}	21.22^{ef}	53.64^{a}
T6	4.77^{bc}	9.57^{b}	10.87^{c}	21.82^{def}	49.80^{ab}
T7	4.73^{bc}	9.53^{b}	11.29^{c}	22.73^{cde}	49.73^{ab}
T8	5.07^{ab}	10.85^{a}	11.71^{bc}	25.09^{bc}	46.75^{ab}
T9	4.83^{abc}	10.05^{ab}	12.45^{ab}	25.88^{ab}	48.16^{ab}
T10	4.50^{c}	9.64^{b}	13.09^{a}	28.06^{a}	46.79^{ab}
LSD	0.43	0.92	1.02	2.19	7.90

Means followed by different letters in a column differ significantly and those followed by the same letter are not significantly different at $p<0.05$ level of significance.

3.4 Effect of Deficit Irrigation on Water Productivity and Harvesting Index of Wheat

The highest BIWUE and GIWUE observed were 28.06 t/ha-mm and 13.09 t/ha-mm respectively, at T10 and the lowest observed were 14.96 t/ha-mm and 7.25 t/ha-mm respectively at T4. The result showed no significant difference between T10 and T9, which indicated that IWUE was maintained when water stress at the yield formation stage was increased from 40 to 60 %. The result showed that highest IWUE was achieved when water stress was imposed during the yield formation stage. At each of the three levels of water deficit, water savings were higher at the yield formation stage compared to the vegetative and the flowering stages. Also, as discussed above, the negative impacts of the water stresses on the yields were less when the deficits were imposed at the yield formation stage. Conversely, the least IWUE observed was at the treatments that received DI during the vegetative stage. The fully irrigated treatment (T1) and the treatments that received DI during the flowering growth stage performed more efficiently than the treatments that received DI during the vegetative stage. Many previous studies have revealed the improvement of water use efficiencies of various crop species under water deficit condition (Zhao *et al.*, 2020). The findings in this work are in line with Zhang *et al.* (2005), Steduto *et al.* (2012) and Degaga (2016) which obtained GIWUE ranges of 11.6-16.8 t/ha-mm, 10-12 t/ha-mm and 1.08-1.86 kg/m^3 respectively.

HI indicates the physiological efficiency or the ability of a crop to convert dry matter into economic yield. The HI observed varies between 53.64 and 45.60 %. The statistical analysis showed that the HI of all the treatments were statistically similar. This might be as DI affected GY, it simultaneously affected BMY. Insignificant relationship between soil water deficit and HI was reported by Degaga (2016), Torrion and Stougaard (2017) and Fahad *et al.* (2019).

3.5 Yield Response Factor (K_y)

Yield response factor (K_y) is a factor that shows the magnitude of the consequences of reduction in ET due to water deficit on yield. Figures 2, 3 and 4 present the graphs of relative yield decrease ($1-Y_a/Y_m$) versus relative evapotranspiration decrease ($1-ET_a/ET_m$) during the vegetative, flowering and yield formation growth stages respectively. Yield response factor (K_y) is the slope of the graph. The plots show that the K_y values of the vegetative, flowering and yield formation stages are 1.46, 0.79 and 0.92 with R^2 values of 0.99, 0.75 and 0.97 respectively. This implied that with K_y value greater than 1, the vegetative stage of the crop is sensitive to soil water deficit (relative yield reduction was higher than relative ET reduction). On the other hand, the flowering and yield formation stages of the crop tolerated the DI imposed because their K_y values are less than 1 (yield reductions were lower compared to ET reduction). From figure 3, the relative yield reduction of T5 (treatment irrigated at 80 % I_g during the flowering stage only) is 0; this showed that there was no noticeable effect of the DI applied on its yield. Several studies revealed that K_y varies for different crop types, stress condition, irrigation method and management (Adeboye *et al.*, 2015; Degaga, 2016). Steduto *et al.* (2012) got lower K_y values of 0.65 and 0.55 for vegetative and flowering stage respectively for wheat. Similarly, the International Atomic Energy Agency (IAEA) reported K_y values of 0.9, 0.48 and 0.62 for vegetative flowering and yield formation stages respectively. After adducing this, Steduto *et al.* (2012) stated that for various crops, results showed a wide range of distinction of K_y values, and variation between crops cultivars can be as large as between different crops.

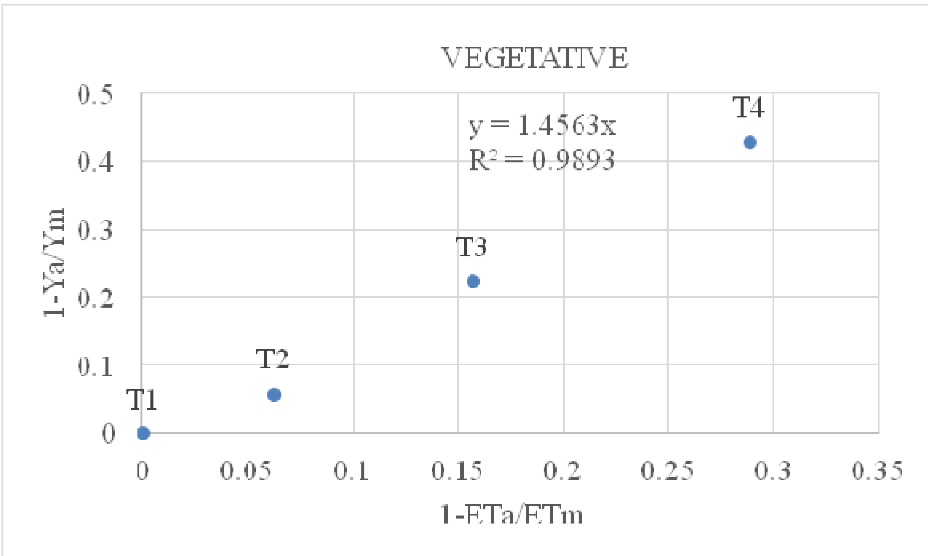

Figure 2: Relationship between relative yield decrease and relative evapotranspiration decrease during the vegetative stage

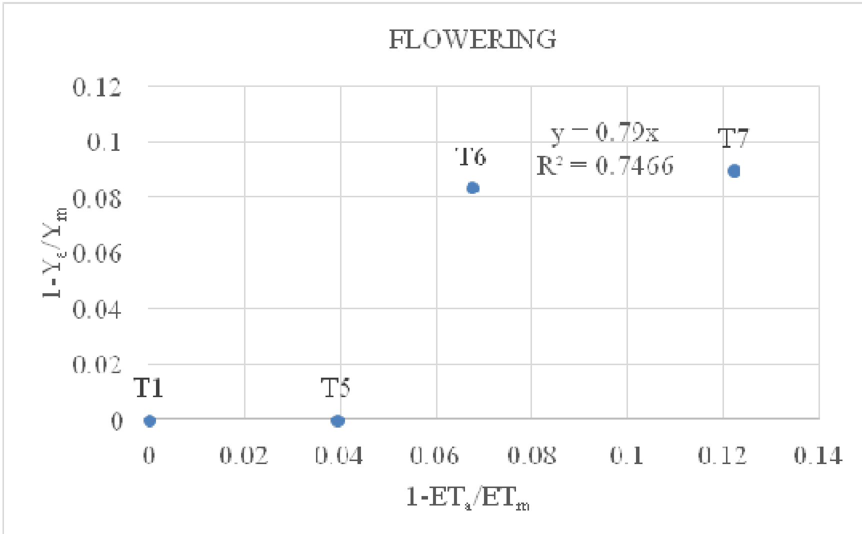

Figure 3: Relationship between relative yield decrease and relative evapotranspiration decrease during the flowering stage

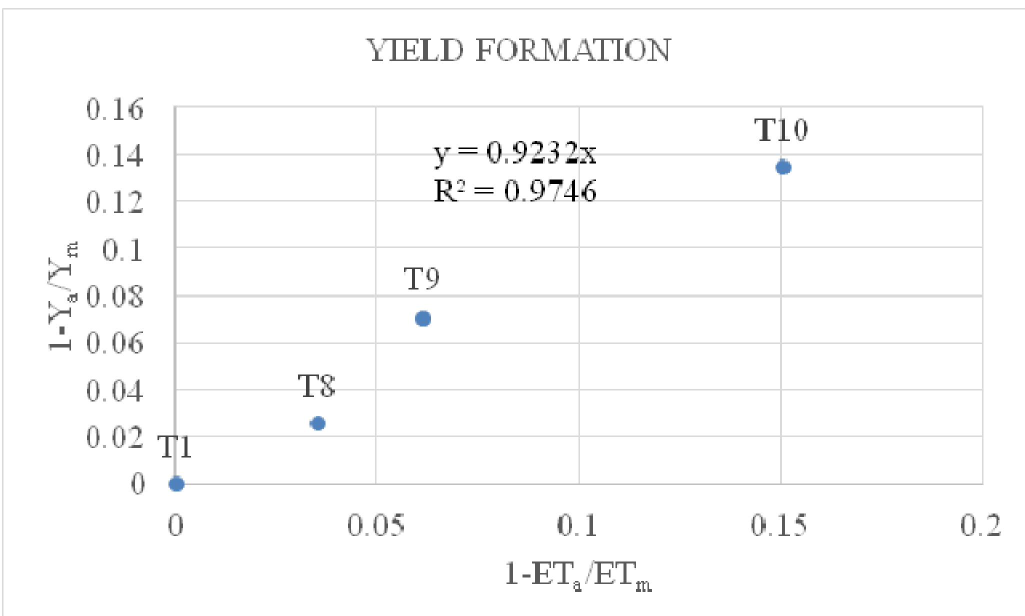

Figure 4: Relationship between relative yield decrease and relative evapotranspiration decrease during the yield formation stage

It was reported extensively that deficit irrigation has significant effect on wheat growth, yield and its components (Degaga, 2016), either the stress occurred during the whole growing season or at a particular growth stage. Several researchers reported that wheat can tolerate certain level of water stress either imposed during the whole growing season or at particular stage. Chai *et al.* (2016) stated that plants can recover to a level similar to fully irrigated treatments if subjected to mild stress and subsequent full irrigation which was also exhibited by treatments T2, T5 and T6.

It can be deduced that the vegetative stage of the wheat variety was more sensitive to water deficit while the flowering and yield formation stages were more tolerant to water deficit. Geerts and Raes (2009) reviewed selected research works on DI from around the world and reported many researches showed the yield formation stage to be a drought resistance stage and drought should be avoided during vegetative and early reproductive stages. El Hwary and Yagoub (2011) irrigated wheat at 10-days interval and reported that in the two seasons, maximum tested parameters values were achieved at the fully irrigated treatment with fewer differences with the treatment that experienced stress during yield formation stage than the treatment that experienced stress during the vegetative stage. Moghaddam *et al.* (2012) reported that DI reduced growth and productivity of wheat, and they found the vegetative stage to be the most sensitive to water deficit. The simulations of DI scenarios using the Aqua Crop model by Mustafa *et al.* (2017) also revealed that vegetative stage is the most sensitive stage to water deficit in wheat. Furthermore, the sensitivity of the vegetative stage to water deficit was observed to be pronounced at 40 % water deficit and beyond in the current work which is similar to the outcome of Memon *et al.* (2021).

Contrasting result was reported by Maqbool *et al.* (2015), where stress induced at grain filling (yield formation) stage showed most significant impact on wheat productivity. Similarly, Sokoto and Singh (2013) reported that the flowering and grain filling stages were the most sensitive wheat growth stages to DI. The flowering stage was also found to be the most sensitive to water stress by Yu *et al.* (2018). These variations could be due to difference in the crop varieties used and study locations. The varieties used in the reported works have more than 30 days flowering period while the one used in this work has only 14 days flowering stage. Globally, results showed inconsistency in determining the most sensitive growth stage in wheat crop (Steduto *et al.*, 2012; Chai *et al.*, 2016) because plants cultivars vary in photosynthesis rate, stomatal conductance and rate of transpiration, thus, their responses to water deficit will vary.

4.0 Conclusion

Irrigation water requirement for optimum water application of wheat in the location was 477.1 mm. Maximum water saving was achieved when DI was applied during the yield formation stage of the variety. Highest grain and biomass yields of 5.2 and 10.93 t/ha respectively were obtained at the application of full irrigation, which were statistically similar with the application of 20 % water deficit at any of the three growth stages. Highest effect of water deficit on yields was observed when severe stress was imposed during the vegetative stage which resulted in 3.0 and 6.12 t/ha GY and BMY respectively. Higher irrigation water productivities were achieved at the application of deficit irrigation during the yield formation stage of the crop. Grain irrigation water use efficiency (GIWUE) of 13.09 t/h-mm and 12.45 t/h-mm were obtained at the application of 40 % and 60 % water deficits during yield formation stage only respectively, which are statistically higher than any other treatment. The vegetative stage of the crop was found to be sensitive to water deficit with K_y = 1.46 whereas, the flowering and yield formation stages tolerated the water deficits imposed with K_y values of 0.79 and 0.92 respectively. Hence, there is need for adequate irrigation at the vegetative stage of the crop. Conversely, applying deficit irrigation during the yield formation stage of the crop could be a promising scheduling option that may result in minute and insignificant yield reduction. Therefore, much irrigation should be avoided during the matured stage of the crop through the application of up to 40 % water deficit which could help in conserving water and energy and their efficient use.

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APPLICATION OF WATER QUALITY INDEX FOR MEASURING SURFACE WATER QUALITY: A CASE STUDY OF DOUGLAS GREEK

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Abstract

This study presents the calculated Water Quality Index for the assessment of downstream and upstream surface water quality. Physicochemical parameters of surface water samples from downstream and upstream were collected from the Health Safety and Environmental Department, Network/Oando Exploration and Production Nigeria Limited (NEPNL) Production Facilities for the month of January 2020 to determine the level of pollution. Values were compared with the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ). For calculating the WQI in the present study, 15 Physico-chemical parameters namely, temperature (°C), pH, electrical conductivity EC, turbidity, dissolved oxygen (DO), total dissolved solids (TDS), total suspended solids (TSS), chloride, BOD, COD, nitrate, lead (Pb), copper, chromium and nickel were used to calculate the water quality index to ascertain its suitability for human consumption and dissemination of wildlife and fish culture. According to (WHO) and (NSDWQ) standards, temperature (31.6 and 30.4 °C), EC (12498 and 11652 µs/cm turbidity (226 and 196 NUT), DO (5.09 and 5.46 mg/l), TDS (7499 and 6991 mg/l), TSS (301 and 256 mg/l), chloride (4954 and 4321 mg/l), Pb (0.073 and 0.068 mg/l) and nickel (0.195 and 0.137 mg/l) were above the permissible limits of drinking water standard which reduced drinking water quality. While pH, BOD, COD, Cu, Cr and nitrate were within the permissible limit of drinking water standard. Water quality index value 735.913 at the downstream and 617.169 at the upstream were above the status of water for human consumption, dissemination of wildlife and fish culture. According to (Mishra and Patel) index value 100 and above means that the water samples are unsuitable for human consumption, dissemination of wildlife and fish culture. This means that surface water at the downstream and upstream sampling locations are unsuitable for human consumption. Public awareness needs to be raised on chemical contents in surface water in the study area in order to improve the health of surface water users.

Keywords: Water Quality Index, Physicochemical Parameters, Assessment, Surface Water Pollution

1 Introduction

Surface water from streams, rivers, lakes, canals and reservoirs is vulnerable to contamination due to anthropogenic activities. Surface water quality is governed by compound anthropogenic activities and natural processes (Javie *et al*., 1998; Ravichandran 2003) namely weathering erosion, hydrological features, climate change, precipitation, industrial activities, agricultural land use, sewage discharge, and human exploitation of water resources (Malvi *et al*., 2005). Widespread deterioration in water quality of inland aquatic systems has been reported due to the rapid development of industries, agriculture, and urban sprawl (Vie *et al*., 2009). The need for water in the lives of organisms can never be undermined by its supportive role; it is one of the most important compounds that strongly influence life. The quality of surface water however is a function of natural and anthropogenic activities in the area. Regular monitoring of surface water is necessary to assess the quality of water for ecosystem health, hygiene, agricultural and domestic uses. The water quality valuation may be difficult to practice in multiple parameters producing many concerns in the overall quality of water. It may be difficult to assess water quality for massive samples containing concentrations for many parameters. The Conventional methods for evaluating the quality of water are based on the comparison of experimentally determined parameter values with the existing guidelines (Debels *et al*., 2005). As a result, water quality indices are methodologists able to integrate a large number of water quality data, i.e., concentrations of quality parameters measured at a specific location or point and time in a particular water body, into a single value which expresses the present quality status of the given body. Based on appropriate classification schemes, determined by each individual methodology, these scores correspond to specific quality classes (1 to 5), each expressing a specific quality condition, such as "very bad", "bad", "medium", and "good", or "excellent" water quality (Tsakiris *et al*., 2017).

Starting with Horton's Index (1965), a large number of indices have been developed for the evaluation of the quality status of water bodies. Many researchers, on a global scale, have implemented water quality index studies in order to investigate and support these tools provide under different local conditions. Scientists have attempted to apply different water quality indices in a certain water body in order to evaluate their comparative performance (Alexakis *et al*., 2016; Hashim *et al*., 2015; Darvishi *et al*., 2016; Nta *et al.,* 2020).

The present study attempts to apply a weighted arithmetic water quality index (Brown *et al*., 1972) in measuring surface water quality in Douglas Greek, Qua Iboe Terminal, Ibeno Local Government Area, Akwa Ibom State, Nigeria, for the purpose of communicating information on water quality trends to the general public or concern authorities like policymakers.

2. Materials And Methods

2.1 Study Site:

The area under study is Douglas Greek, Qua Iboe Terminal, Ibeno Local Government Area of Akwa Ibom State, Nigeria. It lies on the eastern side of Qua Iboe River between latitudes 4.300 and 4.450N and longitude 7.300 and 8.00E. Ibone is one of the largest fishing settlements on the Nigerian coast (Andem *et. al*., 2013).

2.2 Data Collection

The following physicochemical parameters namely temperature (°C), pH, electrical conductivity EC, turbidity, dissolved oxygen, (DO), chloride (Cl), dissolved oxygen, total dissolved solid (TDS), total suspended solid (TSS), chloride, BOD, COD, nitrate, lead (Pb), copper, chromium and nickel were collected from Health Safety and Environmental Department, Network/Oando Exploration and Production Nigeria Limited (NEPNL) Production Facilities for the month of Janu ary, 2020.

2.3 Water Quality Index (WQI)

The water quality index is the most effective tool to communicate information on water quality trends to the general public or concerned authorities like policymakers. It indicates the quality of any water with reference to the index number which represents the overall quality of water for any purpose. WQI is defined as the rating that reveals the combined effect of diverse water quality parameters. However, for calculating the WQI in the present study, 15 Physico-chemical parameters namely, temperature (°C), pH, electrical conductivity EC, turbidity, dissolved oxygen, total dissolved solids (TDS), total suspended solids (TSS), chloride, BOD, COD, nitrate, lead (Pb), copper, chromium and nickel were used to calculate the water quality index.

2.3.1 Water Quality Index Calculation

The calculation of the water quality index was made using a weighted arithmetic index method as described by (Brown *et al.*, 1972) in the following step:

Let there be n water quality parameters and the quality rating (qn) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value. qn values are given by the relationship.

$$qn = 100\ [Vn - Vi / Vs - Vi] \qquad (1)$$

Where:

qn = quality rating for the nth water quality parameter.

Vn = estimated value of the nth parameter at a given sampling location.

Vs = standard permissible value of nth parameter. Vs originate from WHO, 2011 & NSDWQ, 2015 standard.

Vi = ideal value of nth parameter in pure water.

All the ideal values (Vi) are taken as zero for drinking water apart from pH = 7.0 and dissolved oxygen = 14.6 mg/l.

2.3.2 Calculation of Unit Weight (Wn)

The unit weight (Wn) for a number of water quality parameters are inversely proportional to the recommended standard for the corresponding parameters.

$$Wn = K / Sn \qquad (2)$$

Where:

Wn = unit weight for nth parameters

K = proportionality constant (k = 1.85445)

Sn = standard permissible value for nth parameter

2.3.3 Calculation of Water Quality Index

$$WQI = \sum_{n=1}^{n} qn\ Wn / \sum_{n=1}^{n} Wn \quad (3)$$

Where:

qn= quality rating for the nth water quality parameter, and

Wn = unit weight for nth parameters

2.3.4 Assessment of Water Quality Based on Water Quality Index

The suitability of water quality index value for human consumption was assessed according to Mishra and Patel, (2001).

3 Results and Discussion

3.1 Surface water Characteristics

Values of physicochemical parameters of downstream and upstream surface water samples and their recommended standard limits are presented in table 1. The pH values of the present study were within (WHO, 2011 and NSDWQ, 2015) standards 6.5 to 8.5. pH is an important factor that serves as an index for pollution. The pH value of natural water changes due to biological activity and industrial contamination. The temperature of the present investigation ranged from 30.4 to 31.6 ℃. The temperature of the water is an important parameter because of its effect on chemical reaction and reaction rates, aquatic life and the suitability of the water for beneficial uses (Nta and Udom, 2018). A rise in the temperature of the water may lead to the speeding up of chemical reactions in water, reduces the solubility of gases and amplifies tastes and odour.

Turbidity values recorded in the range (196 – 224 NTU) and were above the permissible limit of the drinking water standard (5 NTU). Turbidity though it has no direct health effect, it can harbour micro-organisms protecting them from disinfection and can entrap heavy metals and biocides. Dissolved oxygen values were found outside the range for drinking water standard (2 mg/l) which indicated that the surface water downstream and upstream are unsuitable for human consumption, dissemination of wildlife and fish culture. Dissolved oxygen is an important parameter which is essential to the metabolism of all aquatic organisms that possess aerobic respiration. High dissolved oxygen in the present study may be due to direct diffusion from the air and photosynthetic activity of autotrophs. EC, TDS and TSS were all above the permissible limits in drinking water standards which range (from 11652 – 12498 μs/cm; 6991 – 7499 mg/l; 256 – 301 mg/l). EC is a measure of current-carrying capacity. Thus, as the concentration of dissolved salts increases conductivity also increases. Many dissolved substances may produce aesthetically displeasing colour, taste and odour in water. The amount of total dissolved solids (TDS) in water indicates the salinity of water and may also be used as an indicator for rapid plankton growth and sewage contamination. The total dissolved solids in water comprise mainly inorganic salts and a small amount of organic matter. Values of BOD, COD, Nitrate, Cr and Cu were within the acceptable limits for drinking water standards. BOD and COD are important parameters that indicate contamination with organic wastes. Biochemical oxygen demand (BOD) is the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions (Sawyer and McCarthy, 1978). It is required to assess the pollution of surface and groundwater contamination that occurred due to the disposal of domestic and industrial effluents. Chemical oxygen demand (COD) determines the oxygen required for the chemical oxidation of most organic matter and oxidizable inorganic substances with the help of a strong chemical oxidant. In conjunction with the BOD, the COD test is helpful in indicating toxic conditions and the presence of biologically resistant organic substances. Nitrate is the most important nutrient in an ecosystem. Generally, water bodies polluted by organic matter exhibit higher values of nitrate. In the present investigation upstream and downstream water samples recorded low concentrations of nitrate (8.76 to 9.52 mg/l) well below permissible levels as per the standards. Chloride values obtained in the study are found in the range between 4321 - 4954 mg/l. Chloride occurs in all types of natural waters. Bio-Chemical Oxygen Demand (BOD) & Chemical Oxygen Demand (COD) BOD & COD are the parameters used to assess the pollution of surface water and ground waters. Both of the parameters (BOD & COD) values obtained in the present study are within permissible levels.

Pb was above the permissible limit of 0.01 mg/l in the drinking water standard, which is a clear manifestation of the presence of toxic substances in the water samples. High values of Pb as recorded in this study may cause cancer, interference with vitamin D metabolism, affect mental development in infants, toxic to the central and peripheral nervous systems on the health status of local surface water resource users in the host communities as reported by NSDWQ, 2015. Also, Pb may cause anaemia, brain damage, anorexia, mental deficiency, vomiting and even death in human beings (Maddock & Taylor, 1977; Bulut & Baysal 2006) and is toxic even at lower concentrations. The value of nickel at downstream was above the acceptable limit for drinking water standards.

Table 1. Physiochemical Parameters of Down Stream and Upstream Surface water Samples at (NEPNL) Production Facilities

S/N	Parameters	Downstream Surface Water	Upstream Surface Water	WHO, 2011	NSDWQ 2015
1.	Ph	7.36	7.66	6.5– 8.5	6.5-8.5
2.	Temperature °C	31.6	30.4	25	@
3.	Turbidity	224	196	@	5
4.	DO	5.09	5.46	2	@
5.	EC	12498	11652	1000	1000
6.	TDS	7499	6991	500	500
7.	TSS	301	256	10	
8.	BOD	3.01	3.42	10	
9.	COD	6.44	8.53	10	
10.	Chloride	4954	4321	250	250
11.	Nitrate	8.76	9.52	10	50
12.	Lead	0.073	0.068	0.01	0.01
13.	Chromium	0.001	0.001	0.05	0.05
14.	Nickel	0.195	0.137	@	0.02

15.	Copper	0.07	0.05	@	1.00

3.2 Evaluation of Downstream and Upstream Surface Water Quality Based on Water Quality Index

Tables 2 and 3 presents the calculated water quality rating (qn), and unit weight (Wn). While tables 4 and 5 presents calculated water quality index (WQI) and status of water quality based on water quality index by Mishra and Patel, (2001). The application of water quality index revealed information on downstream and upstream surface water quality trends at Douglas Greek at Network/Oando Exploration and Production Nigeria Limited (NEPNL) Production Facilities. Water quality index values was 735.913 at the downstream and 617.169 at the upstream. According to Mishra and Patel (2001) index value 100 and above means that the water samples are unsuitable for human consumption, dissemination of wildlife and fish culture. This means that surface water at the downstream and upstream sampling locations are unsuitable for human consumption. The reason for high index values maybe as a result of anthropogenic activities and natural processes in the study area which eventually lead to surface water pollution.

Table 2. Calculated Water Quality Rating (qn) of Down Stream and Upstream Surface water Samples at (NEPNL) Production Facilities

S/N	Parameters	Downstream Surface Water	Upstream Surface Water
1.	Ph	24	44
2.	Temperature ℃	126.4	121.6
3.	Turbidity	4480	3920
4.	DO	254.5	273
5.	EC	1249.8	1165.2
6.	TDS	1499.8	1398.2
7.	TSS	10033.33	8533.33
8.	BOD	30.1	34.2
9.	COD	64.4	85.3
10.	Chloride	1981.6	1728.4
11.	Nitrate	87.6	95.2
12.	Lead	730	680
13.	Chromium	2	2
14.	Nickel	975	685
15.	Copper	3.5	2.5

Table 3. Calculated Unit Weight of Down Stream and Upstream Surface water Samples at (NEPNL) Production Facilities

S/N	**Parameters**	**WHO, 2011**	**NSDWQ, 2015**	**Unit Weight (Wn)**
1.	Ph	6.5– 8.5	6.5-8.5	0.218
2.	Temperature ℃	25	@	0.074
3.	Turbidity	@	5	0.371
4.	DO	2	@	0.927
5.	EC	1000	1000	0.002
6.	TDS	500	500	0.004

7.	TSS	3		0.618
8.	BOD	10		0.185
9.	COD	10		0.185
10.	Chloride	250	250	0.007
11.	Nitrate	10	50	0.185
12.	Lead	0.01	0.01	185.445
13	Chromium	0.05	0.05	37.089
14.	Nickel	@	0.02	92.000
15	Copper	@	1.00	0.927

Table 4. Calculated Water Quality Index (weighted arithmetic water quality index) for Down Stream and Upstream Surface water Samples at (NEPNL) Production Facilities

S/N	Sampling Locations	Water Quality Index
1.	Downstream Surface Water	735.913
2.	Upstream Surface Water	617.169

Table 5. Status of Water Quality Based on Water Quality Index (Mishra and Patel, 2001)

Water Quality Index	Status
0 – 25	Excellent
26 – 50	Good
51 – 75	Bad
76 – 100	Very Bad
100 and above	Unfit

4 Conclusions

The findings of this study revealed that surface water at downstream and upstream at Network/Oando Exploration and Production Nigeria Limited (NEPNL) Production Facilities were not suitable for human consumption, dissemination of wildlife and fish culture. According to (WHO) and (NSDWQ) standards, temperature (31.6 and 30.4 °C), EC (12498 and 11652 μs/cm turbidity (226 and 196 NUT), DO (5.09 and 5.46 mg/l), TDS (7499 and 6991 mg/l), TSS (301 and 256 mg/l), chloride (4954 and 4321 mg/l), Pb (0.073 and 0.068 mg/l) and nickel (0.195 and 0.137 mg/l) were above the permissible limits of drinking water standard which reduced drinking water quality. While pH, BOD, COD, Cu, Cr and nitrate were within the permissible limit of drinking water standard. Water quality index value 735.913 at the downstream and 617.169 at the upstream were above the status of water for human consumption, dissemination of wildlife and fish culture. According to (Mishra and Patel) index value 100 and above means that the water samples are unsuitable for human consumption, dissemination of wildlife and fish culture. This means that surface water at the downstream and upstream sampling locations are unsuitable for human consumption. Public awareness needs to be raised on chemical contents in surface water in the study area in order to improve the health of surface water users.

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Conflict of Interest

Authors have declared that no competing interests exist.

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HANDLING ON-FARM WATER SUPPLY IN A CRITICAL SITUATION THROUGH CONSTRUCTION OF A TANK USING SCRAPPED TRAILER CHASIS

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Abstract

Water transportation and distribution is one of the major works in farms. A medium-sized water tanker was constructed for intervention of water scarcity during an emergency requirement in Cocoa research Institute of Nigeria (CRIN). A 4,200 liters capacity tank coupled to the drawbar of a tractor was fabricated using a scrapped medium tractor-trailer chassis considering stability factors. The tanker was an effective, timely and economical intervention to water supply as staffs were able to concentrate on their primary assignments and cost of water supply was highly reduced. Considering the importance of tractor stability, operators expected to handle the tanker were enlightened on wrong tractor handling to avoid accident.

Keywords: Construction, trailer chassis, water tanker, stability, enlightenment,

1. Introduction

In agriculture, water is the principal yield limiting factor among others. Water forms a large percentage of plant tissues and it's also a vital component of animal cells. Global climate change and its negative impact on seedling growth and field establishment of tree crops have made artificial application of water inevitable (Raufu et al., 2015). Various methods of irrigation have been designed for this purpose, especially during the dry season Uneven water distribution and unavailability in the required quantity throughout the year worldwide have led developing countries including Africa and Asia to evolve different techniques to argument water supply from rainfall in an attempt to alleviate water crisis. Residents of both rural and urban areas of Nigeria face water scarcity, which may be acute, in one time or the others, the rain-regions inclusive. Considering the transportation of products which accounts for about half of farm works and the new trends in agriculture due to migration of people, there is demand to handle this aspect with considerable level of efficiency and economy (Adeleke et al., 2017). This has called for involvement of Agricultural Engineers to design appropriate technologies for effective intervention. According to WHO (2011) in Adeleke et al., (2017), water tankering or trucking is a rapid means of transporting water to communities with emergency need, particularly at initial phase. Recommended fundamental requirement for such tankers includes a screened air-vent outlet to prevent dust, insects and similar pollutants.

Cocoa Research Institute of Nigeria (CRIN) with about 1000 staff strength is saddled with research activities of development of five mandate tree crops which are Cocoa, Cashew, Coffee, Tea and Kola. The institute had relied mainly on a self-propelled medium water truck and a mini water supply station for portable water supply for laboratory works and feeding crops. Unfortunately the water station became moribund and the water truck had a major breakdown coincidentally such that institute was without a means of water supply except from external water vendors which were relatively considered expensive. Emergency intervention for water supply therefore became imperative to alleviate stress being experienced by the staff and crops at early stages of developments. In an attempt to proffer solution, a frame/chassis from a scrapped medium tractor trailer was converted to a water tanker of 4,200 liters capacity. The tank fabricated from mild steel sheet was built on the frame supported by 2-wheels which was pulled through the tractor drawbar.

According to (Dennis, 2016), hazards in production agriculture is much associated with tractor; despite the modern tractors has become safer due to inclusion of various devices, the potential instability of tractors is still very vital. Some important elements in this regards are center of gravity, centrifugal force, rear-axle torque and drawbar leverage in relation to stability baselines. Depending on this physical principles the topography of the field and handling during operation, any tractor can overturn either longitudinally or laterally. It is also worth emphasizing that the land terrain and equipments always combine together to influence tractor stability in many working conditions. Enlightenment of the operators/drivers expected to handle the tanker was imperative due to the factors identified above.

This work intended to meet water supply for both human and plant requirements at a low cost during an emergent situation considering availability of fund using immediate available scrapped tractor-trailer frame and tractors

2. Materials and Method

2.1 design consideration

The principle of the construction of the tank was based on the available tractors, the size and capacity of the trailer chassis, the minimum reasonable amount of water required and equipment stability. Ellipsoidal tank was preferred to other shapes because of better load spread possible (Fig. 1 and 2). The tank was designed such that the height was as small as possible according to what was permissible by the dimension of the chassis/frame.

Fig 1: 3D view of the constructed tank

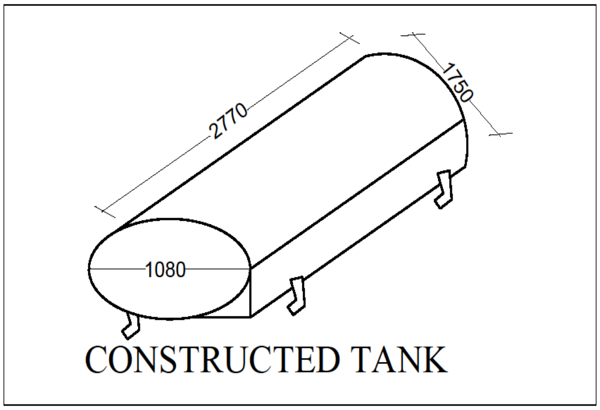
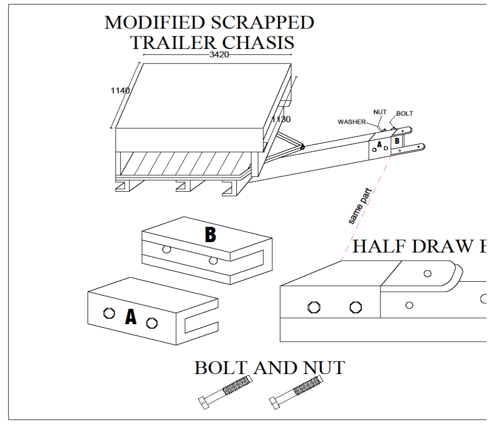


Fig 2: 3D view of modified trailer chassis



2,2 Design calculation

The following expression reported by Adeleke et al., (2017) was employed to determine the dimensions of the tank to achieve 4,200 liters capacity:

Volume of the tank = πabl (1a)

Where;

a = semi-major axis (distance from the centre to the vertex)

b = semi-minor axis (distance from the centre to the co-vertex)

l = length of the tank

2.3 Tractor operational parameters

2.3.1 Centrifugal force

The outward force due to center of gravity of a tractor in a circular motion or sharp turning can cause the tractor to roll over laterally at very high speeds. The higher the speed and the sharper the turning angle, the quicker the tractor overturns. The centrifugal force increased 4 times if the speed is doubled (Dennis, 2016). Rough terrains which cause bouncing of the front tyres may also unconsciously lead to overturn due to centrifugal force. Over-controlling of the steering when a tractor veers off the road is another cause of this overturn. It is therefore very important for tractor operators to pay full attention as information on the location of center of gravity and the amount of centrifugal force are not at their disposal. This force can be defined by the following equation according to Nelkon, and Parker, (1983);

$$F = mr\omega^2 \quad (1b)$$

F – centrifugal force due to turning, m – mass of the tractor, ω – angular velocity and r – radius of turning

2.3.2 Drawbar leverage

The load coupled to the back of the tractor is pulling backward and downward against the forward pull, resulting in an "angle of pull" between the ground surface and the point of load attachment. The heavier the load and the angle of pull the higher the tendency to tip the tractor rearward. If there is sudden obstruction to forward pull when the tractor is climbing a slope at a high speed; rearward pull may be so quick such that the momentum may cause overturn. When the drawbar is not level to the ground, the front or rear tyre of the tractor may not have good contact with the soil surface resulting in loss of traction and pull (Massey Ferguson, 2007). The following equations stated by Nidal and Hamid (2004) can be used to determine the effective pull and loss in pull of an inclined drawbar:

$$P_x = cN_1 + W_2 \sin\beta \quad (2)$$

$$P_y = W_2 \cos\beta - N_1 \quad (3)$$

P_x – effective drawbar pull, P_y – loss in drawbar pull, W_2 – weight of the tanker, N_1 – soil reaction against tanker wheel, β – angle of pull to the horizontal and c – coefficient of rolling resistance.

The coefficient of soil resistance for sand and loose soil is about 4-6 times that of concrete and firm soil: doubling the diameter of tyres we halve the coefficient of soil resistance (Macmillan, 2002).

2.3.3 Rear axle

If the rear axle of a tractor (especially two wheeled type) is unstable to rotate for one reason or the others, such as tyres being stocked in mud/hole or mistakenly locked through differential system, the tractor chassis rotates about its axle causing rearing when the front tyres completely lift-off the ground. A tractor may completely overturn due to this reason within ¾ of a second while an operator may take longer to successfully stop the rearward tipping (Dennis, 2016). Generally speaking, a tractor operator must avoid using it as a playing tool as it had been observed in some organization because of the attendant possible dangers. Macmillan (2002) and Fassara (2014) reported the following equations for determining rearing force and height of lift respectively:

$$Rf = W\frac{Xz}{Xr} \quad (4)$$

$$h = \frac{dr}{2} + \frac{Xz(\cos\beta - 1)}{\sin\beta} \quad (5)$$

Rf – rearing force, W- weight of tractor, Xz – distance of rear wheel from the center of gravity, Xr – tractor wheel base, h – height of lift, dr – front wheel diameter and β – angle of rearing/lifting.

For most common rear wheel drive tractors, Xr is approximately 30% of X; this is also the percentage of the static tractor weight on the front wheels (Macmillan, 2002).

Applying the above equation, if the angle of rearing becomes excessive to the extent that Xz approaches zero; complete overturning of the tractor is imminent.

2.4 Tank fabrication and description

The tank was fabricated from 5mm-thick mild steel plate, through existing templates while arc welding was used for joining individual parts together. A plate opened at its center was welded around the centre inside the tank to give better spread of water/load when the tank is not in full capacity for stability such as during distribution to research plots and staff quarters which are scattered from each others. The entire tank was attached to the chassis by M17 bolts and nuts, such that it could be easily replaced when it is old and out of service. The outer and inner parts were coated with paint and anti-rust for durability. The damaged drawbar of the existing tractor trailer chassis was modified through 2 u-channels (A & B in Fig. 2) and half drawbar which were joined by M14 bolts and nuts. Two ribbed tyres of 12.50 x 18.00 covered with metal plates to prevent mud from splashing on the operator and the tank, were placed to the rear of the centre of the chassis to provide good traction. A water pump of 2.6kw, 600L/min capacity was mounted on the chassis in front of the tank for delivering water effectively. Plates 1-4 show the complete tanker and its operation after construction.

Tree tractors of medium capacity were selected among those available in the institute for pulling the tank with the 4-wheeled type considered the most appropriate because of its ability to work better in a difficult terrain. Culpin (1986) had stated the most important function of small and medium-powered tractors is transport with the most widely used being between 30kw and 75kw maximum drawbar power range. Wheels of large diameter and width were also reported to favor a low-resistance because the wheels sinks as low as possible; tyres having 400mm and 500mm diameter indicated up to 10% difference in draught while towing force was reduced by as much as 50% an 27% respectively in poor and good conditions where 12.50-18.00 tyres were used instead of standard 7.50-16.00. Selection of tractors for this tank was also based on recommended trailer load of 6-10 tons for 55-75 Hp (41.25-56.25 Kw) tractors (New Holland, 2007).

The operation of the tank immediately after construction was monitored to ensure everything was put in the right perspective and smooth operation to prevent accident. In an attempt to prevent avoidable accident due to wrong handling and possible instability of the tractor and tank, operators/drivers were expected to handle the tanker were educated in the following salient factors.

3. Result and Discussion

The construction of the tank was timely and appropriate as it was effectively pulled by selected medium tractors available in the institute. The problem of water supply was adequately addressed as water was supplied to research plots, laboratories and staff quarters (Table 1). In the first 5 months of 2017 a total of 415,800 litres of water was supplied to support research work. Staffs were also supplied at lower cost compared to external vendors as they were charged based on running cost of the tanker. Conversely, research and other staffs were saved from stresses they would have gone through looking for water and were able to concentrate on their real assignments. The tanker was also helpful during emergency needs such as fire outbreak at research plots and for rejuvenation of affected crops. According to Table 2; the growth of mandate crops were positively affected during the dry season which is the stress period for most plants, especially crops at early stages of growth. The important growth parameters responded positively to addition of water through the tanker as number of leaves increased from 13 to 16, leaves area from 296.06 to 363.83cm^2, plant height from 22.28 to 38.13cm and stem diameter from 0.36 to 0.47cm between February and April which are known for serious scarcity of rain. The corresponding average increase in these parameters were 13 for number of leaves, 67.57cm^2 for leave area, 16.05cm for plant height and 0.11cm for stem diameter. Easy access of research plots which would have been almost impossible for a self-propelled tanker was achieved due to versality and manoeuverability of the tractor. There was an added advantage of lower initial cost of less than a million Naira compared to several millions of Naira of purchasing a similar self-propelled tanker. Utilizing the same tractor for pulling the tanker as well as for other farm works such as slashing fields and transporting produce which would have been impossible with a self-propelled tanker resulted in a wider spread of running cost which makes the project more economical and viable. Effectiveness and efficiency of handling water delivery through the introduction of this type of tanker had made the innovation to stay in the institute as a second similar tanker has been constructed.

Table 1: Sample of Water Distribution to Research Plots

Months	No of tanker load	Water quantity (Litres)
December 2016	10	42,000
January 2017	30	126,000
February 2017	21	88,200
March 2017	24	100,800
April 2017	15	63,000
May 2017	9	37,800
February 2020	8	33,600*
April 2021	18	75,600*

Source: Adeleke et al., (2017) * Field record

Table 2: Effects of water supply through the tanker on tea plant during dry season

			Growth Parameters		
Months	No of Leaves	Leave Area cm^2	No of Branches	Plant Height cm	Stem Diameter cm
February	13	296.06	2.5	22.08	0.36
March	15	334.38	3.25	30.75	0.41
April	26	363.83	4.00	38.13	0.47

Source: Adeleke et al., (2017)

4. Conclusion

The tanker was highly useful for on-farm water distribution and it has greatly supported research work in the institute. Particularly, supply of water to crops during the dry season resulted in crop growth as number of leaves increased averagely by 13, plant height by 16.05cm and leave area by 67.57cm^2. Tractor trailers which have been scrapped but are still in good condition for conversion to such water tankers through modification and refurbishing can be put this kind of economical use. This will reduce running cost of farm works and enhance environmental cleanliness.

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VALUE ENGINEERING-BASED FRAMEWORK FOR ASSESSING THE PERFORMANCE OF IRRIGATION SCHEME COMPONENTS

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Abstract

With the aim to meet the heightening food demand of the ever-increasing population, several irrigation schemes were established particularly in arid and semi-arid regions of the world. In Nigeria, huge investment has been made to develop irrigation infrastructures. However, many reported instances revealed that a larger proportion of these irrigation schemes perform far below expectations due to poor management and maintenance culture. Several performance evaluation criteria such as water allocation indicators (equity, adequacy, reliability, etc.), infrastructural, operational, institutional, and participatory are among the popularly known and widely used metrics for assessing irrigation scheme performance. However, an exploratory and robust approach that attracted little attention, especially in Nigeria is the value-based approach such as the value engineering method. To this end, a value engineering-based framework for assessing the performance of irrigation scheme components was developed and reported herein. The framework comprised the following phases; problem identification, system functionality analysis model, creation, evaluation and development of value alternative. Each phase is equipped with a separate framework in the form of a table and/or figure where information can be filled or analyzed. The framework is aiming to serve as a guide to future studies on the performance assessment of irrigation schemes as a whole or its components thereby, generating a set of new information on the state of functionality of the components under study. The information could inform relevant decision-makers, thereby attempting to deploy some corrective measures for sustainable irrigation scheme operation, profitable crop production as well as food security.

Keywords: Framework; Irrigation scheme; Performance assessment; Value engineering,

1.0 Introduction

The need to produce adequate food to feed the ever-increasing population of the world necessitates the establishment of irrigation schemes particularly in dryland areas of the world. In Nigeria, for example, huge capital investment has been made to develop irrigation infrastructures (irrigation schemes) in the last 5 decades (Shanono et al., 2020). These irrigation schemes were mainly positioned in the northern part of the country which is characterized by dryland. Such irrigation facilities were developed to achieve not only food security but also to stabilize the rural economy, social wellbeing and other developmental activities (Jibril *et al.,* 2017). Thus, irrigation schemes have undoubtedly contributed immensely to different developmental sectors of the economy (Raghava, *et al.,* 2011). There are, however, many reported instances that many irrigation schemes in Nigeria do not perform to their expectations (Gorantiwar and Smont, 2005). For instance, many irrigation schemes in the country have been reported to perform poorly due to poor management and maintenance culture. Such poor maintenance culture by both farmers and managers has drastically reduced the overall performance of the irrigation schemes (Belgin *et al.,* 2009; Shanono et al., 2021a).

Routine irrigation performance evaluation is one of the reliable approaches to assessing and monitoring the state of the irrigation scheme's functionality. Through the evaluation processes, existing and potential problems can be identified, thereby taking appropriate actions (Belgin *et al.,* 2009). For example, the water allocation performance of a given irrigation scheme can be determined by computing the ratio of the water delivered to the water released at various levels (irrigation efficiencies). Other indicators for assessing water allocation performance include resilience, vulnerability, adequacy, equity and reliability of supply (Shanono et al., 2012). These water allocation performance indicators depend not only on the water availability for supply but also on reliable water conveyance and control infrastructures, appropriate water allocation methods, competent operators and farmers' level of compliance (Burt and Styles, 1999). Apart from the water allocation performance evaluation criterion, infrastructural, operational, institutional and participatory are also among the popularly known and widely used methods for assessing irrigation scheme performance (Shanono et al., 2015). However, an exploratory and robust approach that attracted little attention, especially in Nigeria is the Value Engineering (VE) method (El-Nashar and Elyamany, 2017).

A value engineering (VE) method is problem identification and solving approach used to study and analyze the level of functionality of a given system, system components, projects, operations, or processes. The aim was to diagnose the system's problems and propose solutions as value alternatives that can improve the performance of the system in terms of efficiency, sustainability, reliability, quality, safety, and life cycle costs. For example, the system components of an irrigation scheme include a dam, main canal, distributary canals, field channels, drain channels, turnout gates, and night storage reservoirs among others. These sub-components are coupled together with human operations to achieve reliable and sustainable irrigation scheme operation. According to Atabay and Galipogullari, (2013) the VE is a technique directed toward analyzing the functions of a system or process to determine "best-value", or the best relationship between work and cost. The VE approach of system assessment was first introduced into the construction industry in the early 1960s. Conventionally, VE is a value-enhancing tool rather than just a method of cost-cutting (Chen *et al.,* 2013). For example, VE on projects can be used to gain cost reduction, time savings, and quality improvement among others. The VE is, therefore, an intensive interdisciplinary problem-solving method that focuses on improving the value of the functions that are required to accomplish specific goals of a system, product, service, or organization (El-Nashar and Elyamany, 2017).

Water shortage downstream of a canal is a problem commonly experienced in an irrigation scheme. A study was conducted in Egypt to study and suggest solutions to the problem of canal tail water shortage. Canal tail water shortage is a situation where inadequate water is supplied to the downstream farmers which severely harms the growth and yields of the crop. The value engineering method was applied to solve this problem, which resulted in the best value alternative that suggested the use of separate pipes to irrigate branch and distribution canals tail end as well as using PVC pipes for field canals (El-Nashar and Elyamany, 2017). Hence, the VE method entails the identification of the problems affecting a given system, analyzing the state of the functionality of the system, creating, generating, and evaluating value alternatives (solutions) for solving the identified problems, and developing a framework of value alternatives that when applied can enhance the performance of the system.

Evaluating the current state of an irrigation scheme's components such as the main canal, and night storage reservoirs can certainly serve as a valuable step toward understanding the causes and effects of the existing problems. Since its inception in 1982, the Watari Irrigation Project (WIP) situated in Kano has been declining in terms of water allocation efficiencies at various levels, infrastructural decay, poor maintenance culture, and stakeholder conflicts among others (Shanono et al, 2020; Shanono et al, 2021b). Several approaches to irrigation performance evaluation have been applied to WIP. This approach includes the water allocation method, soil and water quality, operational, and infrastructure (Shanono et al., 2014; Shanono et al., 2015; Nasidi et al, 2016). None of these studies attempted to apply the robust method of value engineering (VE) which is not commonly practised. An effort toward developing a VE-based framework that can serve as a guide to future studies on the performance assessment of irrigation schemes as a whole or its component is essential. Applying this framework to assess and evaluate the current conditions of an irrigation scheme component is expected to generate a new set of information on the state of functionality of the component under consideration. In addition, the anticipated new set of information could also inform relevant decision-makers, thereby attempting to deploy the proposed corrective measures for sustainable food production and national food security.

2.0 Development of Value Engineering Framework for Solving Irrigation Scheme Problems

Figure 1 shows the step-by-step procedure for the development of a value engineering framework for solving irrigation scheme problems.

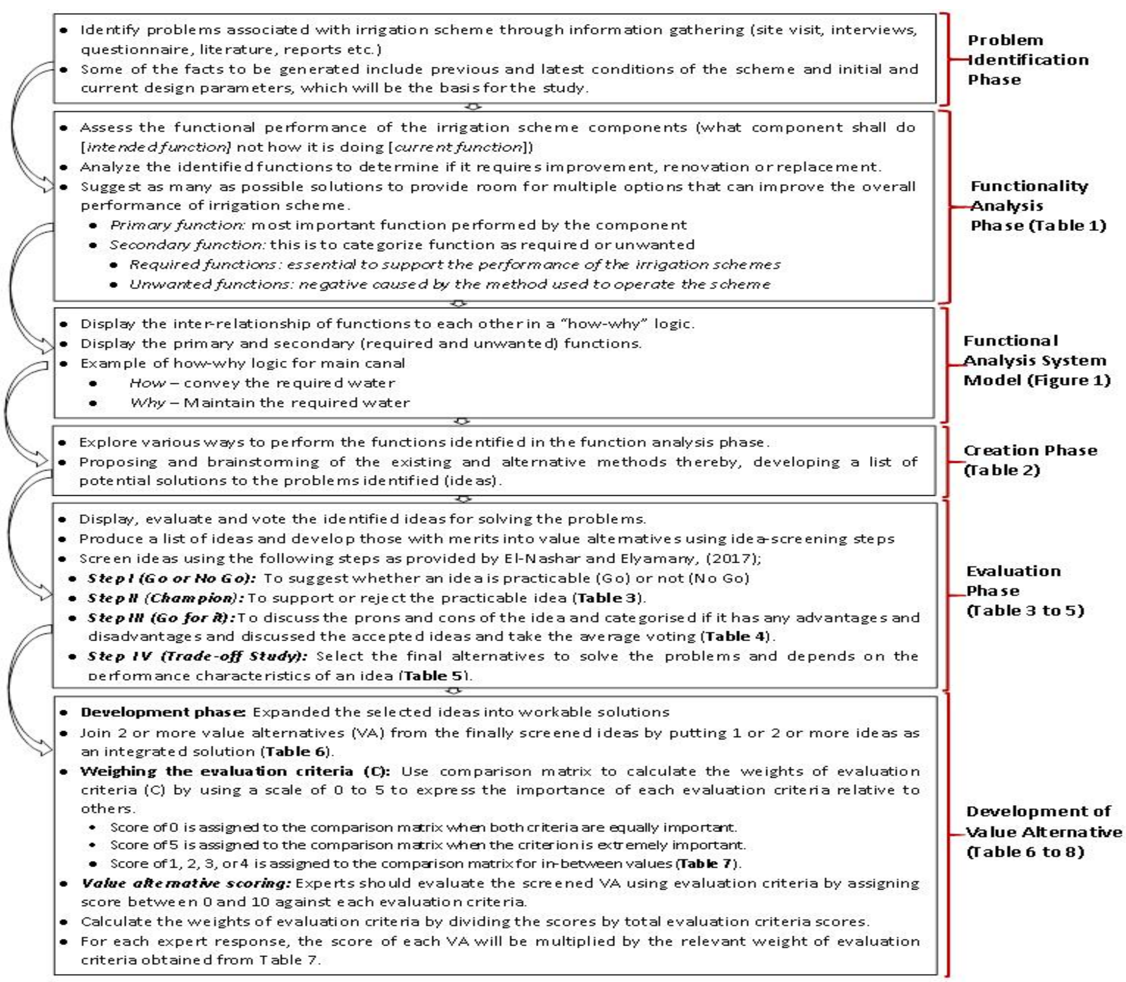

Figure 1: Framework for the development of value engineering solutions to irrigation scheme problems

3.0 Procedure for the Application of the Value Engineering Framework

3.1 Problems identification and functional analysis of the components

The functional analysis of the irrigation scheme subsystem and components under study can be conducted using the proposed framework shown in Table1 below.

Table 1: Framework for functional analysis classification of irrigation scheme components

Irrigation scheme subsection under study				
Components	**Functions**	**Primary Functions**	**Secondary Functions**	
			Required	**Unwanted**
Component I	1)			
	2)			
	"			
	n)			
Component II	1)			
	2)			
	"			
	n)			
Component III	1)			
	2)			
	"			
	n)			

3.2 Development of function analysis model

The function model for solving irrigation scheme problems can be developed using the Functional Analysis System Technique (FAST) diagram. This diagram represents a function displaying the inter-relationship of functions to each other in a "how-why" logic as proposed by El-Nashar and Elyamany, (2017). The logical question "how" is applied to each function starting from left to right and the logical question "why" is applied to validate the FAST diagram starting from the right and left as shown in Figure 1. For example, the higher-order function of the main canal in an irrigation scheme is "***conveying the required water to irrigate land - how***" while the causative function is "***maintaining the conveyance of the required water to irrigate land - why***". For instant, some of the components/elements for functional analysis of the main canal may include cross-section, siltation, weed infestation, cracks, carrying capacity, human activities, etc. Figure 1 presents the proposed framework for the Functional Analysis System Technique (FAST) diagram for the irrigation scheme.

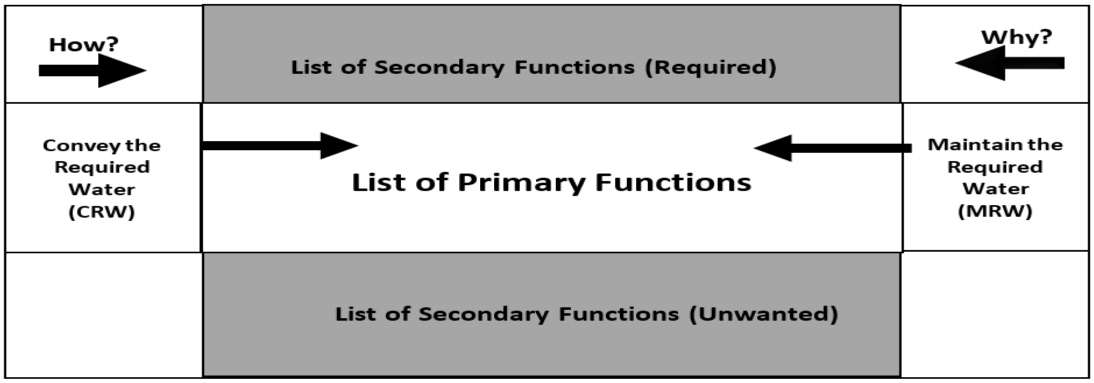

Figure 1: Framework for Functional Analysis System Technique (FAST) for an irrigation scheme.

3.3 Creation of value alternatives for solving irrigation scheme problems

Creation phase: the first session of brainstorming with WIP managers will be conducted to identify new ways to accomplish the MC and NSR operation. It involves exploring the various ways to perform the functions identified in the function analysis phase. It allows the proposing and brainstorming of the existing and alternative methods thereby, developing a list of potential solutions to the problems (ideas). After brainstorming with irrigation scheme managers and other stakeholders, the generated ideas can be coded and tabulated as shown in Table 2.

Table 2: Summary of generated ideas after brainstorming

Code	*Ideas*
I1	Idea 1
I2	Idea 2
"	"
"	"
"	"
In	Idea n

3.4 Evaluation of value alternatives for solving MC and NSR problems

After the brainstorming phase, the identified ideas for solving the problems should be evaluated using the screening steps as shown in Tables 3 to 5.

Table 3: First and second steps – a framework for Go or No Go and Champion evaluation criteria

Code	*Ideas*	*Go or No Go*	*Champion*
I1	Idea 1	Go	Yes
I2	Idea 2	No Go	
"	"	"	"
"	"	"	"
"	"	"	"
In	Idea n	Go	No

Table 4: Third step - Classification of ideas as advantage or disadvantage and voted for the acceptance of the idea

Code	*Ideas*	Advantages	Disadvantages	Average Vote
I1	Idea 1			
I2	Idea 2			
"	"			
"	"			
"	"			
In	Idea n			

Table 5: Fourth step - Trade-off analysis of the performance characteristics of an idea to select the final alternatives to solve the problem. (e.g. water saving, continuity of supply, and easy maintenance)

Code	*Ideas*	*Water saving*	*Continuity of supply*	*Easy maintenance*	*Voting*
I1	Idea 1				
I2	Idea 2				
"	"				
"	"				
"	"				
In	Idea n				

3.5 Development of value alternatives framework for solving irrigation scheme problems

In the development phase of the value alternative, selected ideas will be expanded into workable solutions. This is to form 2 or more value alternatives (VA) from the finally screened ideas by putting 1 or 2 or more ideas as an integrated solution for the 3irrigation scheme component under study as summarized in Table 6.

Table 6: Developed value alternatives for the irrigation scheme components under study3333

Component I	Component II	Component III
VA1 (e.g. ideas 1 and 6)	VA1 (e.g. ideas 2, 4, and 5)	VA1 (e.g. ideas 3 and n-2)
"	"	"
"	"	"
"	"	"
VAn (e.g. idea 4, n-1, and n)	VAn- (e.g. idea 3 n-2 and n)	VAn-NSR (e.g. idea n-13 and n)

3.5.1 Comparison matrix

A comparison matrix can be used to calculate the weights of evaluation criteria (C) by using a scale of 0 to 5 to express the importance of each evaluation criterion relative to others as explained in Figure 1. The comparison matrix is shown in Table 7. For example, if a score of 5 is assigned to C2 against C1, it indicated that C2 is extremely important compared to C1. If a score of 0 is assigned to Cn-1 against C2 it indicated that both Cn-1 and C2 are equally important. If a score of 3 is assigned to the Cn against Cn-1, it indicated that evaluation criterion Cn is more important than Cn-1 by a score of 3 out of 5 as sown in Table 7.

Table 7: Comparison matrix for weighing the evaluation criteria (C)

	C1	**C2**	**“**	**“**	**“**	**Cn-1**	**Cn**
C1		e.g. C2 / 5					
C2						Cn-1 / 0	
“							
“							
“							
Cn-1							Cn / 4
Cn							

3.5.2 Value alternative scoring

A questionnaire can be developed to evaluate the screened VA using evaluation criteria. A score between 0 and 10 will be assigned against each evaluation criterion. These scores will be assigned by experts having great experience. Weights of evaluation criteria will be calculated by dividing evaluation criteria scores by total evaluation criteria scores. For each expert response, the score of each VA will be multiplied by the relevant weight of evaluation criteria obtained from table 7 and the total score will be calculated for each VA to arrive at a VA with the highest score as proposed by El-Nashar and Elyamany, (2017) and shown in Table 8.

Table 8: Weight of evaluation criteria and scores of value alternative developed in Table 6.

Evaluation criteria	*Weight*	*VA1*	*VA2*	*VAn*
C1	Weight 1			
C2	Weight 2			
“	“			
“	“			
Cn	Weight *n*			

4.0 Conclusion

A value engineering-based framework for assessing the performance of irrigation scheme components was developed. The framework comprised the problem identification phase, system functionality analysis phase, creation phase, evaluation phase and development of value alternative phase. Each phase is equipped with framework work in the form of a table where information can be filled or analyzed. The framework is aimed to serve as a guide to future studies on the performance assessment of irrigation schemes as a whole or its components thereby, generating a set of new information on the state of functionality of the component under study. The information could inform relevant decision-makers, thereby attempting to deploy some corrective measures for sustainable irrigation scheme operation, food production, and food security.

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MOISTURE DISTRIBUTION INFLUENCE ON GROWTH AND YIELD DEVELOPMENT OF CASSAVA UNDER DIFFERENT FERTILIZER TYPES AND FERTIGATION SYSTEMS

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Abstract

This study assessed moisture content (MC) influence on the growth and yield of cassava under four different treatment methods. Two cassava varieties, TMS 0581 and TME 419 were used as research crop while the four treatment methods included; fertigation (TRT A), NPK 15:15:15 fertilizer (TRT B), Farmyard manure (TRT C) and control (TRT D) with three replicates each. A Hi 5000 mini fertigator (Hanna series) was used in TRT A which combined excellently liquid fertilizer with irrigation water and administered it in pre-determined rates. Agronomic measurement such as number of leaves, Plant height, stem girth, number of branch and leaf area were taken and soil properties such as the bulk density, particle density, and pH were measured. Soil moisture content at depths 10, 20, 30, 40 and 50 cm were also measured in all the four treatments using standard methods. From the result, agronomic responses were highest in TRT A (fertigation) and was lowest in TRT D (control). Similarly, all the soil properties determined were within the minimum permissible limits as specified by the Food and Agricultural Organization (FAO) values. Using United State Department of Agricultural (USDA) textural triangle, soil in the first two treatments, TRT A and TRT B were clay loamy (38% silt, 31.76% clay, 30.24% sand and 40.21% silt, 27.27% clay, 32.52% sand respectively) while the last two treatment, TRT C and TRT D had a predominantly loamy soil (41.47% silt, 25.36% clay, 33.18% sand and 41.22% silt, 26.43% clay, 32.35% sand respectively). From the soil moisture analysis performed, the same MC pattern was observed in all the treatments with values ranging from 3% through 15% which indicated a considerable effect on the growth and yield parameters of the two varieties of the cassava considered for the study. Most impressive agronomic responses obtained in TRT A as compared with other treatments suggested that parameters other than MC was responsible for the behavior.

Keywords: Moisture content; Soil; fertigation; fertilizer; Cassava; Yield

1.0 Introduction

Cassava (*Manihot esculenta Crentz),* a major staple food crop of the people in most parts of Africa, plays an important role in terms of food security, employment and income generation for farm families in parts of the humid tropics. Apart from its use as food, it is also an important industrial raw material for the production of starch, alcohol, pharmaceuticals, gums, confectioneries and livestock feed (Anthony and Mynie 2005). It is an important dietary staple in many countries within the tropical regions of the world (Perez and El-Sharkawy, 1993), where it provides food for more than 800 million people (FAO, 2007). As a subsistence crop, cassava is the third most important carbohydrate food source in the tropics after rice and maize, providing more than 60% of the daily calorific needs of the populations in tropical Africa and Central America (Ojulong *et al.,* 2005). Presently, cassava has attained the status of an industrial crop in Nigeria because it is now being grown on large scale, repeatedly season after season on the same piece of land. Different cassava varieties exist such as TMS 50395, TMS 30572, TMS 98/0581, 99/0505, 98/0510, 92/0326, M98/0040, 95/0166, 95/0289 98/0002, 95/0166, 30572 and TME 419 and are distinguished primarily by their morphological characteristics resulting in yield and growth performances. Under this condition, the fertility of the soil and yields declined overtime (Nguyen, *et al.*, 2001). Decline in soil fertility is especially serious in tropical regions where the soil lacks adequate plant nutrients and organic matter due to leaching and erosion of top soil by intense rainfall (Ayoola and Makinde, 2007). Cassava extracts substantial amounts of nutrients with the harvested roots, the highest being K, followed by N, Ca, Mg and P; and if not adequately fertilized, will exhaust soil nutrients under continuous cropping (Pellet and El-Sharkawy, 1993; Eze and Ugwuoke 2010). Thus, sustainable continuous production of cassava on the same piece of land would require the application of supplementary nutrients via fertilization.

Fertilizer is an important input that contributes to crop production it increases the productivity of the soil for plant growth and improves the quantity and quality of produce. Fertilizer can either be organic or inorganic. Before the introduction of inorganic fertilizer, organic fertilizers, particularly animal manure, crop residues, green manure and composts, were practically the only source of nutrient for crop production. Apart from the economic cost, the use of chemical fertilizers under continuous cultivation in the tropics is not adequate to sustain crop yield (Ayoola and Makinde 2007).

Variation in soil texture, topography, crop cover and irrigation practices result in large spatial and temporal variability of crop yields (Akinbile *et al*., 2016). Determination of soil moisture is one of the most difficult measurements required in the field of hydrology (Cresswell and Hamilton, 2002) because of the frequency in soil moisture changes in a single sampling point. Soil moisture content is one of factors determining optimal plant growth and crop production and plays important role in environment research which underscored the necessity for its frequent measurement. Soil moisture distribution refers to moisture spread from the emitter of a drip irrigation system. It involves the moisture content of wetted area around drip emitter at various depth which is affected by the pressure of water application. In plastic mulched condition soil moisture under line source of irrigation, increases along the vertical direction while in open field condition, soil moisture increased along vertical and decreases in horizontal direction from emitter point.

Drip irrigation is based on the principle that the most efficient use of available water resources and optimum plant performance may be realized through the prevention of moisture stress by maintaining favorable soil moisture conditions around only a portion of the root system. This is because, drip irrigation can distribute water uniformly, precisely control the water amount, and decrease the danger of soil degradation and salinity. Water, when applied under low pressure and at low volume for a sufficient period of time, often maintain a portion of the soil at or near field capacity. A daily application of water may be necessary to replace moisture lost by soil evaporation and plant transpiration (Cassell and Klute 1986). When applied through emitter, the water spreads in all direction, i.e., above the soil surface, its entry into the soil and its movement within the soil. A comprehensive understanding of the mechanism of soil water distribution and movement in root zone is essential for the design and management of drip irrigation system and irrigation strategies Australia. Diaz-Zorita et al., (2002).

The objective of this research therefore, is to determine the soil moisture distribution under drip irrigation, different fertilizer application and how it affects the growth of cassava. Specifically, to design a drip fertigation system and determine the yield and growth of cassava under the designed fertigation system.

2.0. Materials and Methods

2.1 Land preparation

The experiment was carried out at Agricultural and Environmental Engineering Research Farm situated at the Federal University of Technology, Akure (FUTA), Ondo State. Akure, Nigeria. Located between latitude 9° 17'N and Longitude 5° 18'E and characterized by a tropical humid climate with two distinct seasons, a relative dry season from November to March and a wet/rainy season from April to October. The average annual rainfall ranged between 1,405 mm and 2,400 mm of which the rainy season accounts for 90% while the month of April marks the beginning of rainfall (Akinbile, 2006).

Land preparation activities involving ploughing, harrowing, clearing and marking out for planting were carried out using conventional procedures and equipment while pre-wetting was done preparatory to planting of cassava stems.

2.2 Experimental Design

A total plot size of 20 by 14 m² using randomize block design of four treatment and three replicates each unit size is 4 by 4 m² in area with 1m alley way, making a total number of 12 plots was designed and used of the study. Four different Fertilizer application and methods were adopted for the study.

i. Treatment A has a mixture of soluble fertilizer and irrigation water supplied through Hi5000 mini fertigator. (Hanna Instrument).
ii. Treatment B has farmyard manure. (Poultry droppings).
iii. Treatment C has NPK fertilizer (15-15-15 inorganic fertilizer).
iv. Treatment D is the control.

Two 2 by 2 m² platform of height 2.0 m were erected at about 1m away from the plots. These platforms supported 1000 litre water storage tank used for irrigating the plots. Hi5000 mini fertigator (Hanna instrument) was installed between one of the water storage tanks and treatment A to efficiently optimize irrigation and fertilizer application simultaneously to treatment A and the replicates. Soil sample at depth 0 – 50 cm were obtained from each of the treatment plot and taken to FUTA central laboratory for moisture content analysis using the method adopted by Dane and Topp (2002). The source of water supply was obtained by pumping water from the borehole located at 7.5m north of the experimental plots.

2.3. Measurements and instrumentation

A core sampler was used in soil sampling following the APHA (2005) procedure in storage and transportation to the laboratory for further analysis. A newly-calibrated digital moisture meter was used in measuring the soil's moisture content at depths 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm and 40-50 cm. The measurements were compared with the ones carried out using gravimetric method for reliability of results using equation (1);

$$\% \text{ moisture} = \frac{Loss\ in\ weight}{weight\ of\ soil\ after\ drying} \times 100 \quad (1)$$

Bulk density was determined using the method described by Blake and Hartge (1986)

Bulk Density (P_b) = $\frac{\text{weight of oven dried soil}}{volume\ of\ core(cm3)}$ (2)

Volume of core (cm³) = $\frac{¶r2h}{4}$ (3)

Where d is the internal diameter of the core and h is the height in centimeter

Agronomic parameters such as number of leaves, plant height, stem girth and leaf area were measured weekly using conventional means from 3weeks after planting (WAP) up to 13 WAP. Two variety of cassava varieties TMS 0581 and TME 419 were planted for the experiment. The plant height was measured by a steel rule, stem girth was measured using the vernier caliper, leaf area was measured using canopy analyzer while number of leaves were counted manually per stem.

2.4 Statistical Analysis

The results obtained were subjected to data analysis tools such as Analysis of Variance (ANOVA) version 16, Duncan Multiple Regression Test (DMRT), Linear Regression Analysis and Least Square Distribution at 95% significance level.

3.0 Results and Discussions

3.1 Results of soil physical and chemical properties and particle size distribution

The results of soil's physical and chemical properties analyzed before planting is as presented in Table 1. Using the USDA textural triangle, the soil in the study area was found out to be is clay loam and allows a gradual downward movement of water to the lower layer of soil which is good to both the deep-rooted and shallow rooted crops. The clay loam texture with good aeration favours crop growth under drip or sprinkler irrigation system while the combined physical and chemical characteristics (as presented in Table 1) show that the soil is good for cassava cultivation which agreed with the findings of Akinbile *et al*., (2019).

A more detailed analysis of the soil's particle size in each of the plots (Table 2) revealed that the soil in the first two treatments, TRT A and TRT B were clay loamy (38% silt, 31.76% clay, 30.24% sand and 40.21% silt, 27.27% clay, 32.52% sand respectively) while the last two treatment, TRT C and TRT D had a predominantly loamy soil (41.47% silt, 25.36% clay, 33.18% sand and 41.22% silt, 26.43% clay, 32.35% sand respectively).

3.2 Digital Soil Moisture Meter Calibration

As earlier reported, the digital moisture meter recordings were calibrated with the figures obtained from the gravimetric method used in determining soil's moisture content across all the depths ranging from 0 to 50 cm at the study site. High correlation was recorded between the two sets of values having an R^2 value of 97 % (Figure 1). The quadratic linear equation also attested to its co-variability which is as expressed in equation 4;

$$Y = 0.3449X – 1.7132 \quad (4)$$

And correlation of, $R^2 = 0.9693$

Table 1: Physical and Chemical Characteristics of soil at the Experimental Site

Parameters	NPK	Control	FYM	Fertigation	FAO
bulk density(g/cm^3)	1.39	1.36	1.41	1.44	1.4-1.7
particle density g/cm^3	2.55	2.52	2.57	2.55	2.65
soil pH	5.9	6.34	6.12	5.65	
Nitrogen (%)	0.75	0.58	0.68	0.78	5.1-6.5
Organic carbon (%)	4.21	4.6	4.52	4.64	0.2
EA (%)	4.16	4.1	3.43	3.49	2.0
P (cmol/kg)	4.37	4.34	4.47	4.48	4.1
K (cmol/kg)	0.521	0.21	0.291	0.427	20.0
Mn (cmol/kg)	0.0158	0.6152	0.015	0.013	0.6-1.2
Zn (mg/kg)	10.8	11.35	13.4	11.65	200-2000
Ca (cmol/kg)	2.125	2.145	2.236	2.316	2.0-5.0
Mg (cmol/kg)	0.305	0.31	0.311	0.321	10-20.0
Na (cmol/kg)	1.192	0.972	1.135	1.059	3-8.0
Organic matter	7.258	7.93	8.292	8	2.0++

Table 2: Particle size distribution of soil sampled at the study site

Parameters	NPK plot (A)	Control plot (B)	FYM plot (C)	Fertigation plot (D)
Sand (%)	30.24	32.52	32.35	33.18
Silt (%)	38	40.21	41.22	41.47
Clay (%)	31.76	27.27	26.43	25.36
Class	**Clay loam**	**Clay loam**	**loam**	**Loam**

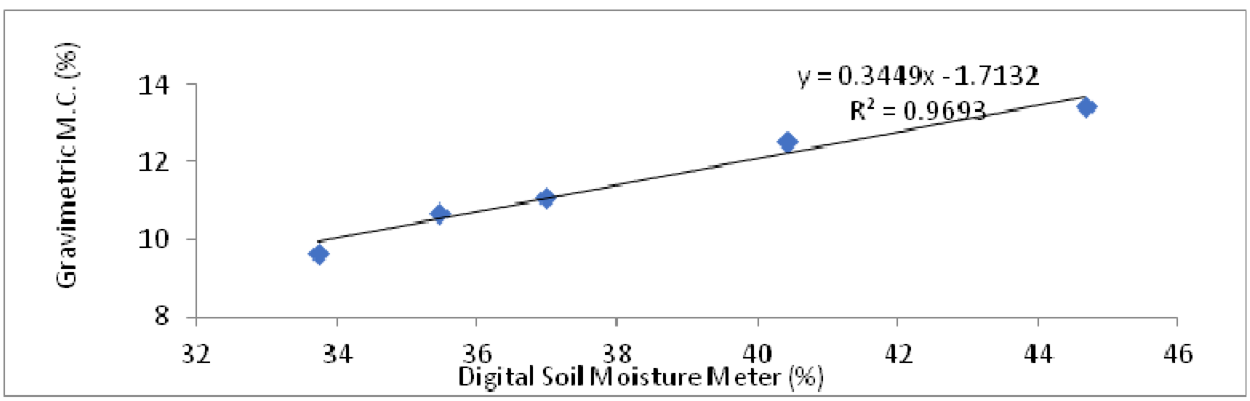
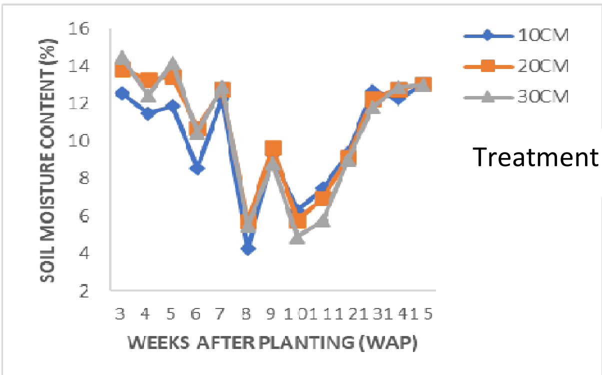


Fig 1: Calibration result for the digital moisture meter viz gravimetric method for moisture content determination

3.3 Moisture content variation during crop growth

Figures 2a through 2d show the effect of moisture content in all the four treatments across the entire growing season which clearly underscored the underlying importance of moisture to crop development and growth. Higher moisture content was recorded at the vegetative and maturity stages of the entire treatments which inferred higher metabolism and beginning of photosynthesis. This is consistent with the results from similar studies conducted by Anthony and Mynie (2005).



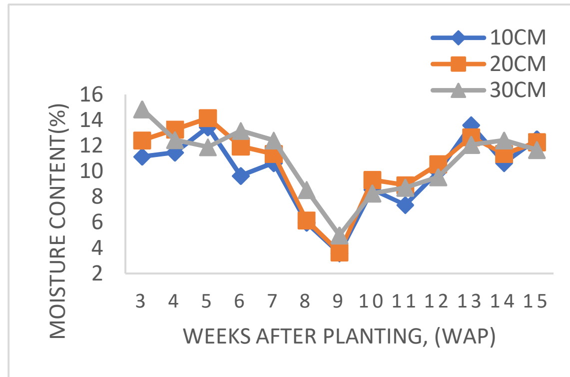
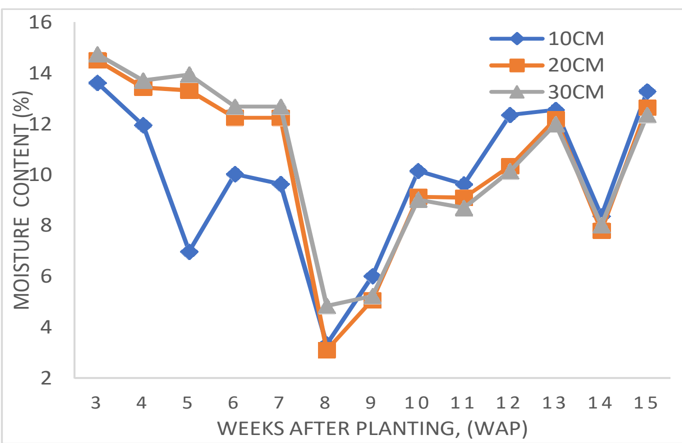


Fig 2 Soil MC versus weeks after planting

(WAP)



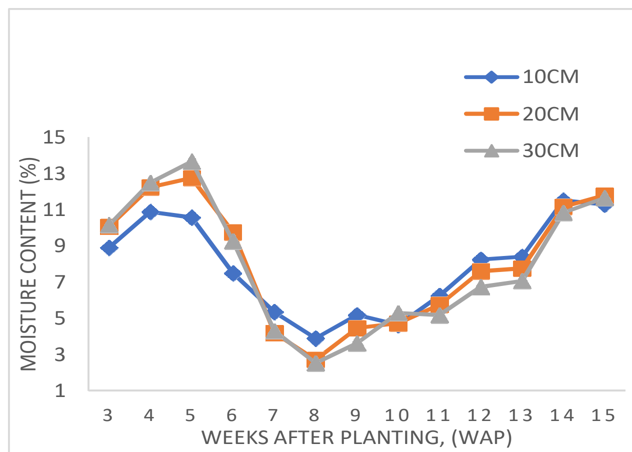


Fig 2c: Soil MC versus weeks after planting (WAP) in treatment C **Fig 2d:** Soil MC versus weeks after planting (WAP) in treatment D

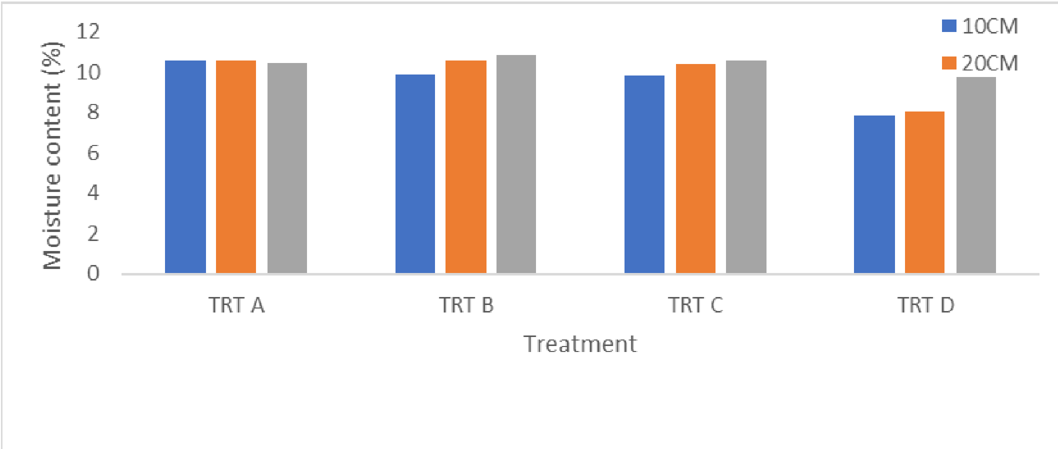


Fig 3: Average Moisture contents at different depths in each treatment

3.4. Agronomic responses with respect to number of leaves, plant height, stem girth and leaf area

Leaves number variation in the cassava plant (TMS 0581 and TME 419) 3 WAP through 13 WAP is as shown in figures 4a and 4b respectively. Highest leaves number were found in treatment A (TME 419) and lowest in treatment D (TMS 0851). At the first 3 WAP, there was a little variation in number of leaves on the cassava plant irrespective of the variety for the four treatments. Results are in agreement with the finding of Akinbile *et al.,* (2019) who reported that combination of manure and inorganic fertilizers, or of inorganic fertilizers alone, generally resulted in yields than the application of only organic manures.

For the plant height, and between 3 WAP and 13 WAP, the trend for all the four treatments is as shown in figures 5a and 5b. TME 0581 varitety in treatment A had highest height of 142cm.

Stem girth results for each treatment measured using a vernier caliper and plotted against WAP is as presneted in figure 6. Highest value of the stem girth was in treatment B, TMS 0581.

The result of leaf area obtained is as shown in figure 7. TMS 0581 had the highest leaf area (702.8 cm^2) in treatment A while treatment D records the lowest (214.9 cm2). Treatment D, due to insufficient amount of nitrogen in the soil and other chemical properties had lower leaf area. This result agreed with the findings of Odedina (2012) who investigated the effect of 3 levels of nitrogen; 0, 50 or 100 kg fed^{-1} with 40 kg P_2O_2 and 75 kg K_2O $fed.^{-1}$ (in clay loam soil), and cleared that leaf area of cassava plant increases with increasing N levels up to 100 kg + 40 kg P_2O_2 and 75 kg K_2O fed^{-1} compared with 0 kg N + 40 kg P_2O_2 and 75 kg K_2O fed $^{-1}$ Pellet and El-Sharkawy (1993) studied the effect of 4 fertilizer treatments; 3 doses of P fertilizer at 0, 50 or 100 kg ha^{-1} with 100 kg from each of N and K fertilizers per hectare in clay soil, plus a control without fertilizer. They found that cassava leaf area (LA) usually increased with soil fertility.

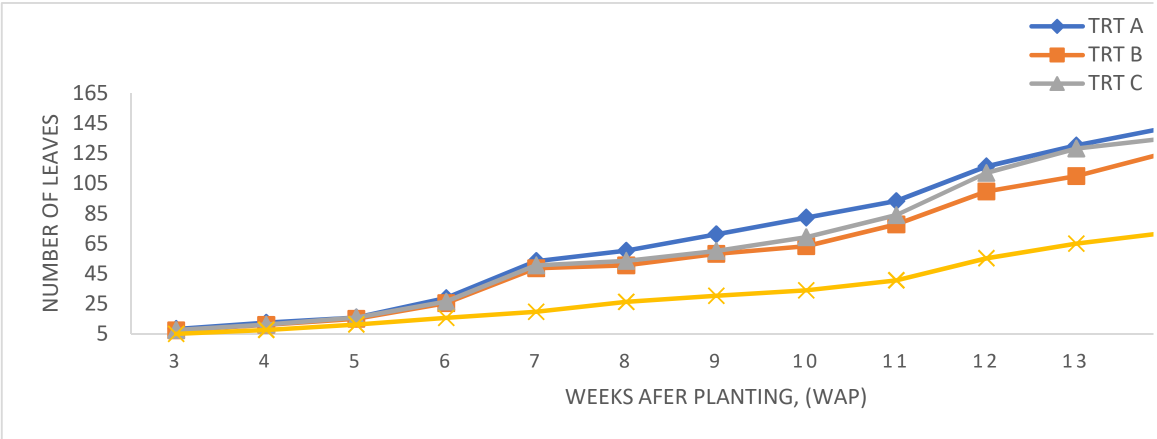


Fig 4a: Number of leaves on Plant versus Weeks after planting for Treatments A, B, C and D (TMS 0581)

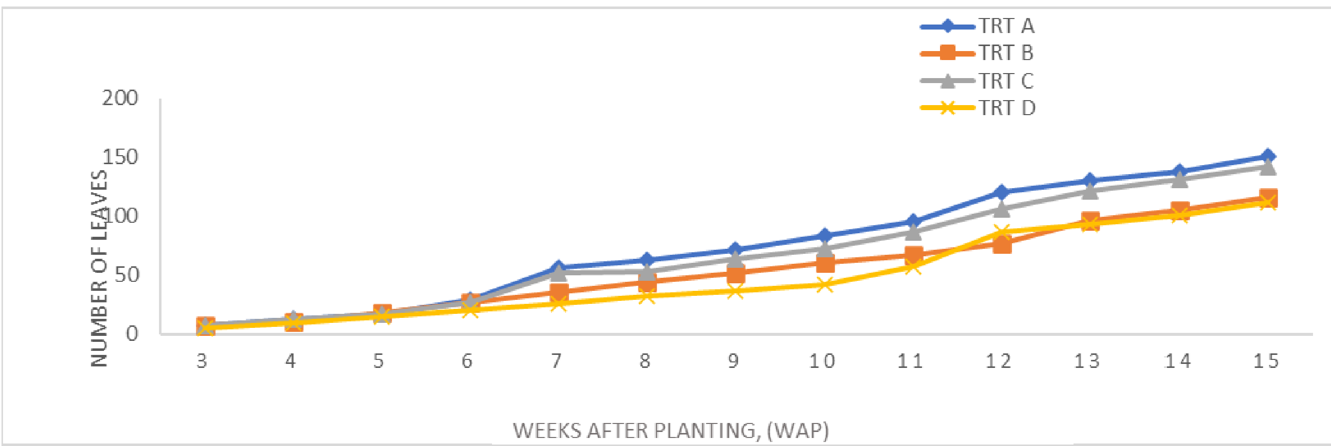


Fig 4b: Number of leaves on versus Weeks after planting for Treatments A, B, C and D (TME 419)

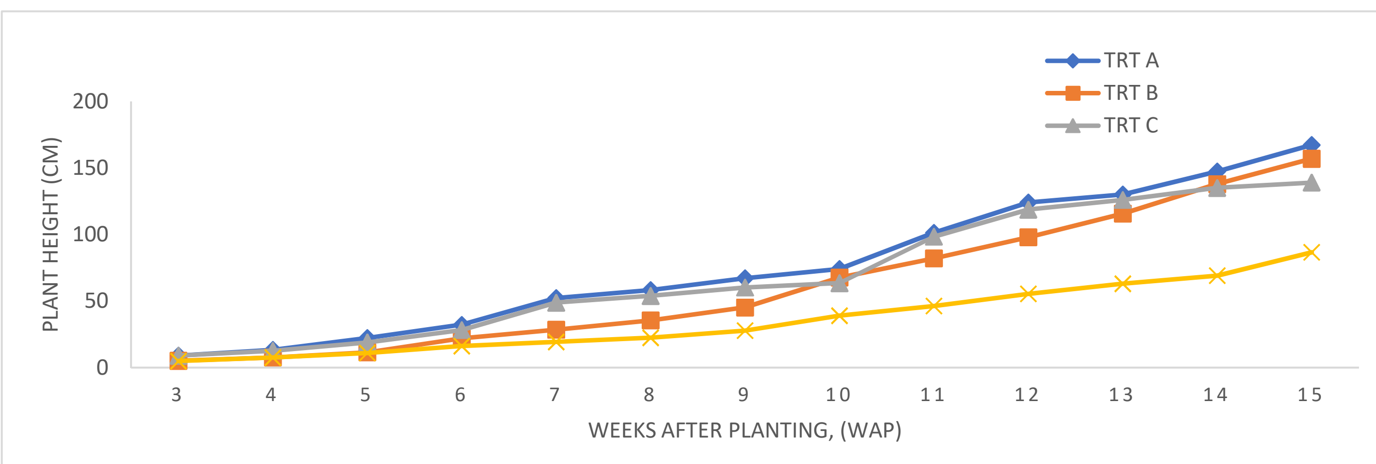


Fig 5b: Plant height versus WAP for TME 419

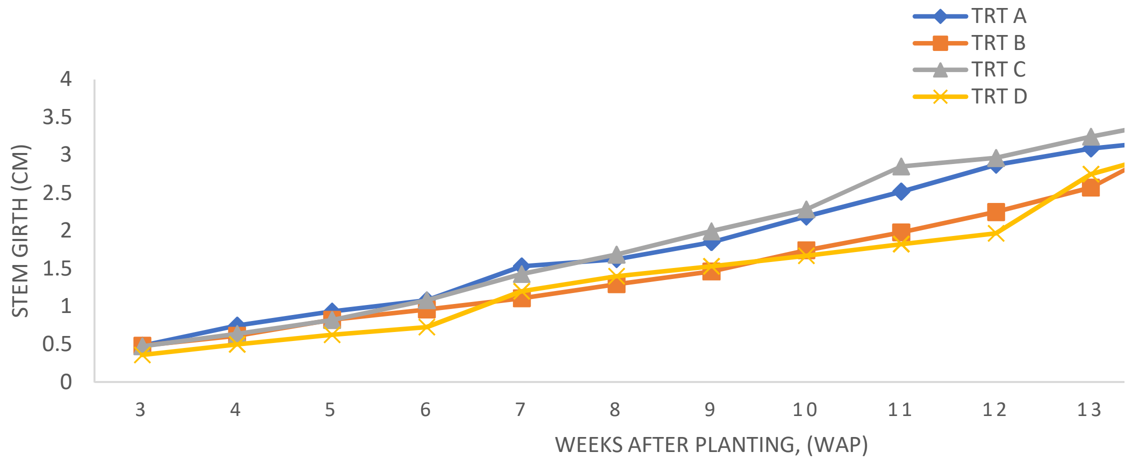


Fig 6a: Stem Girth versus WAP (TMS 0581)

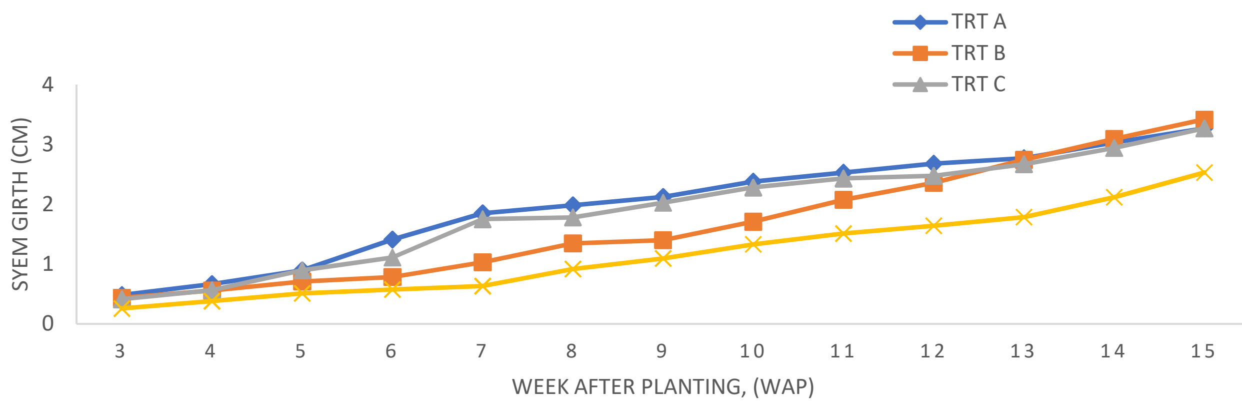


Fig 6b: Stem Girth versus WAP (TMS 419)

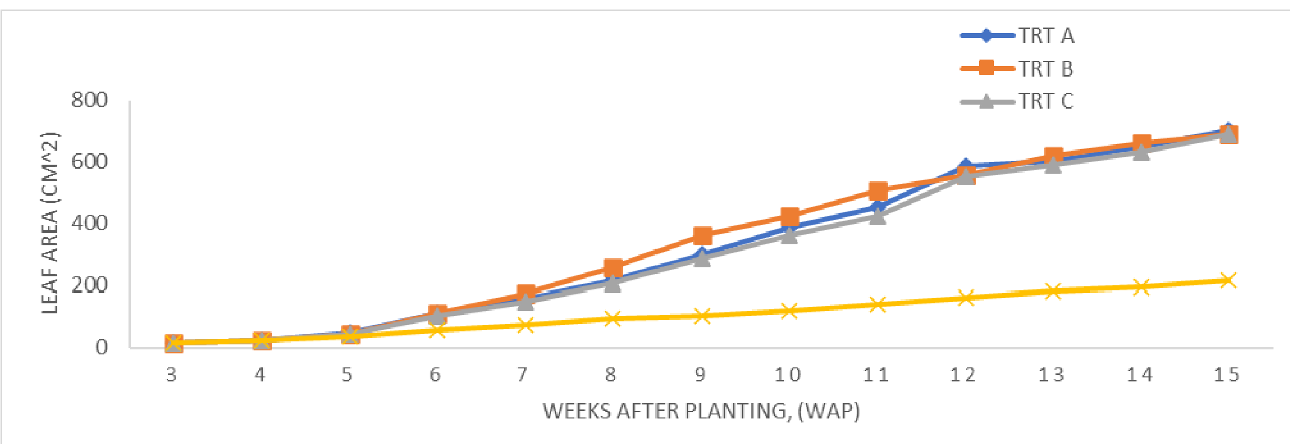


Fig 7a: Leaf Area versus WAP (TMS 0581)

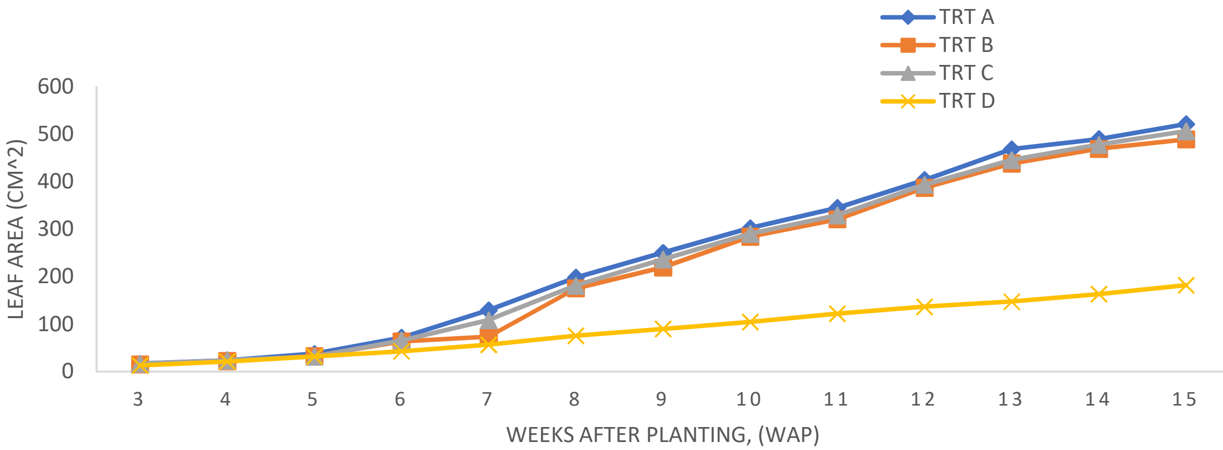


Fig 7b: Leaf Area versus WAP (TME 419)

4.0 Conclusions

Soil moisture has a significant effect on the growth and yield development of cassava, the soil variation notwithstanding. The low soil moisture content resulted in the poor growth of cassava in treatment D while high moisture content in the other treatments (A, B and C) in addition to the fertilizer application could be responsible for relatively higher agronomic development. Increase in soil's moisture content resulted in decreased bulk density and increased soil aggregation, which considerably improved the structure and water infiltration. A clayey loamy soil was discovered at the experimental site using USDA textural triangle which enabled roots greater access to the supply of moisture. Cassava's behavioural pattern in water uptake varied with the phenological stages with the highest amount of soil water extraction took place at the tuberization stage in all the treatments. Treatment A, that used fertigator in administering both fertilizer and irrigation water performed better, followed by treatment C that has fertilizer NPK (15:15:15) from the regression analysis. TMS 0581 variety performed better in plant height, stem girth and leaf area while TME 419 did well in terms of number of leaves and number of branches. A repetition of this study on other soil types and in other agro-ecological zones with different weather and climatic variability pattern is encouraged to ascertain agronomic and yield development under different scenarios.

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EVALUATION OF WATER QUALITY STANDARD AND SANITARY CONDITION IN HARMONY ABATTOIR IN LORIN

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Abstract

This work examined the sanitary conditions and water quality standards in Harmony abattoir in Ilorin West Local Government area of Kwara State, Nigeria. Samples were collected from the hand-dug well and bore hole. The samples were analysed for physico-chemical and biological parameters. The results showed that parameter like temperature (36.4^{0}C) was having value outside the WHO limits as a result of microbiological activities since the samples contain high level of BOD. Higher value of iron, 3.99mgL^{-1} is suspected to come from blood washed into the water and leachates to underground water. There is also higher concentration of manganese, 3.73mgL^{-1} but this was traced to the properties of aquifer on which the abattoir is located. From the bacteria assessment, the samples were polluted with pathogenic organisms of faecal origin.

Keywords: Physio-chemical, Sanitary, Concentration, Abattoir

1.0 Introduction

Most abattoirs aim at optimising the recovery of edible portions from the meat processing for human consumption but significant quantities of secondary wastes materials not suitable for human consumption are however generated.(Chukwu, 2008). Since water is often used to wash excessive waste solids to drain. The method used in handling, treatment and disposal of abattoir waste should be put into consideration, as waste dumped in the open environment; storm drainage, channels, creeks lagoons and other impoundment points could cause serious environmental pollutions and hazards which in most cases adversely affects the air, water and probably the soil conditions and it also constitutes public nuisance (Akinro et al., 2009). Though slaughtering of animals results in meat supply and useful by-products like leather and skin, livestock waste spills can introduce enteric pathogens and excess nutrients into surface water and can also contaminates groundwater (Li, 2009) Abattoir operations produce a characteristics highly organic waste with relatively high level of suspended solid, liquid and fat. The solid waste includes condemned meat, undigested food, bones, horns, hairs and aborted foetus. The liquid wastes usually comprise of dissolved solid, blood, gut contents, urine and wash water (Bello and Oyedimi, 2009). Water is regarded as polluted when it is unfit for its intended use. The self-purification process of groundwater is a function of the depth of the soil and the concentration of the pollutant in the percolating water (Mbuligwe, and Kaseva, 2005). Potable water is defined as the one that does not contain

chemical substances or micro-organisms in amounts that could cause hazards to health. Bacteriological examination of water is therefore a powerful tool in order to foreclose the presence of microorganisms that might constitute health hazards (Singh, and Neelam, 2011). Micro-organisms that are commonly used as indicators of water quality include: coliforms, Faecal streptococci, Clostridium perfringes and Pseudomonas aeruginosa. The physico-chemical and microbiological analysis of surface and groundwater are important towards a meaningful impact assessment of domestic and industrial activities on these water bodies (Nwanta, et al., 2010). Abattoirs are frequently located near urban centres and enormous amount of waste are produced in relatively small areas, In most abattoirs in Nigeria the waste from abattoir operations is a source of embarrassment as conventional methods for disposal of animal wastes, carcasses and manure as well as slaughter house and other animal industry wastes are now proving inadequate in Nigeria (Mkupasi, et al., 2009). Most abattoir wastes dumped in watercourses contain high levels of organic matter, which encourages rapid proliferation of oxygen consuming micro-organism to deplete the water of its dissolved oxygen leading to unacceptable odour condition and also lethal for aquatic life (Amuda, and Alade, 2006). Abattoir waste contamination can also increase the level of nitrates in the ground water which causes methaemoglobinemia or "blue baby syndrome" (De Roos, 2003). The general objectives of this wok are to evaluate the quality of water, both surface and underground water in harmony abattoirs which are being used by butchers in dressing carcasses.

2.0 Materials and Methods

2.1 Study Area

The proposed research was carried out in Ilorin metropolis at Abubakar Bukola Saraki modern Abattoir. Ilorin is situated on longitude $4^0$32′60′′ East and latitude $8^0$30′00′′ North with an altitude of 310m above sea level. The annual rainfall varies from 1000mm-1500mm and the temperature range 30^0C-35^0C. It is a transitional zone between the climate of southern Nigeria and semi-arid Sudan savannah of northern part of Nigeria. (www.worldatlas.com)

2.2 Materials and Experimental Methods

2.2.1 Sample Collection

A plastic container of about 1.0 litre in capacity was used in taking the sample. The containers were properly washed, cleaned and sterilized using sulphuric acid and then rinsed with distilled water. At sample points, the containers were rinsed with the water from which sampling will be collected from before they were later filled with the same water from the same source. The container was clearly labelled and filled with sample to the top. Water samples were taken from the well in the abattoir at 5, 10 and 15 meters. The samples were labelled as W_5, W_{10}, and W_{15} respectively. Also, samples were taken from rain water stored in reservoir in the study site and labelled as R and another sample was taken from bore hole located inside the abattoir and labelled as B. The samples were taken for physico-chemical and bacteriological analysis at a standard laboratory in National centre for Agricultural Mechanization, Ilorin, Nigeria. Organoleptic properties such as appearance, odour and taste were also assessed.

2.3 Bacteriological Assessment

The method of Miles and Misra described by Collins and Lynes, (1976) was adopted to obtain the microbial counts. The media used were nutrient agar for bacterial count; macconkey agar for coliform count and Menterococcus agar for faecal streptococcus count. They were sterilized in an autoclave at 121^{0}C for 15 minutes [APHA, 1995]. Samples were cultured on the prepared medium in duplicate and incubated aerobically at 37^{0}C for 48 hours and the colonies formed were counted using colony counter and expressed as colony-forming units per milliliter (cfu/ml) of the sample. Various biochemical tests were carried out on the isolates for bacterial characterization. One-millimeter broth culture of each isolate was used for each test. Some photographic shots showing butchers' activities and sanitation problems were taken on the slaughter slabs and around the abattoir

Fig 1: Dressing of carcass by butchers.

2.0 Results and Discussion

The physico-chemical analysis results are presented in table 1 and the results of bacteriological examination of the water samples are presented in table 2.

Table 1: Physico-chemical Values of the Water Samples

Physio-chemical Parameters	W_5	W_{10}	W_{15}	B	R	WHO (2006)
P^H	5.57	5.50	6.45	8.40	6.20	6.5-8.5
Temperature ^{o}C	26.4	28.8	23.2	27.60	24.8	-
Sodium (mg L^{-1})	42.5	30.9	45.1	30.52	25.6	20-150
Calcium (mg L^{-1})	136.0	138.0	143.4	220.9	180.0	75-200
Potassium (mg L^{-1})	64.33	42.4	48.0	32.88	1.8	0-2
Zinc (mg L^{-1})	0.62	0.44	0.47	16.57	13.2	5-15
Iron (mg L^{-1})	3.27	2.72	2.85	2.52	0.08	0.10-1.00
Copper (mg L^{-1})	0.34	0.25	0.29	0.42	0.07	0.05-0.50
Manganese (mg L^{-1})	0.24	0.16	0.21	3.53	0.04	0.05-0.50

Total Solid (mg L^{-1})	430.0	422.0	426.0	305.0	207.0	500-1500
Total Chloride ((mg L^{-1})	99.3	81.5	86.7	112.5	118.0	200-250
Total Hardness (mg L^{-1})	175.0	167.5	173.2	165.0	120.8	100-500

Table2: Results of Bacteriological Assessment of the Water Samples

Bacteriological Parameters	W_5	W_{10}	W_{15}	B	R
Feacal Coliform (cfu.mL^{-1})	12.5	8.0	10.6	Nil	Nil
Streptococcus feacalis (cfu.mL^{-1})	11.6	7.62	9.4	Nil	Nil
Echerichia coli (cfu.mL^{-1})	13.6	8.45	10.4	Nil	Nil
Total Plate Count (cfu.mL^{-}	1.66	0.75	1.22	0.81	0.45
Biochemical Oxygen Demand (mg. L^{-1})	23.0	18.4	21.5	1.5	0.02
Dissolved Oxygen (mg. L^{-1})	3.2	2.6	2.8	2.5	0.08

It can be deduced from organoleptic examination that the water samples from the hand dug well and bore holes were clear, odourless and tasteless. However, water samples at W_5, W_{10}, W_{15}, B and R were very rough due to high level of both suspended and dissolved solids as well as activities carried out in the abattoir such as washing of the meat and carcass. The P^H for all the water samples ranges from 5.57 to 8.4 indicating slightly alkaline and strongly alkaline. All the samples fall within the maximum permissible level. The potassium ion concentration and iron of the water sample at W_5, W_{10}, W_{15} and B except R at all the sampling point were above the allowable permissible level. The relatively high values BOD at W_5 W_{10} and W_{10} can be traced to microbiological activities going on in the well as the water samples contain higher level of BOD (table 2) All other physical compositions of the water samples are within the WHO allowable limits. However, zinc level at B went outside the range, this can only be attributed to the properties of the underlying aquifer as the sample satisfies all organoleptic parameters. The relatively higher value of iron and potassium except for rain water than (WHO, 2006) recommendation is suspected to have come from animal blood that are washed into the water and also the leachates from this water that contain high blood content which could have led to higher value of iron and potassium at W_5, W_{10} W_{15} and B . The high level of manganese in all the samples except rain water cannot be attributed to any wastes from the abattoir. However it could have come from underground pollution from high concentration of mineral salts due to geological nature of the bedrock in which the aquifer is situated. Its high level at Borehole from the bacteriological assessment, all the water samples except at Rain water can be from inadequate seals and wrong choice of casing which may lead to corrosion and hence pollution of the water supplies (Roberts, H and Jager, L.D 2004). Were heavily polluted with pathogenic organisms of faecal origin and the abattoir workers should be discouraged from using this water to clean or dress carcasses meant for human consumption. Also the high level of BOD at W_5, W_{10} and W_{15} will lead to high odour generation which will in turn affect the life of abattoir workers. It is advisable that this well water is opened up and allowed to pass freely. Government can also provide a covered channel that will convey this abattoir wastewater to a safe place without creating any nuisance

4.0 Conclusion

The workers should be strictly advised to use only the bore hole water for drinking and carcass dressing since it is the only one free from harmful pathogenic organisms according to this study. There is also the need for Government to provide much more potable water for this very important abattoir since its operations require much water. I recommended that Training should be given to the butchers on how to discharge water into a suitable outlet. The government should dig more bore hole for the abattoir to complement the only three well used in the abattoir since slaughter house required more water. Also Secondary effect of bacteria is recommended for further investigation.

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ASSESSMENT OF SOLID WASTE RECOVERY AND UTILIZATION IN A COSMOPOLITAN CITY: A CASE STUDY OF ORO AREA, AKWA IBOM NIGERIA.

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Abstract

The present work assessed solid waste generation rate and composition at the household level within different income classes, evaluated the existing problems, and proffer feasible solutions. Formal and informal interviews were conducted to obtain data from waste-related government agencies and informal sectors. The study results show that the average generation rate in urban and rural areas are 0.55kg/person/day and 0.51kg/person/day, respectively. There is a slight difference in waste composition within the income class, culture, and customs of the people. The average waste composition generated at the household level indicates that organic waste constitutes the highest portion with 45.8%, paper with 12.7%, ash and dust with 12.2%, metal and grass have relative values, and hazardous waste is the lowest with 1.0%. The informal sector only conducts solid waste recovery in the Oron area. The major problems facing solid waste recovery in the Oron area include a lack of recycling companies, ignorance, and a lack of purchase centers in the villages. However, the study proffers recommendations to include adequate and regular sensitization programs, especially in the villages and towns, on the benefit of waste (solid waste) materials recovery.

Keywords: Solid waste, assessment, utilization, recovery, cosmopolitan,

1. Introduction

In general, waste is any undesired substance(s) produced by human or animal activity. Household garbage and trash, market spoils and rotten goods, street sweeping, building and demolition debris, sanitation residues, non-hazardous industrial refuse, treated bio-medical solid waste, and municipal solid waste is examples (MSW). Anything or object that is no longer appropriate for use in the owner's or user's consideration is garbage. Waste can be the leftovers of valuable objects that are no longer useful, or it might be the results or residues of specialized operations [1].

Solid wastes come in various forms, including solid, liquid, semi-solid, and containerized gaseous materials. Municipal waste (which includes household and commercial waste), industrial waste (which includes manufacturing waste), hazardous waste, construction and demolition waste, mining waste, waste from electrical and electronic equipment, biodegradable municipal waste, packaging waste, and agricultural waste are among the various types of waste. There are also various waste sources, including residential, industrial, commercial, institutional, construction, demolition garbage, municipal services manufacturing processes, and agriculture. Food wastes, paper, cardboard, plastics, textiles, leather, yard

wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes are among the wastes generated by residential, commercial, industrial, institutional, construction, demolition, process, and residential single and multifamily dwellings [2].

In Nigeria, over 25 million tons of solid trash are created each year [3], with organic materials, paper, plastics/rubbers, textiles, and metals making up most of these wastes [4]. Solid waste management is one of the most challenging issues that each developing city faces [5]. In Nigeria, for example, most metropolitan areas are seeing a surge in environmental degradation, with trash thrown on the streets, behind homes, and in drainage channels. According to [6], municipal solid trash is continually created. As a result, the urban resident has many touches with his garbage [7]. Urban land utilization becomes more complicated as the city's population and physical size rise, as does the volume and variety of solid waste generated. Residential, commercial, industrial, institutional, and other land uses exist in cities, and each generates its form of solid waste. However, residential land use is the most critical source of solid waste [8].

In many Nigerian cities, which are already overburdened with urban services, population expansion adds to the demand for urban infrastructure. Water, sanitation, and solid waste management services are in short supply in most cities. Waste management is a significant issue in developing countries. This is because the streets are littered with waste. Open dumps are common near most dwellings, especially in metropolitan areas where garbage collection is managed. In developing nations, open dumping is a viable option. Garbage that litters the streets and drains in an open area close to human houses is open dumping. Although open dumping is the most cost-effective method of waste disposal, it is also a source of public health and safety issues such as diseases, air and water pollution, fire, and other hazards [9]. Methane is produced as organic matter decomposes, which can cause fires and explosions and contributes to global warming [7]. Uncontrolled and unscientific dumping of municipal solid wastes has increased human health risks, including pollution of both surface and groundwater, which poses a severe human health danger. Surprisingly, uncontrolled dumping of municipal solid wastes into water bodies and low-lying regions without regard for the environment is typical in many developing countries' cities [10].

According to [7], the issues in developing nations' Solid Waste Management (SWM) include insufficient service coverage and operational inefficiencies, limited recycling activity utilization, and poor landfill disposal and resource recovery. Resources recovery is converting what was previously deemed trash into a valuable product. [11] claims that we are approaching an energy catastrophe. Converting garbage and other biomass sources into valuable products might be one solution to the problem. [12] examined the possibility of using a variety of municipal solid waste streams as a green energy feedstock. Resources recovery separates valuable items from landfills that may be used for other purposes. Organic waste material reuse, which accounts for more than half of all trash, is restricted, but it frequently has significant recovery potential [13]. A community's garbage reflects its way of life, prosperity, and culture. Some societies consume and discard significant amounts of paper, whereas others waste organic stuff.

Restaurants dispose away large quantities of fresh food, yet it may be valuable to animal owners.
As a result, this study aims to analyze solid waste recovery and use in Oron, Akwa Ibom, as well as to examine the militating obstacles and provide realistic alternatives for a better solid waste management system.

2. Methodology

Questionnaire administration, formal and informal interviews, fieldwork, and observations were all employed. Oro (the research region) was separated into five parts to simplify the sampling process. The research area was chosen from the five local government areas (henceforth referred to as area). An overview of the study area is shown in Figure 1. Data were gathered from three separate sources in each area: households, institutions (schools and hotels), and industries. Based on the size and income of the household, households were further divided into Low, Medium, and High-income groups. In this study, a low-income household is defined as one with five or more people earning less than $20 000 per year. A family of the same size with an annual income of more than $75 000 is considered high income. The remaining group is classified as having a medium income. This is closely connected to the U.S. Department of Commerce's criterion from 1998 [14].

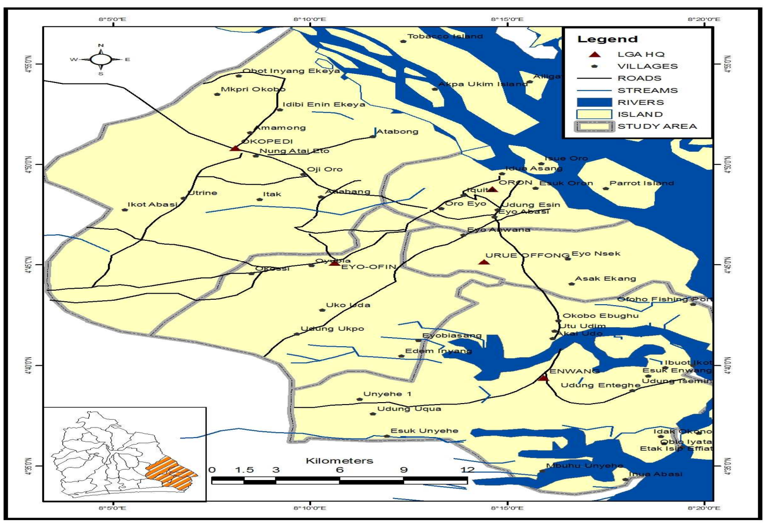

Figure 1. Schematic diagram of the study area.

Thirty households were chosen at random at the household level from the three income zones to administer the questionnaires. After preliminary testing, a total of 300 structured home surveys were distributed. The survey inquired about household income and appliances, as well as the types and extent of solid waste, disposal methods and costs, recycling/reuse, education or sensitization initiatives, and the frequency of such programs. The industry survey requested data on the type and quantity of solid waste created, trash recycling, and any technical difficulties or problems that may have arisen. A formal interview was held to learn more about the Government's role in solid waste recovery and usage. The interview focused on the Government's role in solid waste management, focusing on solid waste recovery and utilization, as well as existing measures to encourage solid waste diversion.

The research area's solid waste generation rate and composition were calculated to provide background data. Fifty (50) households were randomly selected from each Local Government Area to evaluate trash generation rate and composition at the household level, ten (10) each representing low, middle, and high-income areas. This was done to allow for extensive analysis due to the time-consuming nature of manually sorting and weighing garbage from each household regularly; data were obtained from 300 households via a questionnaire. Each home was given a rubbish bin for three weeks, which was gathered and refilled every morning.

Once the wastes were recovered, sorting and weighing took place every morning. The generation rate in kg per head for the day was calculated by dividing the weight (kg) generated by the household size (numbers). Each home's average generation rate was calculated, and the average of the randomly chosen household was recorded in each case. The average generation rate for the study region was calculated by taking the average of the three income categories. After weighing the sample, the garbage was sorted into specified classifications on a significant clean surface (tarpaulin). The proportion of each component was calculated and recorded after each component was weighed. The average proportion of each component was calculated for each income level and the whole research region in the same way as the generation rate was calculated. After preliminary weighing and sorting, the gathered garbage was carried to the disposal site to see how much stuff might be recovered by scavengers. The wastes were separated and placed near the dumpsite, where scavengers were free to choose anything they wanted without interference from the personnel. Following that, resorting and weighing were carried out and documented. The proportion of each recovered component and the total materials recovered as a percentage of total trash created were computed and recorded. Similarly, five dumping sites in each Local Government Area were examined for a physical inspection to determine the presence of recyclable items, non-recyclable materials, and even hazardous garbage and the waste's impact on the environment in the waste stream.

3. Results and Discussions

3.1. Solid Waste Generation Sources and Rates

Institutional, Agricultural, Commercial, Municipal, Industrial, Hazardous, and miscellaneous wastes have been identified as sources of solid waste in the research region. The waste generation study was centered on home activities because they are the predominant source of trash creation in Oro communities. The examination findings in the study region demonstrate that there are minor differences amongst communities due to ideologies, customs, religion, population density, culture, and other factors. Animal and fish farming is strictly restricted in several areas, such as Effect and Enwang. In a low-density environment, farming and agricultural activities are the principal causes of solid waste. Commercial and industrial activities generate solid waste in highly inhabited regions. According to [3], population income significantly impacts garbage output. The higher the income, the higher the rate of garbage creation, is indicating that generation rates vary by income and locality. Table 1 shows the research results on the generation rate kg/person/day. Across income groups of low, medium, and high households, the surveyed Local Government Areas generated 8.22 kg/person/day in solid waste. In the urban area of

Oron, the average waste generation rate per capita per day is 0.55kg/head/day, whereas, in the rural area of UdungUko, it is 0.51kg/head/day. This might be because high-income earners have greater purchasing power, resulting in increased trash creation. This result aligns with previously published [7] [15]. The average per capita trash created in the research area ranges from 0.51 to 0.55 kg/capita/day, depending on the region. [16] found 0.25kg/capita/day for Maiduguri, [17] research study found 0.56kg/capita/day for Mushin, and Lagos and Solomon (2009) found 0.49kg/capita/day for ordinary Nigerian villages with home and commercial hubs. According to [2], the Federal Capital Territory produces 0.59–0.74 kg of garbage per inhabitant each day.

Table 1: Solid Waste Generation per Capital per Day

GENERATION RATE (KG/PERSON/DAY)	LOW	INCOME GROUP MEDIUM	HIGH
Oron	0.37	0.51	0.87
UrueOffong/Oruko	0.35	0.58	0.75
UdungUkoh	0.35	0.50	0.70
Okobo	0.37	0.55	0.69
Mbo	0.36	0.53	0.74
Average	0.36	0.55	0.75

3.2. Waste Composition Analysis

The composition of garbage is affected by income and economic progress. Table 2 shows the results of the waste composition in the research region. The results of the same income class reveal a modest variance from one income area to the next and from one town to the next. Organic trash is the most common type of garbage in the research region, whereas hazardous waste is the least common.

Table 2: Average Composition of Waste in Oro Study Area (%) Income class

CLASS OF WASTE	LOW	MEDIUM	HIGH	AVERAGE
Organic	55.3	46.2	35.8	45.8
Paper	5.2	12.0	20.4	12.5
Plastic/Rubber	5.9	8.8	12.4	9.0
Metal	1.2	3.3	6.0	3.5
Gass	0.7	2.0	5.0	2.6
Ash and Dust	19.0	13.3	3.1	11.8
Consumer Products	1.0	4.0	8.3	4.4
Hazardous	0.4	1.4	1.3	1.0
Others	11.3	9.0	7.7	9.3

High-income earners consume more packaged goods, resulting in a larger ratio of inorganic materials (metals, plastics, glass, and textiles) in their homes. Season, income level, population, social behavior behaviour, climate, industrial output, the size of trash markets and the amount of urbanization, recycling efficacy, and work reduction are all factors that influence waste characteristics [3]. The study area's solid waste composition analysis shows that waste composition differs from one group to the next and from one community to the next. The data reveals that organic waste is higher in the low-income class, followed by the paper waste in the high-income region due to the significant volume of packing paper. Organic waste makes up 45.8% of the total, followed by paper (12.7%), dust and ash (11.8%), rubber/plastic (9%), metal (3.5%), and grass (2.6Munich Munich municipalipal solid waste generated at the home level in the research region is divided into four categories: ash and dust (12.1%), consumer items (4.0%), hazardous (1%), and others (9.3%). Bottles, water containers, soft drink rubber containers, pure water (package water bag), black film (polythene) shopping bags, and black film (polythene) shopping bags account for 3.5 per centper cent of total trash and 25.6 per centper cent of plastic/rubber waste in the research regions. As a consequence of using firewood, old canoes, and other solid waste as a source of energy for cooking and other activities in low-income regions, the range of ashes and dust has decreased from a greater proportion in low-income areas to a negligible value in high-income areas. Furthermore, owing to continuous glasshouses in a high-income region and continuous packaging of containers, plastics, and metals activities in the Oron metropolitan area, there is a rising tendency of plastic, glass, and metal trash. The area (residential, commercial, etc.), the economic level (differences between high and low-income areas), the season and weather (differences in population throughout the year, tourist destinations), and the culture of people living or doing business in the area all influence the composition and characteristics of municipal solid waste. In general, high-income areas create more inorganic materials like plastics and paper, and low-income ones produce more organic trash [2].

3.3. Solid Waste Recovery

Table 3 shows the result of the solid waste recovery analysis; metals and plastics/rubber mainly were recovered in each Local Government Area of Oro. There was a slight difference in the percentage recovery of waste material from one area to another.

Table 3: Analysis of solid waste Recovery

Fraction of Materials Recovered As A Percentage of The Category-Generated Study Zones	Metals	Rubber/ Plastic	Glass	Consumer Product	Hazardous
Oron	79.2	66.4	25.4	21.3	3.4
Urueoffong/Oruko	35.4	31.8	15.8	16.4	6.4
Okobo	69.8	33.2	16.3	25.3	4.3
UdungUko	34.5	33.4	14.3	16.8	3.6
Mbo	51.5	43.2	18.5	17.7	4.5
Average	54.1	41.6	18.1	19.5	4.4

Table 3 shows that metal trash was the most recovered material with 54.1%, followed by rubber and plastic waste. Approximately 41.6% of garbage generated in the home is collected. However, 18.1% of garbage in glass bottles, such as medication, cream, and lotion containers, was retrieved primarily for reuse rather than recycling. This 18.1% solid waste has yet to be developed for commerce. Metals, plastic, and rubber are the most important exchanges between the recycling firm and scavenger (itinerant) purchasers in the study region.

Furthermore, from the garbage dumpsite in the research locations, a scavenger salvaged consumer objects such as stereo/video equipment stoves, old telephones, shops, electric heaters/cookers, and cables. Those in good condition can be reused or sold to a professional who can repair them. Herbicide and pesticide containers, prescription medication containers, dry cell batteries, and Drip and stitch were among the hazardous trash goods salvaged for reuse and sale. Solid waste materials recovered as a percentage of total trash generated at the home level is roughly 7.5% in all categories. This compares to the 6% indicated by [7] for Adamawa State.

3.4. Data from Questionnaire and Formal/Informal Interviews

The results of the 400 household questionnaires administered and 300 were returned correctly across the five Local Government Areas of the study areas. It indicates that papers were generated from the high-income areas (97.5%). According to the data obtained, Food waste was also high in low, medium, and high-income areas. Furthermore, less than 85.2% of plastic and glass waste was generated. The rate of hazardous waste generation, cans/tins containers is low in all the income group class (medium, high and low) due to differences in purchasing power across the income class during the waste composition analysis. One the issue of source separation of waste, very few households, mainly from high-income areas, practice this. In another development, waste reduction at the household level informs that reuse, gifts, or sale of old items was very high (>70%) in all the income areas. Gifts are prevalent across all the income classes by tradition and teachings of the major religions [7]. Moreso, 52.3% of wood is used as a solid fuel for cooking and drying activities. People's awareness of waste recovery, separation, and utilization is low in all income classes in the study area, and no action has been taken so far by State and Local Governments, organizations, or even individuals to encourage solid waste diversion through financial assistance, policy-making, and implementation with the provision of equipment. According to [7], most individuals/households are unaware of the importance of source separation, recovery, and usage of solid waste as a management technique or for the economic advantages that waste may provide.

3.5. Informal Sector Interviews

A depth interview with scavengers reveals that scavengers do not observe safety rules and regulations like wearing Personal Protective Equipment (PPE) during the working hour. Waste materials recovered were conveyed on Trucks and Bags by motorcycle. Meanwhile, the transaction evaluation and cost of transporting the recovered waste materials must be considered, including the gross estimate and profit earning value and the price of the items recovered from the waste stream. On the other hand, scavengers could not adequately disclose what they are earning per month, but monthly earnings range from 25,000 Naira to 45,000= (50%) after expenditure; no form of assistance has been rendered by private or

Government (94.5%). Though help need varies from policies (70%); to loans (86%), the reason for these is mainly unemployment (80%) and poverty (63%). About 98.6% in the study area indicate no formal association among the scavengers, which causes a severe setback due to the public's unsteady prince regulation of purpose material. According to the information obtained during the field survey from the itinerant buyer/retailers that reasonable quantities of metal waste are in high demand by local users and recycling companies outside the state since there is none in Akwa Ibom.

3.6. Waste Related Government Agency

Information obtained from the Chief Environmental and Health officer in each local government secretariat indicates that enforcement and policy formulation for waste collection, disposal, recovery, and utilization are overlooked by the Government in the five Local Government Areas of the study areas. Consequently, the Government has done nothing to address this problem, even in support or repression, resulting in the indiscriminate dumping of waste without any regulation restricting such activities.

3.7. Industry Questionnaire

The result of the industry questionnaire administered indicates that only waste materials damaged during production activities are generated. However, the waste generated is not recycled due to technical difficulty; no reason was given for recycling the waste depending on the data obtained from the respondent. Meanwhile, the practice of source separation of different types of waste is not considered. [18] clarify that recycling has to remain as information due to waste item availability and cheaper market recycle products during the absence of waste secretion practice.

3.8. Institution Questionnaire

Information obtained from the institution questionnaire indicates that different obtained from the generated ranging from papers, papers, food remnants, leaves, streams, scarps from workshops, bottles, water containers (Rubber/Plastic), etc. Local merchants use the paper to wrap meat, fish, Akara, and fry groundnut. In contrast, poultry farmers use food waste, particularly pigs, as their feed for survival, and the rubber/plastic water container is also used by oil and kerosene hawkers in the study areas. The waste separation practice is not neglected, but at least ¼ of the respondents indicate their willingness to separate the waste differently from the source before evacuating it to the dumpsite at Eyetong. According to the respondent, nothing has been done in terms of sensitization. A lot of effort and strategy are needed in the study area by educating the dwellers on the needs of separation, economic benefits, and proper waste management strategies.

3.9. Evaluation of Problems and Possible Solutions

Various factors that affect the potential for waste recovery in the five Local Government Areas are: location, quantity, cost of separating material from the source, and the purities of the materials [13] are very low across the study areas. The results obtained from the findings indicate five purchasing centers in the Oro study area. The material recovered is hauled for a long distance before it arrives at a purchasing center or points to evaluate the transaction's liability with the cost of transportation. It is an expensive business venture since the primary user (recycling companies) are located very far from the study area. Most recycling companies are located in other states like Cross River, Lagos, and Abia State. From the information obtained, it is very and highly limited for the people of Oro to separate different types of waste from the source since there is no financial compensation accorded. Therefore, the purity of recovered waste materials is compromised, contributing to waste negligence [19]. The major hindrance to waste materials recovery is a lack of equipment and capital, especially vehicles, and poor conduct in educating or sensitizing the people on the economic benefits and proper management of waste to avoid advert effect. Lack of sorting waste at the source leads to indiscriminate disposal; therefore, cooperation among authorities and waste collectors (communities, both formal and informal workers) is essential [20]. Solid waste recovery and management may not generate much profit or profit-oriented business venture. However, society's most significant task and goal are to clear and clean the environment from unused or unwanted material emanated from human and animal activities.

Meanwhile, proper solid waste management through material recovery and utilization creates employment as a means of livelihood, provides a source of cheap raw materials to industries, creates a proper friendly environment for humans and animals, and provides a most accessible means of managing waste by reducing waste the quantity. Nevertheless, the Government should create s recycling company in the state since there is none and make use of the best approach in waste recovery, which demands that public manufacturing industries, formal and informal sections, be fully involved. Above all, the Government should develop strategies and policies on waste recovery and utilization by putting the necessary workforce to ensure stick compliance. These policies should cover regular sensitization programs on waste recovery, utilization of waste materials by industries, separation of waste from the source by the public, recognition and financial support for informal workers involved in material recovery, and general study areas.

4. Conclusions and Recommendations

The informal sector in Oro Areas is in charge of solid waste materials recovery. The problem facing solid waste recovery in the study area includes ignorance, lack of adequate purchase center at the grass-root level, lack of support from the government sector or individuals, low price, lack of source separation of waste, contamination of recovery items, long distance between the generation center and the potential user of the recovered waste items. Several future recommendations are proposed for a better understanding of the results. First, there should be an adequate and regular sensitization program primarily in the villages and towns to benefit from waste (solid waste) materials recovery. Also, there should be the establishment of efficient recycling companies by the Government, manufacturing industries, public with a proper recycling program. Furthermore, the Government should have an adequate awareness campaign on the source separation of waste materials and proper finance of the program. Finally, recognition and proper support program for informal waste collectors and scavengers in Oro Area must be encouraged.

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EFFECTS OF SOIL WATER CHARACTERISTICS ON CANOPY DEVELOPMENT OF TOMATO IN EPE LAGOS STATE NIGERIA

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Abstract

The objective of this paper was to show the wellness of crop canopy under effective water management in the tropical soil. Canopy development entails the growth of the upper structure of the crop to its full potential. Research location is at Epe in Lagos state, Nigeria which lies on the latitude and longitude of 3^0. 96′ E. Climatic data on rainfall (mm), radiation (MJ/M^2), maximum and minimum temperature (^{o}C), wind speed (m/sec), mean relative humidity (%) and Carbon dioxide concentration from 1982 to 2018 were obtained from the website of National Aeronautics and Space Administration. Aqua crop model of version 6.1 Food and Agriculture Organization and Soil and Water Characteristics of version 6.02.74 USDA Agricultural research service were used and tomato was chosen crop. The results show that the canopy was fast developed with the size of 15 cm^2/plant and a density population of 3.3 plants/m^2 on the sandy loam soil with a hydraulic conductivity of 22 mm/day and total available water of 80 mm/m, with curve number 46 which shows that the soil is agriculturally sustainable and erosion not infested. Conclusively, effective management of canopy development as a result of sound soil practice and adequate and appropriate water application will lead to improvement in yields.

Keywords : Canopy, Aqua crop, Soil horizon, water management and Hydraulic Conductivity

1.0 Introduction

How effective a crop canopy is developed depends on the management of the available water in the soil which can be through rainfed or irrigation. Canopy management is imperative in achieving water use efficiency and adaptation strategy to climate change; and also canopy appearance is the first feature to show a red alert if a crop is water stressed.

Plant canopy development is easily influenced by effective water management and soil conservation practice, while water efficiency and soil interaction play a significant role in yield increase as a result of maximal use of available soil nutrients (Fuente *et al*, 2015). More water is required at the vegetative and flowering stages than in the fruit bearing stage due to the activities of pollination agents and as well as favourable soil temperature (Alli and Omofunmi, 2021). Growth may be more strongly affected by water limitation at reproductive demands for carbon in the developing roots of the plant (Sara et al., 2020; Comas et al., 2005).

Soil moisture hampers the production potential of forage in no small way in the arid and semiarid regions. The difference in soil layers in terms of physical, chemical and biological characteristics is called a soil horizon which is described among other properties; as colour, texture, structure, thickness and particle size distribution (Blum et al, 2018). Meanwhile, the objective of this paper is to show the wellness of crop canopy under effective water management in the tropical soil.

2.0 Materials And Methods

2.1 Study Location: The study was conducted at the Department of Agricultural and Bio-environmental Engineering, School of Engineering, Yaba College of Technology, Epe Campus, Lagos Nigeria which lies on the latitude $6^0$58′ N and longitude $3^0$96′E with an elevation of 3.98 meters above sea level.

2.2 Soil water Characteristics Software: Soil water characteristics is a graphic computer program used to estimate the hydrologic water holding and movement characteristics of an agricultural soil profile layer. The version used was 6.02.74, Keith E Saxton of USDA Agricultural Research Service and which can be retrieved through this website (http://hydrolab.arsusda.gov/soil water/index. htm). This graphic computer program is used to estimate the hydrologic water holding and transmission characteristics of an agricultural soil profile layer.

2.2.1 Soil Horizon and Profile: The study location was made of loamy sand with 82% sand and 6 % clay as shown in figure 1 below. The soil contains five horizons ranging from Sandy loam, loamy sand, sandy clay loam, and sandy clay loam.

2.3 Aquacrop: Aqua crop used is version 6.1, FAO Land and water division, Rome, Italy, Nr. 02052018. It is of crop water productivity model (Hsiao et al., 2009; Steduto et al., 2009; Todorovic et al., 2009).

2.4 Climatic Parameter Data Source and Processing: Thirty- six years data (1982-2018) used for this study was obtained from the archive of the National Aeronautics and Space Administration on daily basis. Data were processed into Aqua crop format and saved in Microsoft Excel with CSV or text file for compatibility in the directory of the aqua crop after removing voids and non-numeric elements. The details of simulation and data analysis were explained in the Figures 2-5 and Tables 1-3 accordingly.

3.0 RESULTS

The result shown in Figure 1 was the classification of Epe soil indicating 82 % sand and 6 % clay as a result of the sieve analysis carried out. The result of the sieve analysis was input into the soil water classification which generated curve number, soil thickness, and soil profile used for simulation.

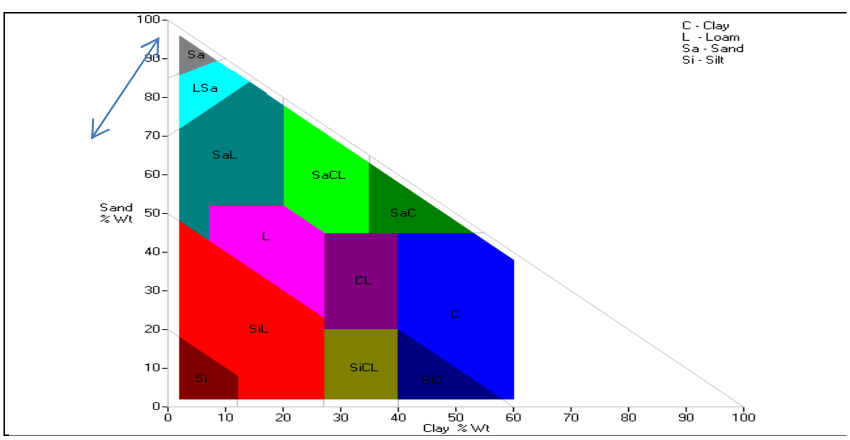

Figure 1. Soil Classification of Epe

The results shown in Figures 2- 5 and Tables 1- 3 are generated from the simulation results of the aquacrop. Data related to the study location were fed into the aqua crop such as rainfall (PLU), minimum and maximum temperature (txn), relative humidity, evapotranspiration (ETo), and carbon (iv) oxide (Mouna Loa of SRES A2) data were uploaded into the climate compartment of Aqua crop; sandy loam was selected as soil profile; under irrigation management, drip irrigation was selected and tomato was chosen as a crop (crop cycle was November 8, 2017 to February 22, 2018).

Table 1. Descriptive Statistics of Aquacrop Simulation Results of Tomato Canopy Development

STATISTICS	G D	Z	CC	CCW	B	HI
Mean	17.55	0.84	49.26	49.26	4.26	24.00
Standard Error	0.13	0.02	2.87	2.87	0.37	2.41
Standard Deviation	1.34	0.22	30.08	30.08	3.90	25.26
Sample Variance	1.79	0.05	905.08	905.08	15.20	637.89
Kurtosis	-0.90	0.02	-1.32	-1.32	-1.28	-1.44
Skewness	-0.61	-1.16	-0.71	-0.71	0.42	0.49
Confidence Level(95.0%)	0.25	0.04	5.69	5.69	0.74	4.77

GD- Growing Degree; Z- Effective root Zone of Tomato= 1 M; CC- Green Canopy Cover; CCw- Green Canopy Cover in weed- infested field; B- Biomass; and HI- Harvest Index.

Table 2. Aqua crop Simulation Results of Epe Soil Profile

Horizon	Types of Soil	Thickness mm	TAW mm/M	Soil Water/Stonness Retention in Fine Soil Fractions			Hydraulic Conductivity	
				PWP	F.C	SAT	KSAT mm/day	TAU
1	Sandy loam	0.12	120	10.0	22.0	41.0	12.0	1.00
2	Loamy sand	0.12	80	8.0	16.0	38	22.0	1.00
3	Loamy sand	0.29	80	8.0	16.0	38	22.0	1.00
4	Sandy clay loam	0.39	120	20.0	32.0	47	22.5	0.58
5	Sandy clay loam	1.00	120	20.0	32.0	47	22.5	0.58

Table 3. Aqua crop Simulation Results on Agronomy of Epe

Parameters	Values
Canopy Development	
Canopy size of transplanted seedling	15.0 Cm^2/plant
Plant density	33.33 plants/ ha or 3.3 plants/ m^2
Initial canopy cover (CCo)	0.50 %
Canopy expansion =	fast expansion
Maximum canopy cover	fairly covered I.e 75%
Canopy decline	very slow I.e 37 %
Maximum effective rooting depth	1 M

Meanwhile, aqua crop contains the following compartments; climate, crop, irrigation management, ground water, project and simulation. Ground water was ignored because the effective root of the tomato was 1 M and the project was to give a description.

Figure 2 -5 shown the graphs of the day after planting (DAP) versus canopy cover (CC); growing degree (GD); biomass (B); and harvest index (HI) respectively while Tables 1-3 show the descriptive statistics of Aquacrop simulation results of tomato canopy development; Aqua crop simulation results of Epe soil profile; and Aqua crop simulation results on the agronomy of Epe respectively . Figure 2 shows four stages involved in canopy development of tomatoes such as emergence or transplant recovery, vegetative, flowering and yield formation and ripening stages. The emergence and transplant recovery stage started from DAP 1 to DAP 5, and canopy development was in rapid form during the vegetative which covered DAP 5 to DAP 37. The flowering stage started from DAP 37 to DAP 77 and thereafter yield formation and ripening set in. Canopy started declining after the ripening stage. The longest stage in canopy development is the flowering stage. Canopy development grows with biomass production.

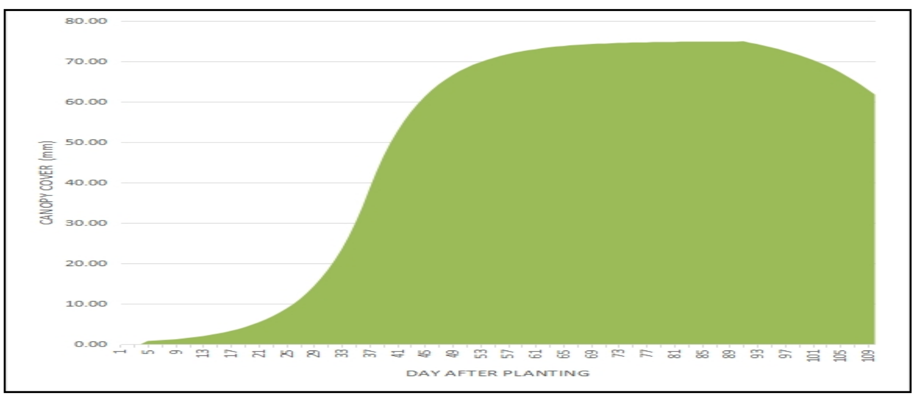

Figure 2. Graph of Days After Planting (DAP) Versus Canopy Cover of Tomato

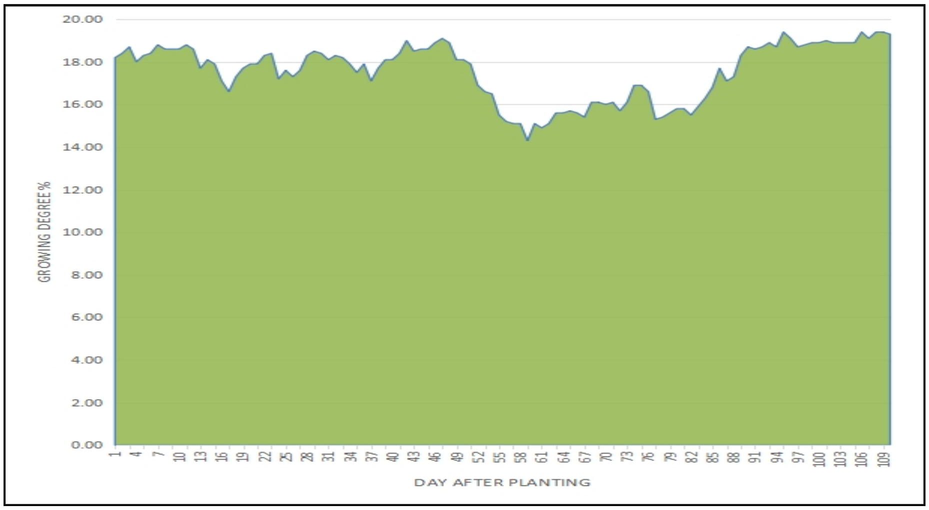

Figure 3. Graph of Days After Planting (DAP) Versus Growing Degree of Tomato

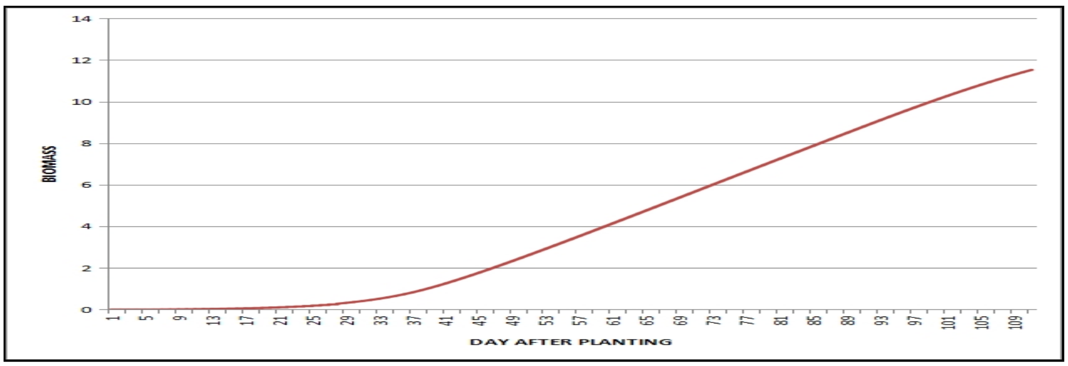

Figure 4. Graph of Biomass Versus Day after Planting

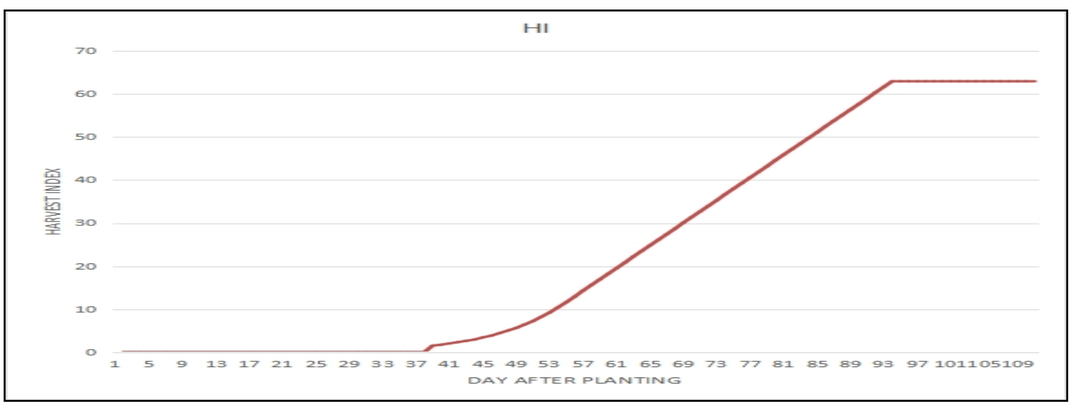

Figure 5. Graph of Harvest Index Versus Day after Planting

Table 3 shows that the readily available water during the growing period was 7 mm with an evaporating surface layer of 0.04 m and base and upper soil temperatures of 7.0 ^{0} C and 28.0 ^{0}C respectively. The canopy size of transplanted seedling was 15.0 cm^2/plant and plant density of 3.3 plants/m^2, initial canopy cover (CCo) was 0.5 % with the fast expansion of the canopy. The maximum effective rooting depth was 1 m and the canopy decline is at a 37 % rate which was considered to be very slow.

4.0 Discussion

In irrigation management, DAP 1 to DAP 5 which is the emergence and plant recovery stage requires little amount of water due to low evaporation loss as supported by Ouda, et al. (2018). At this stage, water application has to be done gently and with caution to avoid crop being been destroyed as a result of the erosive power of the water. While DAP 5 to 77 are vegetative and flowering stages where crops are in dearth need of water. Vegetative and flowering stages can be referred to as the longest and peak period for irrigation water management due to activities of insects and other pollination agents (Mahdi Al-Kaisis, 2022). Meanwhile, the canopy will start declining after the ripening stage (DAP77-110) due to the senescence which will begin to set in (Yahia et al., 2005) .

As shown in Figure 4, biomass is a source of alternative energy (Akinrinola et al.,2014). It is almost zero at nursery and plant recovery stages but starts picking up at the vegetative stage until it reaches the yield stage, and eventually climaxed at yield formation and ripening stage. The growth pattern of biomass takes the pattern of the crop, making every crop or plant support combustion at the ripening stage (Ladapo, et al . 2018).

Table 2 shows that Epe has 5 soil horizons ranging from Sandy loam, loamy sand, loamy sand, sandy clay loam, and sandy clay loam with a curve number of 46 and thicknesses of 0.12 mm, 0.12 mm, 0,29 mm, 0.39 mm and 1.00 mm respectively. Curve number 46 shows that the soil is agriculturally sustainable and not prone to erosion (Montgomery., 2007; Cal and Bank., 2020). The values for total available water (TAW) were recorded for the Epe soil horizons as thus; sandy loam (120 mm/M), loamy sand (80mm/M), and sandy clay loam (120 mm/M). Values for the permanent wilting point (PWP) and field capacity (F.C) for the five horizons are indicated in Table 2 as shown below. Meanwhile, hydraulic conductivity at saturation (KSAT) of 12 mm/day, 22 mm/day and 22.5 mm/day is recorded for sandy loam, loamy sand and sandy clay loam respectively.

The hydraulic conductivity and other characteristics of the soil horizons, especially sandy loam showed that Epe soil was agriculturally sound for the growth of tomatoes (Osunbitan., et al; Rosas, et al., 2014) which resulted in the fast expansion of the canopy as shown in table 3. This claim that the soil composition contributed to the fast expansion of the canopy was supported by Collins and Wein., 1998.

The result also showed that the canopy was properly managed as it declines at a slow rate after senescence showing that the crop received adequate, good aeration and other parameters that aid plant growth (Arocena et al., 2003; Pardini et al., 2004). Oner et al. (2008) reported that if effective Canopy management is ensured it will lead to conservation of water and improvement in yields.

The negative signs shown by kurtosis and skewness in table 1 signified a decline in canopy which will in turn affect the biomass and harvest index as well as portending that risk is impeding (Korathi et al., 2014).

5.0 Conclusion

Conclusively, effective management of canopy development as a result of sound soil practice and adequate and appropriate water application will lead to improvement in yields. Hydraulic and other water characteristics results generated from this research showed that Epe soil is agriculturally sound for the growth of tomatoes with a curve number of 46 showing that Epe soil is not prone to erosion. More also, the values recorded for the total available water (TAW) of Epe soil showed that water sufficiency is moderate as shown thus; sandy loam (120 mm/M), loamy sand (80 mm/M), and sandy clay loam (120 mm/M).

Recommendation and Prospect

Aqua crop is a crop growth model developed by the Land and Water Division of FAO to address food security and to assess the effect of environment and management on crop production. It simulates yield response to water of herbaceous crops, and is particularly suited to address conditions where water is a key limiting factor in crop production. It can be used to carry out simulation under different irrigation scenerios. Its calculation procedures is grounded on basic and often complex biophysical processes to guarantee an accurate simulation of the response of the crop in the plant-soil system.

There is a prospect for Scientists, Engineers and other Aqua crop 'practitioners' to exploit the efficiency of aqua crop to solve more complex water and soil related problems in Africa in particular and global in general.

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POST-HARVEST TECHNOLOGY

RICE STRAW MANAGEMENT BY RICE FARMERS IN ANAMBRA STATE VALUE CHAIN DEVELOPMENT PROGRAM

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Abstract

As more rice is grown each year to meet the rising demand of the commodity in Anambra State, open field burning of the straw becomes the readily available means to get rid of it which is one of the major contributors of air pollution with associated health hazards. This study therefore seeks to assess different rice straw management practices adopted by rice farmers in Anambra State Value Chain Development Program (ANSVCDP). Straw composting as well as soil incorporation of the rice straw are the disposal means readily adopted by the rice farmers in the program. In-depth interviews, survey using a well-structured questionnaire and personal observation were used to obtain information on farmers' different rice straw management practices, while multi-stage sampling techniques was used for the selection of the study representative. The result showed that 56.73% of farmers dispose their rice straw through open field burning, while 18.7% and 12.13% of farmers dispose their rice straw through composting and soil incorporation respectively. Rice straw composting with animal droppings proves to increase the yield of the rice crop with average output of 6.5 tons per hectare compared to soil incorporation of the straw with 4.5 tons per hectare and the use of rice straw with average output of 3.5 tons per hectares . It is therefore recommended that farmers should adopt rice straw composting management system, since this helps to curbs diseases, reduce pest attacks and eliminate environmental pollution through open field burning of the straw.

Keywords: Rice straw management, Value chain, Rice Farming, International Fund for Agricultural development (IFAD)

1.0 Introduction

Production and consumption activities in Agriculture generate waste and causes pollution. The atmospheric environment can absorb this waste and pollutants up to a limit (Chen et al., 2019). Rice straw is one of the waste products of rice production at harvest. The total biomass of the straw depends on various factors such as varieties, soil nutrient management and weather (Liu et al., 2014). At harvest, rice straw is either piled or spread in the field depending on the harvesting methods using stationary threshers or self–propelled combine harvesters respectively. The amount of rice straw taken off the field depends mainly on the cutting height (that is height of the stubble left in the field). Rice straw that remains in the field after harvest can be collected, burned or left to decompose (soil incorporations). The stubble, the uncut portion of the rice straw after harvest remains and can be burned or incorporated into the soil in preparation for the next crop cycle (Chen et al.,2019). The ratio of straw to paddy varies ranging from 1.0 to 4.3ha (Zafar, 2015) and 0.74 to 0.79ha (Nguyen et al., 2016). The burning of rice straw by many rural farmers has severe impact to the environment, this justifies the reasons several agricultural programs are targeted at the rural populace, not only to address hunger through the adoption of good agronomic practice, but also for sustainable environment (Chukwukelu 2017).

The International fund for agricultural development (IFAD) funded the value chain development program (VCDP) in Nigeria to assist cassava and rice smallholder farmers through a value chain approach to enhance productivity, promote agro-processing and to increase access to markets. The program which has been implemented since 2014 in its original six states of Anambra, Benue, Ebonyi, Niger, Ogun and Taraba; was later in 2018, extended to three other states (Kogi, Enugu and Nasarawa) and its implementation increased to eight Local Government Areas (LGAs) each from initial five states. The aim of the program is to transform the agricultural sector of rural Nigerians by achieving food security, increasing income and creating new employment opportunities.

Rice production in Anambra State VCDP was conducted in the following LGA of Anambra State viz: Ayamelum, Anambra East, Anambra West, Awka North and Orumba South LGAs due to their potential and comparative advantage for rice production. Rice farmers which are grouped into various cooperatives according to the design of the program, are supplied with agro inputs at a subsidized price with trainings on good agronomic practices to ensure production increase, food sufficiency and sustainability. Faro 44 (SIPPA 692033) rice seed for shallow and lowland rain–fed field and Faro 52 (WITA 4) rice seed for deep swamps are recommended to rice farmers in the program due to their high yielding capacity, early maturity and disease resistance (IFAD/ANSVCDP, 2017).

The magnitude of rice straw generated by rice farmers in the field depends on the size of their farmlands (Paddy field) which ranges from one hectare to five hectares and the frequency at which the crop is cultivated per production cycle in a year. The early maturity of the recommended rice seed species in about 90 days has created room for its cultivation for more than once in a year and thus increased generation of more rice residues (straw) per year. Management of rice straw remains a major challenge in Anambra State VCDP. There is need to investigate the impact of the program on the management of rice straw as a critical tool in environmental monitoring and assessment on the study areas. Rice straw burning in the open field, rice straw incorporation in the soil, and rice straw composting with animal droppings are the readily practiced rice straw management by the rice farmers in the state program but there are no or scanty studies on the environmental effects of the above management practices and what lures rice farmers into those straw management options. The objectives of this study therefore are to identify the different disposal means of rice straw generated by rice farmers in the study areas and to assess the environmental effects of different rice straw management, and the factors that influence it.

Different Disposal Means of Rice Straw and Their Environmental Effects

Open field burning of the rice straw.

Many farmers in the program adopt open field burning of the rice straw considering the short period between harvesting and cultivation of the recommended rice varieties in the program, and owing to high frequency of the rice plantation at the rate of 2 to 3 times in a year as well as high yield due to high abundance of water source and soil nutrient in the selected area, rice straw burning is therefore a common residue management practice among rice farmers. They believe that rice residue burning has beneficial effects on the yields and primarily adopt such practice in order to remove the waste residue, control weeds and release nutrients for the next crop cycle (Chiaranaikun, 2017). Open burning of rice straw has a negative environmental and agronomic impact. It causes atmospheric pollution and reduction of soil quality through the killing of soil micro-organisms that aerate and improves the soil structure. Furthermore, it emits hazardous greenhouse gases such as CO_2, CH_4 and N_2O, and other trace gases that contributes to depletion of the ozone layer and the formation of black carbons in the atmosphere.

Despite the established negative long-term impacts of burning on soil quality, soil organic carbon sequestration and air quality, most rice farmers prefer burning rice straw in the field due to lower cost of the disposal means, reduction in soil acidity as ash is normally returned to the soil, reduction in weed and disease carryover, and ease of tillage (Chukwukelu, 2017).

Rice Straw Composting

Straw composting with animal droppings (manure) is one of the rice waste management approach adopted by some rice farmers in the program to fasten its mineralization and decomposition rate. Straw composting with manure can be an effective option to reduce methane emissions associated with in-field straw incorporation along with nitrous emission and accounts for 11% of global agricultural emission (FAO, 2017). Aerobic composting as mostly practiced by the rice farmers is an effective method to reduce methanogenesis of methane from anaerobic manure storage in settling ponds. Compost is used by the farmers as a soil improver or directly as a planting substrate. Application of compost results in an increased in, not only crop yield, but also soil fertility (Vo et al., 2014). Studies suggest that aerated manure with straw can reduce methane emissions up to 90% compared to anaerobic storage (Petersen et al., 2013).

Rice Straw Incorporation

Rice straw incorporation is another common management option being practiced by rice farmers in the program, but adequate time is allowed for its decomposition to ensure effective release of the straw nutrients and production efficiency. The benefits of complete straw removal on reducing methane emission from the residue however, are offset by reduced soil organic carbon sequestration, soil quality and long term yields. Maximum emission reductions and yield may be best achieved by rice straw incorporation in most continuous rice system (Romasanta et al., 2017). Because straw decomposition rates, and emission depend on climate, cropping system and soil type, these factors can help determine the appropriate percentage of straw to incorporate. Generally soils that are well-drained or have low soil organic carbon with aerobic periods, benefits from increased straw incorporation, to maximize soil organic carbon sequestration and increase yields with minimal methane emissions, that is, the percentage of straw incorporated should be approximately proportional to the percentage of time under aerobic conditions (Monteleone et al., 2015). Methane (CH_4) emissions from rice are highly dependent on the amount of straw or crop residue incorporated under continuously flooded conditions (Liu et al, 2014). Because of this, removing rice straw in flooded rice is considered a mitigation strategy that could theoretically reduce the global warming potential of emissions from rice by 45% (Wang et al., 2016).

2.0 Materials and Methods

The approaches used for data collection include in-depth interviews, survey by using well-structured questionnaire and personal observation. These triangulation techniques are used to support evidence from other sources. The data collected involves:

i. Farmers who use rice straw as compost in rice crop production
ii. Farmers who burn the rice straw in the field and use the rice straw ash in rice crop production.
iii. Farmers who incorporate the rice straw into the soil for rice crop production.

A multi-stage sampling technique was used for the selection of the study representative. A sample frame of 7283 was obtained from the list of registered rice farmers in the initial five participating Local Government Areas from the program database in Anambra State. Taro Yamane (1967) sample size determination in Otabor and Obahiagbon (2016) was further used to calculate the sample size for the study as stated thus;

$$n = \frac{N}{1+N(e)^2} \qquad (1)$$

Where:

N = population of the study

n= sample size

e=Margine of error = 0.05

I = unit (a constant)

$$n=\frac{7283}{1+7283(0.05)^2} = \frac{7283}{1+7283\ (0.0025)}$$

$$\frac{7283}{1+18.2075} = \frac{7283}{19.2075} = 379.17$$

Approximately = 379 farmers

Moreover, R. Kumaison formula was further employed to allocate sample stratum for the study and defined by

$$1th = \frac{ni}{N}\ x\ n \qquad (2)$$

Where:

n = total sample size

ni= number of items in each stratum in the pollutions

N= the population size in the strata

Ith = sample allocation

Therefore;

Anambra East, ith =$\frac{428}{7283}$ x 379 = 22

Anambra West, ith =$\frac{1154}{7283}$ x 379 = 60

Anambra North, ith =$\frac{1262}{7283}$ x 379 =66

Ayaelum, ith =$\frac{2237}{7283}$ x 379 = 116

Orumba South, ith = =$\frac{2,202}{7283}$ x 379 = 115

The sample representation of rice farmers in the five participating LGAs in the VCDP is shown in the Table 1:

Table 1: Sample representation of rice farmers in the five participating local government areas of the program

S/N	Local Government Area	No Of Farmers	Sample Size
1.	Anambra East	428	22
2.	Anambra West	1154	60
3.	Awka North	1262	66
4.	Ayamelum	2237	116
5.	Orumba South	2202	115
	Total	7283	379

4.0 Result and Discussion

The results presented below were based on data collected from the five LGAs of Anambra state VCDP. Table 2 presents the data on the different management practices adopted by farmers in the study area.

Table 2: Data on different management practices of rice farmers.

S/N	L.G.A	Sample size	Rice straw composting	Rice straw burning	Rice straw incorporation	Other uses not related to soil
1.	Anambra East	22	6	9	4	3
2.	Anambra West	60	10	35	7	8
3.	Awka North	65	14	33	8	10
4.	Ayamelum	116	18	75	9	14
5.	Orumba South	115	23	63	18	11
	Total	379	71	215	46	46

All the respondents interviewed were rice farmers cultivating one of the recommend varieties in the program, this involved about 264 men (69.7%) and 115 women (30.3%), as seen in Table 3. A large number of respondents were between the age brackets of 31-40 years and had obtained secondary school education. This indicates that most of the farmers in the area are young but do not have higher qualification in education such as diploma and degree. A total of 158 respondents (42%) have been working on rice plantation for more than 20 years. This indicates that they have many years of experience in rice cultivation and management.

Table 3: The Respondent Profile from the five LGA that participated in the program

Farmers profile	Total	Percentage%
Age		
Less than 20 years		
21-30 years	45	12
31-40 years	182	48
41-50 years	64	17
More than 51 years	88	23
	Education/Qualification	
Not in school	12	3.2
Primary school	172	45.4
Secondary school	182	48
Tertiary education	13	3.4
	Duration On Rice- Field Working	
Less than 5 years		
5-10 years	16	4
10-15 years	127	33
16-20 years	78	21
More than 20 years	158	42

Source: Field Survey, 2021

The study further assessed the straw management practice across the study area, Table 4 shows the data on the farmers that utilizes compost in management of rice straw.

Table 4: Response on compost application to rice straw management

No of farmers	Rice variety	Soil type	L.G.A	No. of hectare	Planting method	% percentage	Tone produced/ha
6	Faro 44	Clay-loam soil	AN/East	2	Row planting 20cm x 20cm	27	5.5 tons
10	Faro 44	Clay-loam	AN/West	2	Row planting 20cm x 20cm	16	6.0 tons
14	Faro 44	Clay-	Awka	2	Row planting	21	6.0 tons

		loam	North		20cm x 20cm		
18	Faro 44	Clay-loam	Ayamelum	2	Row planting 20cm x 20cm	16	6.5 tons
23	Faro 44	Clay-loam	Orumba south	2	Row planting 20cm x 20cm	20	5.0 tons

Source: Field Survey, 2021

In the response to compost application in rice straw management (Table 4), the data revealed that 18.7% of the total respondents applied rice straw as compost back to the field. This has not only boast their rice productivity to the tune of 6.5 tons/ha but has also reduce their cost of production in terms of disease and pest control as most of this pests and disease causing organisms are destroyed as a result of high temperature range during composting process. Weed growth is naturally suppressed since compost was applied as mulch. This management option reduced over- reliance on pesticides and herbicides and thus their run-off into natural water bodies (Barzan et al., 2015). Faro 44 rice variety is mostly planted by rice farmers because of its high yielding capacity and early maturity. Some of the farmers for various reasons practice straw open combustion in the field, to convert the straw to ash, Table 5 shows the data obtained from farmers who practice this system of rice straw management.

.**Table 5:** Response on rice straw ash application management option (open burning of the straw)

No of farmers	Rice variety	Soil type	L.G.A	No. of hectare	Planting method	% percent age	Tone produced/ha
9	Faro 44	Clay-loam	AN/East	2	Row planting 20cm x 20cm	41	2.0 tons
35	Faro 44	Clay-loam	AN/West	2	Row planting 20cm x 20cm	58	2.5 tons
33	Faro 44	Clay-loam	Awka North	2	Row planting 20cm x 20cm	51	2.0 tons
75	Faro 44	Clay-loam	Ayamelum	2	Row planting 20cm x 20cm	65	3.5 tons
63	Faro 44	Clay-loam	Orumba south	2	Row planting 20cm x 20cm	55	2.0 tons

In the response to rice straw ash application management option (Table 5), the rice crop productivity ranged from 2.0 tones produced per hectare to 3.5, this is low compared to that of rice straw compost. This is probably as a result of high loss of plant nutrients and destruction of soil micro-organisms that aids in improving the soil nutrient during the burning of the rice straw. The result revealed that 56.73% of the total respondents indulge in this straw management option. The process does not only retard the yield of rice production but also promote environmental pollution as much greenhouse gases are released into the environment, in addition this system of poses health problems to living organisms in the ecosystem (Chen et al., 2019). Some of the farmers indulge in the practice of incorporating the straw to the soil, Table 5 provides the data obtained from farmers who practice this system of rice straw management.

Table 6: Response on rice straw compost management option

No of farmers	Rice variety	Soil type	L.G.A	No. of hectare	Planting method	% percent age	Tone produced/ha
4	Faro 44	Clay-loam soil	AN/East	2	Row planting 20cm x 20cm	18	4.0 tons
7	Faro 44	Clay-loam	AN/West	2	Row planting 20cm x 20cm	12	4.0 tons
8	Faro 44	Clay-loam	Akwa North	2	Row planting 20cm x 20cm	12.3	4.5 tons
9	Faro 44	Clay-loam	Ayamelum	2	Row planting 20cm x 20cm	7.8	4.5 tons
18	Faro 44	Clay-loam	Orumba south	2	Row planting 20cm x 20cm	16	4.0 tons

In the response on the incorporation of rice straw management option (Table 6), the rice crop produced varied from 4.0 tones produced per hectare to 4.5, this is lower to the output from rice straw compost management option, but however better than the open field burning system. The data showed that 12.13% of the total respondents practice this rice straw management option. According to Romansanta et al., (2017), maximum emission reduction and yield is best achieved by rice straw incorporation. A comparative study as shown in this study indicates Romansanta et al., (2017) assertion might not be the best for the study area. that Soil with low organic carbon benefits from increased straw incorporation to maximized soil organic carbon sequestration and increases yield with minimum methane emission (Monteleone et al., 2015). The time consuming process of straw decomposition probable affected the adoption of this management option, and reduced the number of rice farmers that adopt the system.

Factors that Influence the adoption of rice straw management option

Results revealed that there are several factors that influence farmers' adoption of a particular rice straw management option; such as agronomic issues, facilities and farmers attitude etc. Table 7 shows the data obtained on the factors that influence a farmers' straw management option.

Table 7: Factors that influences farmers adoption of a rice straw management method in the program

Factors	More influence		Less influence		Un-influence	
	Total	%	Total	%	Total	%
Agronomy issues						
i. Conscious of weather condition	224	59	152	41	3	0.79
ii. Disease and pest attack consciousness	215	57	117	31	46	12.13
iii. Limited time for the crop production	215	57	110	29	53	13.98
Facilities						

i. Lack rice straw collection Technology	247	65	92	24.3	40	10.55
ii. Lack of logistics facilities						
a. Storage	220	58	112	29.55	47	16.85
b. Transportation	232	61	137	36	10	2.6
Farmers perspectives						
Low level of skills and knowledge	184	48.5	182	48	13	3.4
Lack of capital	274	72.29	95	25	10	2.6

The Table 7 indicates that lack of capital and technological facilities for improved management practices was ranked the highest about 72.29 and 58 to 65 percent, respectively. Most farmers (59%) stated that harvesting in the rainy season is a key factor that influences the adoption of rice straw management option. Information garnered from the interviews shows that wet rice straw could not be used as a by-product because of the poor quality and would also be mouldy when stored. It is therefore burnt after drying from sun light, this is associated with heavy smoke. About 57% of farmers adopts rice straw burning in order to eliminate sources of pest and disease causing organisms from attacking the next crop plantation. Consequently lack of rice straw collection technology such as baler machines and trucks for transportation of the rice straw led to the poor management options and utilization of rice straw in a sustainable way as stated by 65% of the rice farmers. The result also revealed that 48.5% of farmers acknowledged that they lack technical skills on rice straw management options that could boast their rice yield and therefore require appropriate training. Therefore, appropriate scheme that incorporates best practices in straw management will be critical for environmental sustainability in the region.

5.0 Conclusion

Upgrading the value chain of rice straw-by products and employing sustainable straw management practices is the key to influence farmers not to practice open-field burning and thus avoid the negative environmental and health consequences. Incorporating rice straw into the soil as an option, needs to be considered carefully to ensure timely decomposition and to minimize greenhouse gas emissions. Alternative straw management option such as composting to produce organic fertilizer proves to be more environmentally sustainable and increases rice yield especially when animal droppings (manure) are incorporated in the composting process to facilitate its decomposition rate in an aerobic environment. Poor rice straw utilization in the five participating LGA in Anambra state value chain development program is shown by low rice production per hectare as a result of poor management practices. Mechanized collection of rice straws should be adopted and balers provided by relevant agencies as it plays a critical role in the sustainable use of rice straw. Sensitization on rice straw management both on field and off-field is needed to further promote best agronomic activities and environmental sustainability. If efficiently demonstrated in the field, with continuous advise from extension workers on theory and practices, farmers will be more skilled and knowledgeable, as well as competitive in managing their crops and crop residues.

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ASSESSMENT OF POST-HARVEST HANDLING PRACTICES OF WATERMELON IN KANO STATE, NIGERIA

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Abstact

The knowledge of the existing traditional post-harvest practices and the techniques applied to agricultural product handling and processing by farmers in developing countries are needed to understand the areas where improvement is required. Because the information assists the food processing engineers in the upgrade design, fabrication and performance evaluation of improved equipment that will alleviate the drudgery in that aspect of farming. In the present study, the post-harvest practices of watermelon fruit along the supply chain in some areas of Kano state were investigated. The survey was done using a structured questionnaire in which relevant questions were asked. The population consists of both the watermelon farmers and the fruit vendors in the selected areas. The results showed that the activities of post-harvest handling of watermelon are predominantly carried out by male workers, this can be attributed to the religious and cultural background of the people in the study area. The results indicated that 78.70% of the respondents have experience of at least 5 years. Based on the local taxonomy, the major types of watermelon in the areas are the *Baka*, *Fara*, *Mai-Yashi* and *Rosma* with the percentage of availability of 33.30%, 33.30%, 24% and 9.30%, respectively. Three main types of transportation used to convey watermelon in the area are carrying on the head, wheelbarrow and trucks. Sorting and grading of watermelon are usually done manually and these could cause serious health problems because of the drudgery and poor posture involved. The majority of the watermelon produced in the area is consumed directly and it is a very small quantity that is used for industrial processing such as beverages and powder juice. An assessment of post-harvest handling practices of watermelon in Kano state, Nigeria was carried out to know the level of technology involved. It was observed that the traditional methods of handling the fruits which are rigorous, injurious, unhygienic and time-consuming prevail. Therefore, there is the need to increase efforts toward developing small and medium-scale processing devices such as fruit ripening testers, conveyors, fruit peeling machines, juicers and dryers to alleviate the present situation of the watermelon industry in the area.

Keywords: Survey**,** post-harvest practices, watermelon handling, processing, storage.

1.0 Introduction

Fruits and vegetables are plant materials performing a key role in maintaining human health, especially in disease prevention, growth and development. They are excellent sources of minerals, vitamins, and enzymes that are easily digested and exercise cleansing effect on the blood and the digestive tract (Diana, 2018). In the recent era, fruits and vegetables are becoming popular due to consumer awareness regarding their health-enhancing potential (Naz et al., 2013).

Watermelon (*Citrullus lanatus*) belongs to the family of Cucurbitaceae plants (Edwards et al., 2003). Its fruit has a thick rind (exocarp) that has variable pigmentation with a solid or striped appearance, a fleshy mesocarp, and an endocarp that varies in colour from white to yellow or red (Bahari et al., 2012; Munisse et al., 2013). Watermelon is a cheap, nutritious and readily available fruit for all the socio-economic groups in Africa. It is a fruit with the potential to improve nutrition, boost food security, foster rural development, and support sustainable land conservation (Ufoegbune et al., 2014). Therefore, any effort to improve its production and processing is an effort in the right direction. Watermelon flesh is a source of carotenoids, Vitamins A, B6, C, lycopene, and antioxidants. Watermelon rinds are edible containing many nutrients (Jensen et al., 2011). In Sudan and Egypt, watermelon seeds are roasted, salted, and eaten as snacks. Watermelon fruit is used as a source of drinking water during drought seasons in parts of Sudan and Nigeria (Ayodele and Shittu, 2013; Goda, 2007). Nutritionally, watermelon contains more than 91% water and up to 7% of carbohydrates. It is a rich source of lycopene, citrulline, many essential micronutrients and vitamins. Medicinally, watermelon contains high levels of lycopene which is very effective in protecting cells from damage and reducing the risk of heart disease (Le et al., 2005). The lycopene in watermelon makes it an anti-inflammatory fruit and an inhibitor for various inflammatory processes and also works as an antioxidant to neutralize free radicals (Edwards et al., 2003). The fruit contains a good amount of vitamin B6 (pyridoxine), vitamin C and manganese. Watermelons are the perfect example of a food that can help you stay hydrated because it is rich in electrolytes and water content. Vitamin A in watermelon helps keep skin and hair moisturized and it also encourages the healthy growth of new collagen and elastin cells. Like other fruits and vegetables, watermelons may help in reducing the risk of cancer through their antioxidant properties. According to the National Cancer Institute, Lycopene in watermelon help in reducing prostate cancer cell (Naz, et. al., 2014).

Post-harvest losses of watermelon are estimated at 5-20% in developed countries and 20- 50% in developing countries (Mashav, 2010). In Nigeria post-harvest Losses of watermelon amounts to 35-45% of the annual production (FAO, 2004). The huge post-harvest loss is due to the lack of watermelon fruit processing factories that process the fruits into more durable forms (bottled juice, sachet beverages powder etc), especially during the glut period. Other important factors that contribute to the post-harvest losses of watermelon include environmental conditions such as heat, drought, damage during harvesting and handling, improper post-harvest sanitation, unsuitable packaging materials, and poor cooling and storage practices (Byezynski, 1997). Vibrations resulting from transportation transfers undulations and irregularities on the products, contribute greatly to post-harvest losses (Fejokwu, 1992). A little effort can make a huge difference when applied correctly, for example reducing mechanical damage during harvesting, sorting, grading and good packaging greatly decreases the likelihood of post-harvest losses due to pathogens, because pathogens enter through wounds. This simple step would improve the overall quality and food safety, translating to higher profits for growers, marketers and even processors.

Due to the foregoing problems, the objectives of this study are to assess the post-harvest handling practices of watermelon in Kano state. It is expected that the present study would provide useful information that can be used to identify the causes of losses in the supply chain of watermelon. Also, the information can be used by engineers in providing better handling methods and equipment that can curtail these losses, reduce the drudgery in the current process and upgrade the quality of our watermelon to meet the international market standard. This study focused on the assessment of the post-harvest handling practices of watermelon in *Karfi konar Dan-hassan, Na'ibawa Yanlemo, Yankaba* and *Ɓagwai* town Kano State Nigeria. These areas were selected because they are watermelon production cluster areas in Kano.

2.0 Materials and Methods

Similar to the method of Aviara and Haque (2002), the study was carried out using a questionnaire, field trips and interviews with the watermelon farmers and vendors in the study areas. The questionnaire focused on the socioeconomic information of the respondents, harvesting methods, storage techniques, available variety of watermelon, loading and unloading methods, transportation, sorting/grading and packaging methods used and also constraints and limitations in watermelon handling.

2.1 Sampling Procedures and Sample Size

In sampling, four watermelon production cluster areas were adopted. These include, *Karfi konar Dan-hassan* (*Kura* LGA), *Na'ibawa Yanlemo* (*Kumbotso* LGA), *Yankaba* (*Nasarawa* LGA) and *Ɓagwai* Town (*Bagwai* LGA). A total of seventy-five (75) questionnaires were used in the study. Each respondent was separately interviewed and responses were filled on to the questionnaire. The responses of all the respondents were then gathered, analyzed and discussed. Analyses of the data obtained were done using descriptive statistics including the percentage, and the frequency table.

3.0 Results and Discussion

3.1 Socio-Economic Information

From the data collected (Table 1), it was revealed that 100% of the respondents were males this infers no female respondents. Therefore, the activity of handling watermelon fruits is predominantly carried out by male workers and this can be attributed to the socio-cultural and religious background of the people in the study area. The study revealed that 69.30% of the respondents are below 40 years of age, which shows that majority of the respondents are youths, this may be because of the rigour and high energy requirement of the handling process of watermelon. Also, it was found that 21.30% of the respondents have 1 – 4 years experience in the work, 42.70% of the respondents have 5 – 9 years experience the work, and 36% are in the business for 10 years and above. It can, therefore, be concluded that 78.70% of the respondents have enough experience of at least 5 years which is enough to know the nitty-gritty required in the work and the information from them will be more reliable based on their years of experience.

Table 1. Socio-economic Information of the Respondents

Parameter (s)	Frequency	Percentage (%)
Gender		
Male	75	100
Female	0	0
Total	75	75
Age (Years)		
Below 20	18	24
20 – 40	34	45.30
Above 40	23	30.70
Duration in Business (Years)		
1 – 4	16	21.30
5 – 9	32	42.70
10 and above	27	36

3.2 Varieties of Watermelon Available in the Study area

It could be observed from the results that different varieties of watermelon are available in the study area. Based on the local taxonomy, the predominant types of watermelon in the areas are the *Baka* (dark green) 33.30% and the *Fara* (light green) 33.30% as presented in Figure 1. The possible reasons for these varieties dominating the market could be because the two varieties are always available all year round. The other varieties available in the study area include *Mai-Yashi* (grits mesocarp) and *Rosma* (light green with dark green strips) as shown by the percentage of availability (24% and 9.30%, respectively). The information here is a clue for the food processing engineers who might want to design equipment for the processing of the available varieties of fruits.

3.3 Harvesting

Fruit quality is an important attribute in the production of watermelons for marketing purposes (Kuvare, 2005). Generally, the consumers prefer ripened red-fleshed fruits (usually sweet) as opposed to those that are not ripe white or yellow-fleshed fruits (usually not sweet). Most farmers harvest the watermelon fruits manually by using hoes or sickles when it is fully matured. It is always a big challenge for novices to identify a ripened watermelon, but experienced farmers and the vendors in the area have their methods of checking for the ripeness of the fruits. Some of the methods employed in identifying the ripened watermelon are: the fruit sound method, checking for the dryness of the pedicel of the fruit. These methods are very subjective and many at times fail. Therefore, there are needs to develop a reliable watermelon fruit ripen tester. The study showed that two safety precautions are observed to prevent the damage of the harvested watermelon fruits. These include precooling and gentle handling of the harvested fruits.

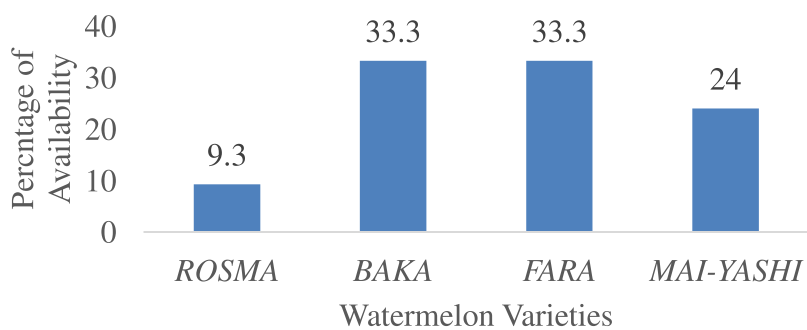

Figure 1: Watermelon varieties availability in the study area

3.4 Method of Transportation and Packaging materials used

From the result obtained, it was established that there were three (3) main types of transportation methods usually employed by the respondents depending on the destination distance and quantity of watermelon handled. These are carrying on the head, wheelbarrow and trucks. To aid the transportation, packaging materials such as baskets, plastic sacks or jute bags are employed.

i. *Head conveyance*

The use of the head involved carrying the sack of watermelon on the head or back of an individual called '*Yan Doko*' to the intended destination. This method is usually employed for short-distance transportation of fruits within 1-2 km. The method results in a lot of hardship and drudgery during transportation. This might also result in the deformation of some portion of the watermelon in the sack, thus by extension, it is a loss to the dealers.

ii. *Wheelbarrow conveyance*

The conveyance using wheelbarrows involved carrying the sacks or individual fruits of watermelon on the wheelbarrow as shown in Plate 1. This provides some sort of convenient way of transporting the sacks or individual watermelon fruits with minimum damage. The disadvantage of this method is that only a few sacks or fruits could be carried at a time and over a few kilometers.

Plate 1: Watermelon Conveyance using Wheelbarrow

iii. Truck conveyance

The use of a truck to transport the watermelon fruits (Plate 2) provides a more convenient way of transporting large quantities of the fruits over a long distance that is over several kilometers with little damage to the products. In truck transportation sometimes, damages do occur during the loading and unloading of the fruits. This is because the loading and the unloading are done manually by throwing the fruits serially amongst the labourers who are positioned at a certain distance to each other between the fruits in the truck and the place in the store where the fruits are to be kept. This problem can be solved by providing a mechanical conveyance system to transport from the truck to the store and vice vasa.

3.5 Sorting and grading method

It was observable that the watermelon dealers in the study area usually perform two sorting operations. The first operation is grading which is to separate the damaged watermelon from undamaged and the second sorting are to group the watermelon based on size and variety. Both two types of sorting are usually done manually as witnessed in the study area. This is of concern due to the volume of watermelon being handled. These operations may cause serious health problems because of the drudgery and poor posture while performing them. There is a need for mechanized sorting devices/systems for these operations

3.6 Storage Method

The study revealed that most watermelon dealers do not engage in long-term storage of the fruits. This is because the fruit is perishable and can only be kept just for a few weeks. Traditionally, while awaiting a buyer of the fruits, the dealers jumble-packed the watermelon fruits on the bear floor under a shed or in a well-ventilated warehouse. Plate 4 presents the covered and uncovered stored watermelon fruits. The fruits in the store are attacked by pests such as rodents, insects or theft. It is also being damaged by microbes like fungi and bacteria or as a result of over-ripening which causes changes in texture, aroma and flavour. To reduce the losses incurred due to pests and microbes, there is a need for the processing of the fruits locally to a more stable form such as dried powder form and fruit juice.

Plate 2: Watermelon Conveyance using Truck

3.7 Uses of Watermelon

The results from the respondents on the uses of watermelon show that the fruits are used for juice making, direct consumption and industrial purposes. Figure 2 presents the different uses of watermelon in the study area. From the results 16% of the watermelon produced in the area are used for fruit juice, 51% are used for direct consumption and only 8% is purchased for industrial uses. it can therefore be concluded that the majority of the watermelon produced in the area is consumed directly and it is a very small quantity that goes for industrial processing such as beverages and powder juice. This explains the reason why plenty part of the fruits produced are being lost to pest attacks and microorganisms. Therefore, food processing engineers need to increase efforts towards developing small and medium-scale processing devices such as fruit ripening testers, fruit peeling machines, juicers and dryers, for the product to alleviate the present situation in the watermelon industry of the area.

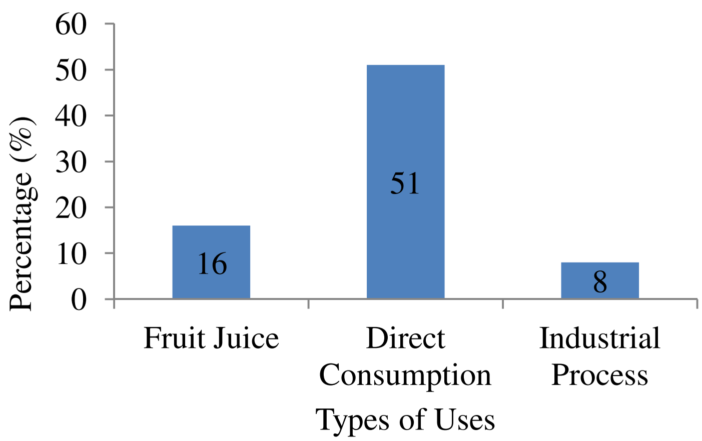

Figure 2: Uses of Watermelon in the Study Area

4.0 Conclusion and Recommendations

An assessment of post-harvest handling practices of watermelon in Kano state, Nigeria was carried out to know the level of technology involved. It was observed that the traditional methods of handling the fruits which are rigorous, injurious, unhygienic and time-consuming prevail.

In the light of the above, there is, therefore, the need to improve the various methods of handling, processing and storage of watermelon in the study area based on the following recommendations:

i. A reliable watermelon fruit ripens tester should be developed to tackle the subjective nature of the present method used which often fails.
ii. A mechanical conveyance system should be introduced to transport the fruits during loading and unloading to reduce the damage incurred during transportation.
iii. The sorting and grading of the fruits should be mechanized to reduce the drudgery of the process.
iv. Generally, there is the need to develop processing equipment for watermelon fruits such as fruit peeling machines, juicers and dryers to reduce the losses and increase the industrial use of the fruits.

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MODIFICATION AND PERFORMANCE EVALUATION OF A COWPEA SHELLING MACHINE

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Abstract

Institute for Agricultural Research (IAR) Zaria had a cowpea shelling machine which was developed in 1985 and the design was based on the properties of the then cowpea variety. New varieties were later developed whose acceptability in practice override the initial variety. This called for the modification of initial developed cowpea shelling machine and evaluation using the new crop varieties. The machine size was modified which involves redesigning of its components for the new variety . The machine consists of the hopper, shelling cylinder, removable concave, blower, chaffs outlet, grains delivery chute, clearance adjuster and frame. A combination of three cylinder speed levels; 2.39, 2.59, and 2.79 m/s (120, 130 and 140 rpm) and three feed rates levels; 12, 15 and 18 kg/min, were used for the evaluation. The results were analyzed statistically in a completely randomized block design and Least Significant Difference (LSD) method was employed to assess the effect of parameter levels. The optimum performance was found at a cylinder speed of 2.79 m/s (140 rpm) with a feed rate of 12 kg/min and a 10 mm concave clearance. These resulted in output capacity, shelling efficiency, cleaning efficiency, scatter loss, and damaged grains of 546.18 kg/h, 93.24 %, 98.31 %, 0.625 % and 0.00 % respectively. Most of the performance indices increased with the increase in cylinder speed but indicated no specific pattern with the increase in feed rate. The effects of the selected variables on the performance indices were assessed and found that the effects of cylinder speeds and feed rates were not significant on all indices except scatter loss and output capacity.

Keywords: Modification, Performance evaluation, Performance indices, Cowpeas, Parameter levels

1.0 Introduction

Cowpeas (*vigna unguiculata*) also called black-eyed pea or southern pea or locally known as "wake" or "beans" are annual leguminous crops yielding grains or seeds used for food, feed and sowing purposes. Cowpeas are crops yielding from one to twelve seeds of variable size, shape, and colour within a pod. In addition to their values as food and feed stuffs, cowpeas are also important in cropping systems for their ability to produce nitrogen and thus increase the fertility of the soil (FAO, 2011). Cowpea is one of the most economically and nutritionally important indigenous African grain legumes produced throughout the tropical and subtropical areas of the world (GATE, 2008). In Africa, despite the values of cowpea, the methods involved in its production, harvesting and shelling are mostly manual. For instance, shelling is done by pounding in a mortar with a pestle or spreading the dried crop on the floor where it is beaten with a stick (Dauda, 2001). Cowpea cultivation is very essential in Nigeria; it plays a key role in the agriculture and food supply of the country. Nigeria is the largest producer and consumer of cowpeas, accounting for about 45 percent of the world's cowpea production (GATE, 2008). However, most of the farmers grow it as inter crop (Rowland, 1993), though its post-harvest operations are mostly done manually due to lack of precise machines for such operations and this curtailed its effective productivity.

Production of cowpea on a large scale is likely to continue to increase with the adoption of improved production technology and availability of wider market. This would mean a higher demand on labour for all farming operations particularly harvesting, threshing, cleaning and grading (Irtwange, 2009). Most of the imported shelling machines are very costly and hence beyond the reach of Nigerian small-scale farmers. Some have been found unsuitable for shelling the local varieties (Adewumi *et al.*, 2007a). If there has to be increased production of cowpea, farmers have to be provided with the means by which their products can be processed with minimum drudgery, cost and achieving good quality products. Due to the lack of an efficient motorized machine to shell cowpea, small scale farmers generally depend upon manual shelling.

Institute for Agricultural Research (IAR) Zaria had a cowpea shelling machine which was developed in 1985 and the design was based on the properties of the then cowpea variety. New varieties were later developed and were tested on the machine. The machine usually got chocked with a lot of cracks and breakages on the grains. This called for the modification of initial developed cowpea shelling machine and evaluation using the new crop varieties. The machine size was modified which involves redesigning of its components for the new variety. The machine components modified include the hopper, shelling cylinder, concave clearance, blower, chaff outlet, grain delivery chute, and frame.

2.0 Materials and Methods

2.1 Materials Used

Gauge 16 (A36 mild carbon steel) with a Minimum yield stress of 250 MPa and ultimate tensile strength of 400 – 550 MPa was used for the production of machine members such as cylinder, sides and top cover of cylinder housing while Gauge 18 plate was used for blower casing, fan blades, chaffs outlet frame, feed hopper, grain delivery chute among others. Medium carbon steel alloy rod (C1040) with yield stress of 568.7 MN/m^2 and ultimate tensile strength of 668.8 MN/m^2 was used for the shafts. The beaters were made from cast iron bars. The materials used for the performance evaluation of the machine were 12 bags of unshelled cowpea (Kanannado) for preparation of samples, tachometer for the measurement of cylinder speed, weighing balance for quantifying samples, and stop watch for recording the shelling time.

2.1.1 Sample preparation

A local variety known as *Kanannado*, used for this study, was procured locally from local farmers in Zaria. The bulk of materials were prepared in to 28 samples of 12, 15 and 18 kg as feed rates.

2.2 Methodology

2.2.1 Description of the modified machine

The cowpea shelling machine used in this present study, is a modified form of IAR groundnut shelling machine (figure 1). The machine shells and cleans. The two processes are achieved in one operation with the delivery of clean grains at the grains outlet. It consists of the prime mover, shelling unit and cleaning unit. The prime mover is a diesel engine of 6 hp capacity. The components of the machine are; hopper, shelling cylinder, removable concave, clearance adjuster, blower, chaffs outlet, grains delivery chute and frame.

Figure 1: A Pictorial View of the Modified Shelling Machine

2.2.2 Operational procedure

The crops were fed through the hopper to the shelling chamber where shelling is achieved by impact and rubbing action of the cylinder. The shelled materials were pushed through the concave to the cleaning chamber where a stream of air from the blower passed across the falling materials to blown off the chaffs to the chaffs outlet and allow grains to be delivered to the grains outlet.

2.2.3 Design considerations

This research work adapted a cylinder speed range of 130 rpm (2.59 m/s) to 160 rpm (3.18 m/s) Abou El-Kheir and Shoukr (1993). The machine height of 110 cm was adapted from the report of Smith *et al.*, (1994), for the purpose of the machine height reduction to enable easy access during operation. A moisture level of 11.11 % was used as the moisture content of the crop during the operation.

2.3 Power Required for Shelling

The power required for shelling as reported by Abubakar and Abdulkadir (2012) is;

$$H = WK_k\, F_C Log\frac{L_1}{L_2} \quad (1)$$

Where: H = Power W, F_C = Crushing strength of groundnut (N/m²), K_k = Kick's constant (1.2), W= Average weight of unshelled groundnut (kg), L_1 = Average length of unshelled groundnut (m), L_2 = Average length of shelled groundnut (m). This was determined to be 0.387 kW (0.526 hp) for the used variety.

2.4 Design Calculations

2.4.1 Shafts design

2.4.1.1 Determination of shafts torsional moment

Hall and Hallowenko, (1982) gave torsional moment as;

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

Where: P = Power required for shelling (W) and S = Speed of the prime mover (rpm) M_t = 20.62 Nm and 48.65 Nm for cylinder and fan shaft respectively

2.4.1.2 Determination of shaft bending moment

The bending moment (M_b) was determined based on the lateral loadings on the shaft. The loads were weight of the pulleys, weight of the shelling drum, weight of the fan blades and belt tensions. Total bending moment, M_b = 177.90 Nm and 75.11 Nm for cylinder and fan shaft respectively

2.4.1.3 Shafts diameter

The shafts sizes were determined using relationship given by Hall and Hallowenko, (1982). As;

$$d_s = \frac{16}{\pi\tau_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (3)$$

Where: d_s = Shaft diameter (mm), K_b = Shock and fatigue factor applied to bending moment = 1.5, K_t = Shock and fatigue factor applied to torsional moment = 1.0, M_t = Torsional moments (Nm), τ_s = Allowable stress of the steel shaft (40 N/mm^2)

Hence, d_s = 32.42 mm and 25.00 mm for cylinder and fan shaft respectively

2.4.2 Power transmission parameters

2.4.2.1 Belt length

The effective belts length was determined using the relationship outlined by Sanjay (2010);

$$L_b = \frac{\pi}{2}(D_1 + D_2) + \frac{(D_1 - D_2)^2}{4x} + 2x \qquad (4)$$

Where: D_1 = Diameter of driver pulley (cm), D_2 = Diameter of driven pulley (cm), x = Center to center distance between the driver and driven pulley (cm) Hence, the fan belt was determined 142.10 cm while the cylinder belt was 112.44 cm

2.4.2.2 Belt tension

The following expressions were used to determine the belt tension (Sanjay 2010);

$$M_t = (T_t - T_s)R \qquad (5)$$

$$\frac{T_t}{T_s} = e^{\mu\theta Cosec\beta} \qquad (6)$$

Where: T_t and T_s = Tension in the tight and slack side of the belt respectively (N), R = Radius of the shaft pulley (m), μ = coefficient of friction between the pulley and belt, θ = angle of contact between the pulley and belt (^{o}), β = half angle of groove of the pulley (^{o}), when μ = 0.25, 2β = 34^o, and θ = 170^o. Therefore, the tensions in the tight and slack side of the fan belt were determined 877.5 N and 6.5x10^{-61} N respectively while those of cylinder belt were 1755 N and 1.6x10^{-60} N respectively.

2.4.2.3 Belt speed

Belt speed was estimated using the expression given by Khurmi and Gupta (2007) as;

$$V = \frac{\pi DN}{60} \qquad (7)$$

Where: V = Belt speed (m/s), N = Drive speed (rpm), D = Diameter of drive pulley (m)

The fan and cylinder belt speeds were 5.03 m/s and 2.51 m/s respectively.

2.4.2.4 Pulley diameters and speed ratio relationship

The pulleys diameter was determined using the expression outlined by Sanjay (2010) as;

$$N_1 D_1 = N_2 D_2 \quad (8)$$

Where: N_1 = Speed of driving pulley (rpm), N_2 = Speed of driven pulley (rpm)
D_1 = Diameter of driving pulley (cm), D_2 = Diameter of driven pulley (cm)
The sizes and speeds of 4 pulleys were determined as prime mover pulley (D_p = 8 cm and N_p = 1200 rpm), fan shaft pulleys (D_{f1} = 8 cm and N_{f1} = 1200 rpm, D_{f2} = 4 cm and N_{f2} = 1200 rpm) and cylinder shaft pulley (D_c = 38 cm and N_c = 130 rpm).

2.4.3 Blower design parameters

2.4.3.1 Number of blades required

For the number of blades required the following expression was used (Mohammed 2009).

$$N_b = \frac{4WDV_t}{\pi L d^2} \quad (9)$$

Where: d = Diameter of air flow rate channel (0.08 m), W = Width over which air is required (0.12 m), L = Width of the inlet duct minus the clearance (0.187 m), V_t = Terminal velocity of the seed (7.59 m/s), D = Dimensional properties of crop seeds (0.836 m).Therefore, N_b = 4 blades

2.4.3.2 Weight of the fan blades

The weight of the fan blades was determined using the relation (Mohammed, 2009);

$$W_f = \delta g v \quad (10)$$

Where: W_f = Weight of the fan blade (N), δ = Density of the fan galvanized steel blade (7850 kg/m^3), g = Acceleration due to gravity (m/s^2), v = Volume of the fan blades (8.453x10^{-5} m^3). Hence, W_f = 6.51 N

2.4.3.3 Air discharge through the blower

The air discharge through the blower was determined as (Joshua, 1981);

$$Q = V D_a W_a \quad (11)$$

Where: Q = Air discharge rate (m^3/s), V = Velocity of air required for cleaning (19.48 m/s), D_a = Depth of air stream (0.08 m), W_a = Width over which the air is required (0.12 m). Hence, Q = 0.187 m^3/s

2.5 Machines Performance Evaluation

The performances were evaluated as outline by Abubakar and Abdulkadir, (2012).

i) Shelling efficiency, S_e (%):
ii)

$$S_e = \frac{(Q_T - Q_U)}{Q_T} x100 \quad (12)$$

iii) Cleaning efficiency, C_e (%):

$$C_e = \frac{Q_G}{W_C} x100$$
(13)

iv) Grains split, G_s (%):

$$G_s = \frac{Q_D}{100} x100 \quad (14)$$

v) Scattered loss, S_L (%):

$$S_L = \frac{W_S}{Q_T}\ x\ 100 \quad (15)$$

vi) Output capacity, C_P (kg/hr):

$$C_P = \frac{Q_g}{T} \quad (16)$$

Where: Q_D = Quantity of damaged groundnut in sample (kg), Q_g = Total quantity of grains collected per unit time (kg), Q_G = Quantity of shelled groundnut (kg), Q_L= Quantity of scattered, damaged, and unshelled grains (kg), Q_T = Total quantity of groundnut sample (kg), Q_U = Quantity of unshelled groundnut (kg), T = total time of shelling (hr), W_C = Weight of whole materials collected at the outlet (kg), W_S = Weight of scattered groundnut (kg

3.0 Results and Discussion

3.1 Effect of Cylinder Speed and Feed Rate on Machine Performance

3.1.1 Effects of cylinder speed on shelling efficiency at various feed rates

The shelling efficiency ranges from 92.29 % to 95.75 % at a speed of 2.39 m/s (120 rpm) and 2.79 m/s (140 rpm) respectively. The minimum efficiency was obtained at a feed rate of 12 kg/min while maximum was at 18 kg/min (Table 1). Dauda (2001) presented threshing efficiency between 84.1% to 85.9% for a manually operated cowpea thresher while Adewumi et al. (2007a) reported a threshing efficiency in the range of 67.5 - 97.7 % for a motorized medium scale thresher-cleaner and Irtwange (2009) reported a range of 95.49 – 96.98 % threshing efficiency of a motorized cowpea thresher for Nigerian small scale farmers.. The shelling efficiency increased with increase in cylinder speed at different feed rates which was due to increase in impact force on the pods as shown in Figure 2. It could be seen from the figure that the shelling efficiency increased with the increase in feed rates at all speed levels except 2.39 m/s. This is because the feed rates do not chock up the shelling chamber and the cowpea pods were not hard; hence, could easily be shelled. The results of the analysis of variance shows that the effect of speeds, feed rates and their interactions were not significant on shelling efficiency at 5% level of confidence (Table 2).

Table 1: **Average calculated data for the evaluation of cowpea Shelling machine**

S/N	TRMT	CRC (mm)	SPD (m/s)	FDR (kg/min)	S_e (%)	C_e (%)	G_s (%)	S_L (%)	C_p (Kg/h)
1	S1F1	10	2.39	12	93.25	97.80	0.000	0.413	299.93
2	S1F2	10	2.39	15	92.75	97.62	0.000	0.175	331.12
3	S1F3	10	2.39	18	93.84	96.97	0.000	0.179	276.76
4	S2F1	10	2.59	12	92.29	98.22	0.000	0.559	396.70
5	S2F2	10	2.59	15	94.51	97.95	0.000	0.202	463.27

6	S2F3	10	2.59	18	94.06	97.81	0.000	0.238	353.15
7	S3F1	10	2.79	12	93.24	98.31	0.000	0.625	546.18
8	S3F2	10	2.79	15	94.93	96.90	0.000	0.317	463.65
9	S3F3	10	2.79	18	95.75	98.32	0.000	0.623	372.21

Where: TRMT = Treatment, SPD = Cylinder Speed, CRC = Concave to cylinder clearance, FDR = Feed rate, Se = Shelling efficiency, C_e = Cleaning efficiency, M_d = Damaged grains, S_L = Scatter loss, C_P = Output Capacity

Table 2: Summary of the analysis of variance for the performance indices of cowpea shelling

Source of Variance	DF	Calculated F – Values				Tabulated F - Values	
		S_e	C_e	S_L	C_p	5 %	1 %
Replication	2	1.997^{NS}	0.220^{NS}	7.724**	0.90^{NS}	3.63	6.23
Speed	2	2.630^{NS}	0.468^{NS}	8.403**	203.60**	3.63	6.23
Feed rate	2	0.213^{NS}	0.658^{NS}	4.581*	54.14**	3.63	6.23
Speed x Feed rate	4	1.553^{NS}	0.651^{NS}	1.497^{NS}	14.45**	3.01	4.77
Error	16						
Total	26						

Where: DF = Degree of freedom

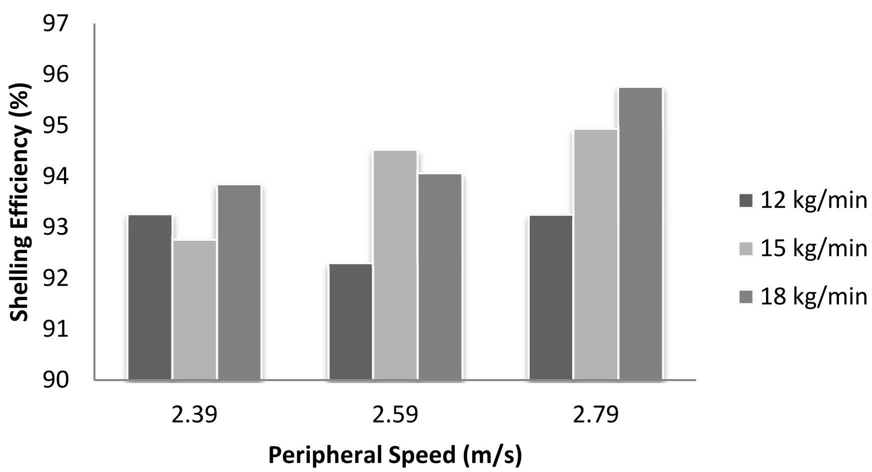

Fig. 2: Variation of cowpea shelling efficiency with the cylinder speeds at various feed rates

3.1.2 Effects of cylinder speed on cleaning efficiency at various feed rates

The cleaning efficiency of cowpea ranges from 96.90 % to 98.32 %. The minimum efficiency was obtained at a speed of 2.79 m/s (140 rpm) and a feed rate of 15 kg/min while the maximum was at a speed of 2.79

m/s (140 rpm) and a feed rate of 18 kg/min (Table 1). Dauda (2001) reported a winnowing efficiency in the range of 92.35 - 92.75 % while the cleaning efficiency of the medium-scale thresher cleaner reported by Adewumi et al. (2007b) had an effectiveness rate of 98 - 100 % for Ife-Bimpe and Irtwange (2009) reported a range of 94.62 – 96.95 % cleaning efficiency of a motorized cowpea thresher for Nigerian small scale farmers. The cleaning efficiency increased with increase in cylinder speed at different feed rates (Fig. 3) which was due to the fact that the aerodynamic properties of the cowpea pods makes its chaffs sensitive to the change in air speed and liable to be blown off as the cylinder speed increased. It could be seen from the figure that the cleaning efficiency decreased with the increase in feed rates at all speed levels except 2.79 m/s. This could be because of the inadequate volume of air required to separate the materials in bulk at a lower speed level. The results of the analysis of variance shows that the effects of speeds, feed rates and their interactions were not significant on cleaning efficiency at 5 % level of confidence (Table 2).

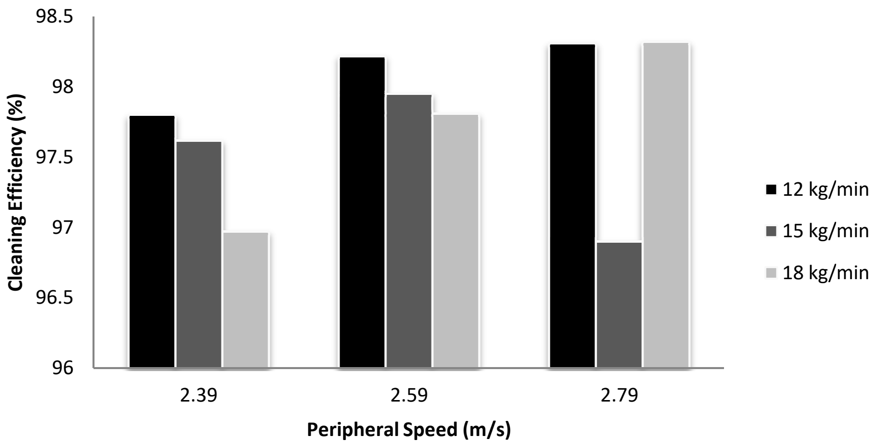

Fig. 3: Variation of cowpea cleaning efficiency with the cylinder speeds at various feed rates

3.1.3 Effect of cylinder speed on grain damage at various feed rates

The mechanically damaged grains for cowpea shelling were found to be 0.01 % for all the treatment of the cowpea shelling (table 1); however, Irtwange (2009) reported a range of 1.97 – 5.08 % grain damage of a motorized cowpea thresher for Nigerian small scale farmers and Dauda (2001) reported 1.8 - 2.3 % for a manually operated cowpea thresher. The value obtained for grain damage in this machine implies that the machine was not associated with mechanical grains damage at the selected speed and feed rate levels as far as cowpea shelling is concerned. This is attributed to the fact that the nature of the crop variety used is hard and the impact force exerted while shelling at all speed levels do not exceed its crushing strength. Hence, the grains might not break at all instances.

3.1.4 Effect of cylinder speed on scatter loss at various feed rates

For cowpea shelling, a maximum scattered loss of 0.625 % was obtained at a speed of 2.79 m/s (140 rpm) with a feed rate of 12 kg/min while a minimum of 0.175 % was obtained at a speed of 2.39 m/s (120 rpm) with a feed rate of 15 kg/min (Appendix A). Irtwange (2009) reported a range of 3.02 – 4.51 % scatter loss of a motorized cowpea thresher for Nigerian small scale farmers. The scattered losses of the machine increased with the increase in cylinder speed at various feed rates but adapted a pattern of decreased then increased with the increase in feed rates at all speed levels (Fig. 4). These were because at the higher speeds there could be more volume of air stream required to blow off the chaffs hence increasing the tendency of the premature grains to be blown off. The analysis of variance shows that the effect of speeds was highly significant at 1% level while that of feed rates was significant at 5% level on the scattered losses but their interactions were not significant at 5% level (Table 2). Further analysis of cylinder speed levels using LSD method shows that the effect of 2.79 m/s was greater than that of 2.59 m/s but 2.59 m/s and 2.39 m/s were statistically having the same effects in terms of scattered losses. For the feed rate levels, 12 kg/min and 18 kg/min were statistically at par but their effects were higher than that of 15 kg/min (Table 3). Therefore, a speed level of 2.59 m/s or 2.39 m/s in combination with a feed rate level of 15 kg/min could be the best in terms of minimum losses.

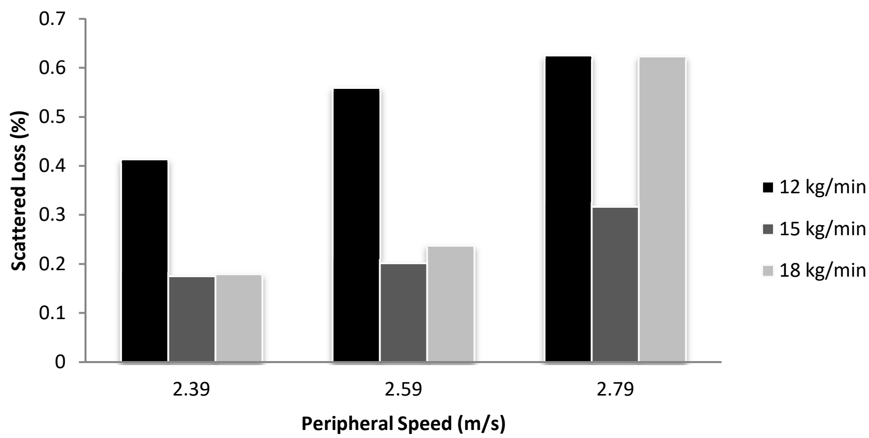

Fig. 4: Variation of cowpea grains scatter loss with the cylinder speeds at various feed rates

Table 3: Operation parameters ranks based on Fisher's least significant difference (LSD) method for cowpea shelling

Machine	**Cowpea shelling machine - Cowpea**			
Operation parameters	S_e (%)		C_p (kg/h)	
Performance indices	Speed	FDR	Speed	FDR
	S_3^a	F_1^a	S_3^a	F_2^a
Ranks	S_2^b	F_3^{ab}	S_2^b	F_1^b
	S_1^{bc}	F_2^b	S_1^c	F_3^c

Where: S = Speed levels, F = Feed rate levels

3.1.5 Effect of cylinder speed on output capacity at various feed rates

The output capacity, when evaluated with a cowpea, increased with increase in cylinder speed at various feed rates but does not have specific pattern with the increase in feed rate at various speed levels (Fig. 5). A maximum output capacity of 546.65 kg/h was obtained at a speed of 2.79 m/s (140 rpm) with feed rate of 12 kg/min. A minimum of 276.76 kg/hr was obtained at a speed of 2.39 m/s (120 rpm) with feed rate of 18 kg/min (Table 1). Dauda (2001) reported throughput capacity for a manually operated cowpea thresher of 95.4, 93.5 and 92.8 kg/h for Kanannado, Borno Brown and Aloka Local, respectively while Irtwange (2009) reported a range of 74.33 – 110.86 kg/h output capacity of a motorized cowpea thresher for Nigerian small scale farmers. Both the effects of the speeds and feed rates were highly significant at 1% on the output capacity, likewise their interactions (Table 2). When the effects of both the speed and feed rate levels were further analyzed, a speed level of 2.79 m/s was the best while that of the feed rates, 15 kg/min was the best. For their interactions, a speed level of 2.59 m/s and a feed rate of 18 kg/min formed the best interaction (Table 3).

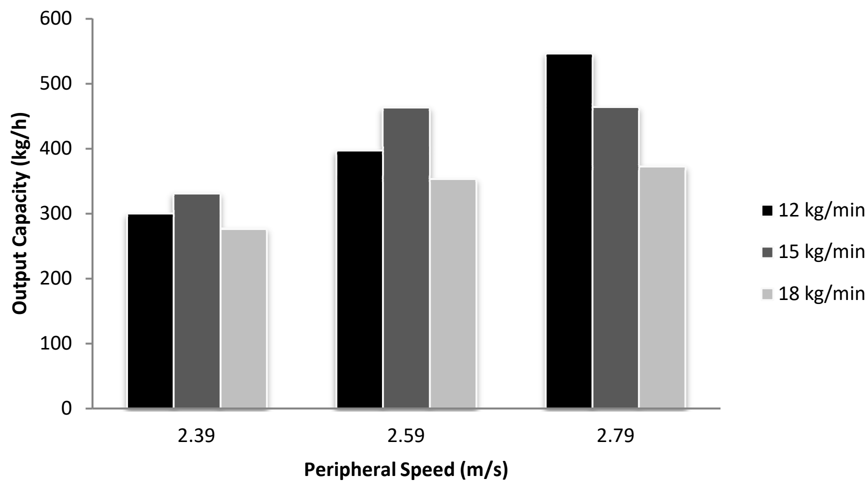

Fig. 5: Variation of cowpea output capacity with the cylinder speeds at various feed rates

4.0 Conclusions

The existing IAR groundnut shelling machine was modified for cowpea shelling and the performance of the modified shelling machine was evaluated using cowpea as test crop. Most of the performance indices increased with the increase in cylinder speed but indicated no specific pattern with the increase in feed rate. The best performance of the modified machine was found at speed of 2.79 m/s (140 rpm) with a feed rate of 12 kg/min and 10 mm concave clearance. These gave; an output capacity, shelling efficiency, cleaning efficiency, scatter loss and grain damage of 546.18 kg/h, 93.24, 98.31, 0.625 and 0.00 % respectively. The effects of the selected variables on the performance indices were assessed and revealed that the effects of cylinder speeds feed rates were not significant on all indices except scatter loss and output capacity.

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ASSESSMENT OF BANANA *(MUSA SPP)* SUPPLY CHAIN ACTIVITIES IN JEMA'A LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

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Abstract

This project research was design to assess banana supply chain in Jema`a local government Area of Kaduna state, Nigeria and to examine the influencing factors. The objectives of the study was to determine the socio – economic characteristics of the farmers and traders in the study area, determine and asses the banana supply practice and methods the farmers/traders are utilizing; to assess the farmers awareness and adaption of improved supply method and challenges militating against banana supply chain activities in the study area. Multi – stage sampling technique were used for the study, while the data were collected with the used of structural questionnaire. The data were also analyzed using both descriptive statistic, frequency distribution and percentage respectively. The result indicated that majority (33%) of the respondents were in the youthful age, more than half (57%) of the respondents were females and large family size among the respondents. Results on marital status, education status and occupation, this shows that 49% less than half of the respondents are single, while education status reveals that 28% of the respondents go beyond primary school level and 65% are for business. The distribution of respondents based on their exposure to information source reveal that less than half (8%) of the respondents acquired their information from extension agents, while 30%, 59% and 3% are aware about new methods of supplying banana through radio, television, friend and colleagues respectively. From the result it shows that 36% of the Respondents are now using other method for packaging particularly cartons, banana are packaged in perforated cartons of stable corrugated board. It was observed from the results that 80% of the respondent are aware about the improve variety of banana. Results obtained from the studies revealed that 74% of the respondent are not planting the new variety. And 55% of the respondent shows their preference on the new variety of banana, 47% shows their preference because of its easier to sale than others and 68% of the respondent are not prepared for the new variety because it's not sweet all.

Keyword: Banana, supply chain, farmers, traders, assessment

1.0 Introduction

Banana (*Musa spp)* is the fourth most valuable food products in the world after rice, tomato, and potato. It is used both as cash crop and food. It is among the world's most widely consumes fruits and varies in size, color and shape. The most common variety is the Cavendish which is green when unripe and yellow when fully ripe. Banana contains fiber as well as several antioxidants. Each fruit contains approximately one hundred and five (105) calories with ampule amount of water and carbs. Banana contains little protein with no fat (Ajibade et al., 2022).

The largest producer of banana in the world is India with an estimated annual production of 39 million metric tons representing 18% of the total world's production (FAO, 2021). Uganda is the largest producer of banana in sub Saharan African followed by Rwanda, Nigeria, Ghana and Cameroun (FAOSTAT 2021). Nigeria ranks among the largest producers of banana in Africa producing about 2.8 million metric tons annually on 450,000 hectares of land. The crop is widely cultivated in the south and central region of the country. Banana fruits have always been a staple fruit for both the rich and poor of the society of Nigeria. However, the distribution of the fruits within the country is a bit complex. Farmers' whose farms are closer to the major road network, harvest the mature green fruits and directly display it on the road or transport the fruits in bunches to a nearby market, enabling small scale wholesalers, retailers and final consumers to purchase directly. In other cases, assemblers collect the fruits from various farms then transport it to cities where they sell to wholesalers who in turn hand over the fruits to the retailers for sale to final consumers (EPAR, 2013).

Banana fruits have greatly contributed to the economy of Nigeria over the years, in terms of nutrient improvement, employment creation, extra income for the farmers and reduction of poverty in rural areas (Kamal et al., 2014). Moreover, the consumption of banana has risen tremendously in Nigeria in recent years due to rapidly increasing urbanization and the great demand for easy and convenient foods by the non-farming urban populations (Akinyemi et al., 2010). In ensuring the availability of Musa spp. and its products to millions of consumers, marketing of the commodities plays a crucial role (Idah *et al*., 2007).

Previous studies on plantain/Banana shows that the business of banana marketing is profitable. Ariyo *et al*. (2013) identified high transportation cost, rapid deterioration in quality/spoilage and seasonal price fluctuations as major challenges to plantain/Banana business in their research studies on profitability analysis of banana marketing in Kaduna State, most of the banana traded and consumed in Kaduna State Nigeria are produced in southern part and transported to northern part of the country. This translates to high transportation and marketing costs for the plantain/banana. Banana are highly perishable and, in the absence of modern technology and advanced harvesting practices, must be consumed within 3 weeks post - harvest. To reduce perishability, they require rapid distribution and marketing. Banana marketing involves the role of middlemen in getting the products, which are traded mostly in unprocessed forms, from the farms to the markets and then to the consumers. This research aimed at assessing banana supply chain in Jema'a Local Government Area of Kaduna State Nigeria and also to access the famers' awareness and adoption of improved banana supply methods.

2.0 Methodology

The study was carried out in Jema'a Local Government Area (LGA) of Kaduna State, Nigeria. The LGA is bounded by latitude 9.3827º north and longitude 8.2681º east on a total land area of 1,384 km² and a population of 278,202 at the 2006 census. Jema'a Local Government Area consist of a number of related ethnic groups and subgroups as well as a migrant population from other parts of the country, especially in the Local Government Area headquarters of Kafanchan (Fantswam) and the towns of Jema'a, Dangoma and Jagindi where the migrating Fulani population from Kajuru were accepted by the locals and settled in the early 19th century.

2.2 Methods of Data Collection

Data to this research where collected using both primary and secondary sources. The primary data were collected through structured questionnaire which was administered to the 110 respondents in the study area in order to meet the objectives of the work, while the secondary sources involve the use of relevant research reports in textbooks; student project, newspaper, guide bulletin journals and internet. The data was collected in February, 2021 for previous late harvest of 2020 production season. The questionnaire was designed with simple and straight questions, comprehensive enough to cover all the research objectives.

2.3 Data Analysis

Data was analysis performed using statistical package for the social sciences (SPSS) (version 17) Using descriptive data analysis and frequencies.

3.0 Results and Discussions

3.1. Socio-economic characteristics of the farmers/ traders

The result presented in Table 1 showss the socio- economic characteristics of the respondents. From Table 1 it can be observed that female traders dominate the marketing and supplying of Banana in the study area. From the table, 57% of the respondents are female and 43% were male. This revealed that the marketing and supplying of Banana in the study area is dominated by female gender. This can be attribute to the cultural background of the people in the study area. Banana traders were more within the age bracket of 24-31 years, followed by those between 17-23 years, followed by 32-41 and 41 above. The study revealed that almost all the suppliers of Banana fell within the active age of 17-60 years. The marital status of respondents shows that 49% of the respondents were single, 41% were married, 7% are widowers, 2% are widow and only 1% are divorced.. About 38% have secondary school education, 27% have primary education, 15% of the respondents has tertiary education, 12% attended adult education class while only 8% were found with no formal education in the study area. The study showed that majority of the respondents have formal education as it is reflected in (Table 1). This support the study of Ariyo *et al* (2013) whose finding revealed that over 87% of the plantain traders in Kaduna had formal education. From the data collected it show that 65% of the respondents are relied on the business of banana and plantain, 35% combine it with other occupation apart from the business of banana/plantain, 6 % engaged themselves as handcraft business e.g. Sewing, tailoring, saloon etc. and only 4% of the respondents in the study area are Civil servant. This revealed that the majority of the respondents relied on the business of anana.

Table 1: Socio-economic status of the farmers/traders

Variables	Categories	Frequency	Percentage
Gender	Male	43	43
	Female	57	57
Age	17-23	29	29
	24-31	33	33

	32-40	20	20
	41- above	18	18
Marital status	Single	49	49
	Married	41	41
	Divorce	1	1
	Widow	2	2
	Widower	7	7
Educational status	None	8	8
	Primary	27	27
	Secondary	28	28
	Tertiary	15	15
	Others	12	12
Occupation	Civil servant	4	4
	Business	65	65
	Handcraft	6	6
	Others	35	35

3.2 Farmers/ traders experience in banana and plantain business

Results in Table 2, shows the years of experiences in Banana/plantain business of the respondents. Banana traders who came into the business in the past 5 years were 24%, this was closely followed by those that came into the business in the last 11-15 years being 27%, followed by those with 6-10 years' experience being 25%, 26 Above being 9% and those with the experience of 21-25% being 5%. The result revealed that increased or steady growth in the number of Banana and Plantain traders in Jema`a local government area in the last eleven to fifteen (11-15) years. The Increasemay be due to growth in demand of the Banana and plantain in the study area.

Table 2 Years of Experience of Banana Traders

Age bracket	Frequency	Percentage
1-5	24	24
6-10	25	25
11-15	27	27
16-20	10	10
21-25	5	5
26 above	9	9

3.3 Method of Banana/plantain supply chain and trader's awareness about improved supply methods

It could be observed from the data collected that 51% of the traders of Banana and Plantain in the study area are aware about new method of transporting bananas/plantain from farm to the markets and 49% are not aware about the new methods as shown in Table 3. Table 3 revealed that the 8% of the traders are aware about new methods of supplying banana through extension workers, 30 % are aware through mass media particularly radio, newspaper and television and 59% of the traders are aware through other sources like friends, colleagues, and only 3% are aware through extension workers. From the result obtained, it was established that there are different methods of transporting banana and plantain usually employed by the respondents depending on the destination distance and quantity of the products handled. Because of its Impact and pressure sensitivity, the fruit has to be handled with appropriate care. As shown in (Table 3) 45% of the respondents are currently using other methods like using tricycle, wheel barrow and motorcycle, 29% are using trucks if the Banana supplied are in huge amount, 10% are wrapped it with Sack and carrying it on the head or shoulder of an individual to the intended destination usually from farm to the main road. This method results in hardship and drudgery during the operation. Only 1% among the respondent are using animal draught to transport the product. The result from Table 3 shows that 36% of the respondents are now using other method for packaging particularly perforated cartons of stable corrugated board. Banana are laid in the bottom of cartons and covered with protective packaging material and another are laid on top, the polythene bag is used to seal or merely folded. The carton is Provided with perforation to ensure a proper flow of cooling air around the bananas. The result obtained shows that 21% of the respondents in the study area are now using Plastic rubber like Basing for packaging of banana to ease the movement and this method is used mostly during taking the product to Market. 20% were using Perforated Basket and also, 20% of the respondents were using piece of ordinary Sack to wrap the products.

Table 3: Method of Banana/plantain supply chain and trader's awareness about improved supply methods

Varieties	Categories	Frequency	Percentage
Awareness about new method of transporting banana	Yes	51	51
	No	49	49
Sources of awareness	Extension workers	8	8
	Mass media	30	30
	Workshop/seminar	3	3
	Other	59	49
Method of transporting of Banana	Truck	29	29
	Van	15	1
	Animal draught	1	10
	Sack	10	45
	Others	45	
Method of Packaging			3
	Wooden box	3	20
	Basket	20	21
	Plastic	21	20
	Sack	20	36
	Others	36	

3.4 Summary of Major finding

The data collected were analyzed using descriptive statistics such as tables, frequency distribution and percentages for the socio-economic characteristics of plantain traders; From the results it can observed that most of the respondents are Banana traders with more than 21-25 years of experience in the business, 59% of the respondent from the study area are aware about new method of supplying banana from farm to the final destination through the other source of friends, banana traders, and colleagues. From the result it shows that 36% of the respondents are now using other method for packaging particularly cartons, banana are packaged in perforated cartons of stable corrugated board. Banana are laid in the bottom of cartons and covered with protective packaging material and another are laid on top, the polythene bag is used to seal or merely folded. The carton are provided with perforation to ensure a proper flow of cooling air around the bananas. It was observed from the results that 80% of the respondent are aware about the improve variety of banana and plantain. Results obtained from the studies revealed that 74% of the respondent from the study area are not planting the new variety this shows that most of the banana farmers in the study area are using the local variety in their farm. And 55% of the respondent shows their preference on the New Variety of banana, 47% shows their preference because of It's easier to sale than others and 68% of the respondent are not prepared for the new variety because It's not interesting at all.

4.0 Conclusion

This research study has been able to determine that banana and plantain in Jema'a Local Government Area of Kaduna state with regard to the fast-growing population of the study area, the prospects of banana and marketing is high. It is therefore a good business opportunity for creating employment for many Nigerians to become actors in the banana and plantain value chain (as inputs dealers; farmers, marketers, transporters and processors).

Based on the data obtained and the observations made during the study, it was established that the banana and plantain handling operation is extensively carried out manually with attendant drudgery. Most of the devices/equipment used were improvised for handling banana or other fruits which could lead to mechanical damages of the fruits. These resulted in a lot of problems that possibly lead to the depreciation and subsequent deterioration of the banana, which causes huge losses usually experienced by the traders.

5. Recommendation

Based on the findings of this research study, the following recommendations are made:

1. More entrepreneurs should come into the plantain value chain business as farmers for increase in production output, transporters and marketers
2. Training of the Banana traders on proper handling of banana and plantain.
3. Engineers should develop suitable handling/storage equipment that can be adaptable to the banana traders. Since the use of refrigerators is exorbitant and out of reach to the banana traders.
4. Awareness should be developed to disseminate the new method of transporting and packing of banana.
5. The various levels of Governments should give serious attention to the challenges posed by high costs of transportation by constructing access roads network to link farm-gates in the rural areas to market locations in the urban centers.

6. The Ministry of Trade and Investment should encourage value addition to plantain produce in order to avoid the challenge posed by its high rate of perishability.

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DRYING RATE OF FISH AS AFFECTED BY TRAY LOCATIONS FROM HEAT SOURCE IN THE KILN

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Abstract

This paper investigated on how variations of tray locations in kiln from heat source can affect drying rate of fish. This study was based on the preservation of fish from spoilage through drying method, using two different heat sources (Charcoal (C_H) and Gas (G_H)). A constructed kiln of 850 mm wide, 600 mm deep and 1050 mm high, with three trays having distances; D_1 of 215 mm, D_2 of 341 mm and D_3 of 467 mm from heat source, dimensioned 750 mm x 550 mm x 25 mm was used in the experiment. Hake fish of 15kg at 5 kg per tray was used for each replication in two times for the two heat sources. Temperatures in the Kiln (K_T) and at the Chimney (C_T), and fish weights based on each tray were determined at the intervals of 15 minutes all through to 135 minutes of the experiment. The Drying Rate (DR) and the Body Mass Reduction (BMR) were calculated. Data were analysed using descriptive statistics. The results showed that K_T / C_T temperatures for C_H and G_H are 193.80 ± 37.7 ^oC / 88.22 ± 8.30 ^oC and 104.6 ± 30.3 ^oC / 83.61 ± 14.62 ^oC respectively. The drying rates at D_1, D_2 and D_3 for C_H: G_H are 0.024 ± 0.013 kg/min: 0.23 ± 0.018 kg/min, 0.014 ± 0.005 kg/min: 0.016 ± 0.006 kg/min and 0.014 ± 0.005 kg/min: 0.013 ± 0.008 kg/min respectively. Apart from tray at distance D_1, the mean dry weight of samples at trays D_2 and D_3 were lower while using G_H: 3.18±0.66 and 3.43±0.56 kg as compared to C_H: 3.38±0..63 and 3.52±0.60 kg. Percentage BMR across D_1, D_2 and D_3 were 63.0 %, 56.o % and 47.4 % for G_H and 65.0 %, 49.0 % and 45.0 % for C_H, respectively. The heat supplied by G_H demonstrated steady increment from the minimum to the maximum temperatures (K_T) of 63.50 ^oC to 153.50 ^oC which was corresponded to minimum to maximum time taken of 15 to 135 minutes. This study revealed that in order to achieve even drying rate across each tray in the kiln, a specified time of trays rotation must be adopted. In addition unsteady heat supplied while using requires constant adjustment and reloading of charcoal box.

Keywords: body mass reduction, drying rate, heat source, steady increment, tray location, tray rotation

1. Introduction

The fisheries sector is crucial to the Nigerian economy for contributing about 5.40% of the nation's Gross Domestic Product (FDF, 2005). The importance of the fishery sector is such that it is the most common and cheapest animal protein source to mankind especially among the poor dwellers in Nigeria (Ovie and Raji 2006). In Africa, fish is a significant source of animal protein accounting for up to 80 % of daily animal protein intake (FAO, 2007). An estimated 20 to 50 % of the fish produced in the remote coastal centres and hinterland of many tropical countries perish before they get to the consumers due to poor handling, preservation and processing practices adopted by the artisanal fisherman, fish farmers and fisheries entrepreneurs. Though much attention is being paid to fish preservation to extend its shelf life and improve fish quality, adequate interest must be shown in the technology of fish processing to meet consumers taste and thereby enhance fish utilization and improved marketing of the catch (Eyo, 2001).

Nigerians have been regarded to have a huge appetite for fish with an annual demand of 1.50 million metric ton (Ovie and Raji, 2006). This figure has since been on the increase such that FDF (2013) projected the fish demand as 2.055 million metric ton in 2015. Based on sources, the fish supply to meet the increasing fish demands by Nigerians is from two major groups, which are the domestic production of fish and importation of fish. Importation has served as a major supply of fish in Nigeria providing more than half (56.0%) of fish supply (Akazawa *et al.,* 2013). The Nigeria policy has now seen the potential in fish development through aquaculture practice, taking into cognizance the high water availability in the country. The campaign for higher fish production is not only to improve in the protein intake in the country but also to increase employment generation and improve on the national foreign exchange earnings (Iliyasu *et al.,* 2011).

Due to chemical compositions of fish, fish muscle is perishable and its flavor and texture are altered quickly after death and during storage (Sogbesan and Ibrahim, 2017). Fish is highly susceptible to deterioration immediately after harvest. Immediately fish dies a number of physiological and microbiological deterioration sets in which reduces the quality of the fish (Afolabi and Adegboye, 2019). A number of methods have been utilised to extend the shelf life of fish by employing some preservative and processing techniques, such as temperature control using ice, refrigeration, freezer, canning, drying, salting, smoking and freeze-drying (Pigott, 2015; Adeyeye, 2017). Fish drying is an age long practice across the world. It is one of the methods of processing fish. Afolabi and Adegboye, (2019) submitted that the developed countries smokes fish for the purpose of flavour enhancement rather than preservation which is the primary aim in the developing countries, owing to the availability of temperature control systems and integrated infrastructures for the proficient conveyance of perishable farm produce which are in position.

Silva *et al*. (2009) stated that smoking has become a means through which varied high value added products as an additional marketing option for certain fish species where fresh consumption becomes limited. Oyetoro *et al*. (2012) reported that the paramount reason for all types of smoking is to preserve the product flavour and colour, these arise as a result of preservation function. In the process of improving shelf life and adding flavour to fish, drying is of utmost importance because the moisture level in the flesh of fish gives way to bacterial activity and spoilage (Olayemi *et al.*, 2013).

This investigation was necessary to determine if the arrangement of trays in the kiln would result in homogeneous drying of fish to meet the required drying conditions for fish at the same time frame. Hence, the objective of this study was therefore to determine and to compare the effect that distance from heat source has on drying rate and the body mass reduction of fish base on heat supplied for the drying process inside the kiln from two different sources of heat.

2.0 Materials and Methods

2.1 Materials

The materials used are smoking kiln, hake fish, stopwatch, infrared thermometer, charcoal, gas cylinder, salt, meter rule, weighing balance, marker, hose and controller and bowl. A fish smoking kiln used in this study is a two walled structure with lagging material of 25 mm thickness. Its outside dimensions are 1080 x 600 x 850 mm for height x width x length respectively. The inner wall was made of stainless steel sheet, while the wall was made of mild steel and the size of the square pipe for the frame equivalent to the thickness of the lagging material. There pairs of racks were welded to the two opposite inner side walls to hold the trays in position. The rectangular trays were made from stainless mesh of 5 mm holes diameter, dimensioned 850 x 550 mm with folded edges of 25 mm.

Samples of Hake fish of total weight of 60 kg were purchased at the one of the cold room, Apata area, Ibadan, Oyo state and prepared for the study. 30 kg each was used for two replicates for two sources of heat. Stopwatch was used to monitor the time during the experiment, while High Definition Non-Contact Infra-Red Temperature Gun was used for the measurement of temperature at different time interval at designated points. 6 kg of charcoal as well as gas was use for the two replications for each heat source. Weighing balance with an accuracy of 0.01 g (Avery Berkel- A very weigh-Tromix HL122) was used to measure all weights, while metal rule was used for all linear measurement from point too point inside the kiln.

2.2 Experimental Procedure

The hake fish that was bought was separated from the mass and were cleaned with salt solution for osmotic pretreatment. Thereafter the fish were drained by arranging on drying trays to ensure that surface water is removed before putting them into the kiln. Each of the trays was labelled D_1, D_2 and D_3 in the increasing order of 215 mm, 341 mm and 467 mm distances from the heat source respectively and each tray were weighed on the weighing balance to obtain their initial weight and fish sample of 5kg were arranged on each of the tray. The samples were then placed in experimental smoking kiln that had been allowed to heat up.

After the introduction of the samples into the kiln, the initial temperatures inside the kiln and at the chimney together with the temperatures attained alongside with time taken for each of the heat source were recorded. The samples were then weighed, and temperature measured at the specified points in the interval of fifteen (15) minutes all through the experimental time frame and were recorded concurrently.

2.3 Determination of Drying Rate

The rate of moisture removal (drying rate) was calculated from the data recorded during drying.
The drying rate was calculated according Ichsani and Dyah, (2002) as equation 1.

$$DR = \left(\frac{\partial m}{\partial t}\right) = \frac{m_i - m_f}{t} \quad (1)$$

where; DR = the drying rate in kg/min; ∂m = change in mass (kg); ∂t = change in time (min)
t = total time (min); m_i = initial mass of fish sample (kg); m_f = final mass of fish sample (kg).

Determination of Body Mass Reduction

$$BMR = m_i - m_f \quad (2)$$

where; BMR = body mass reduction (kg)

The percent reduction in mass is determined using;

$$\%BMR = \frac{mi - mf}{m_i} * 100 \quad (3)$$

Calculation of Quantity (kg) of Charcoal used for the Experiment

$$ACU = \frac{CU_1 + CU_2}{2} \quad (4)$$

ACU = average charcoal utilized
$CU_1 ; CU_2$ = quantity of charcoal utilized in first and second replicates

Calculation of Quantity (kg) of Gas used for the Experiment

$$AGU = \frac{GU_1 + GU_2}{2} \quad (5)$$

ACU = average gas utilized
$GU_1 ; GU_2$ = quantity of gas utilized in first and second replicates

Statistical Analysis

Statistical analysis to investigate the interactions between heat variations in the kiln and the drying rates at different tray locations was carried out in Minitab and Excel Programmes. Descriptive Statistics and Surface Plots were carried out to present the interactions between heat variations in the kiln and the drying rates at different tray locations and to compare the effect of the two type of heat sources.

3. Results and Discussions

The Effect of Heat on Fish Weight Reduction at different Locations in the Kiln when using Charcoal

In the first 15 minutes of the drying process, with charcoal as heat source the temperatures above the charcoal pot inside the kiln and at the chimney were 180 ^oC and 73 ^oC respectively, and the fish weights decreased from initial weight of 5 kg to 4.30, 4.35 and 4.50 kg for distances D_1, D_2 and D_3 respectively (Table 1). On the average from Table 1, the total heat of temperature of 193.80 ± 37.70 ^oC was supplied for drying fish in the kiln from 5.00 kg to 2.78 ± 0.90 kg at D_1, 3.38 ± 0.63 kg at D_2 and 3.52 ± 0.60 kg at D_3, out of which the unutilized heat on the average was at 88.22 ± 8.30 ^oC temperature. The maximum generated temperatures of 261.30 ^oC in the kiln and 99.50 ^oC at the chimney were recorded at 30 min and 120 min respectively. Weights of 1.75 kg for the fish at D_1, 2.55 kg for fish at D_2 and 2.75 kg for fish at D_3 were attained as final weights, and minimum values at 135 min of the drying process (Table 1).

Table 1: Variations in Temperature and Weight of Fish at different Locations within the Kiln

S/N	Time (min)	Oven Temp. (˚C)	Chimney Temp. (˚C)	Fish Weight(kg) D_1 = 215 mm	D_2 = 341 mm	D_3 = 467 mm
1	15	180	73	4.3	4.35	4.5
2	30	261.3	83.3	3.75	4.05	4.15
3	45	216.5	84.3	3.4	3.85	3.9
4	60	229.55	90.4	3.05	3.6	3.75

5	75	200.5	89.5	2.6	3.35	3.5
6	90	184	96	2.3	3.15	3.25
7	105	175	95.5	2.05	2.9	3.05
8	120	159	99.5	1.8	2.65	2.85
9	135	138	82.5	1.75	2.55	2.75
Mean	75.00	193.80	88.22	2.78	3.38	3.52
StDev	41.10	37.70	8.30	0.90	0.63	0.60
CoefVar	54.77	19.45	9.41	32.51	18.59	17.07
Minimum	15.00	138.00	73.00	1.75	2.55	2.75
Maximum	135.00	261.30	99.50	4.30	4.35	4.50
Skewness	0.00	0.42	-0.45	0.48	0.14	0.27

Replicate = 2 Heat source = Charcoal D_1,D_2,D_3 = distances from heat source

The Effect of Heat on Fish Weight Reduction at different Locations in the Kiln when using Gas

Table 2 showed that temperatures of 63.50 ˚C and 77.50 °C were recorded in the kiln and at the chimney at the first 15 minutes of the drying process with gas as heat source, these gave rise to weight reductions to 4.00 kg at D_1, 4.18 kg at D_2 and 4.30 kg at D_3 from initial weights 5.00 kg each. It was observed that the temperature in the kiln increases with increase in drying time, having average value of 104.6 ± 30.30 ˚C, with minimum and maximum values of 63.5 ˚C and 153.5 ˚C which is corresponded to 15 and 135 minutes respectively (Table 2). Temperature at the chimney portrayed decrease from 15th minutes of the drying process through to the 45th minutes with values of 77.50 °C to 64.00 °C, however, from 60 minutes upwards, there was corresponding increase in temperature starting from 71.50 °C to 107.50 °C which was the maximum temperature and also, was corresponded to highest time taken for the drying process (Table 2).

Table 2 presented final weights of the fish at 135 minutes as 1.85, 2.20 and 2.63 kg for D_1, D_2 and D_3 respectively. Total temperature generated on the average while using gas as heat source was 104.60 °C out of which 83.61 °C was not used in the drying process.

Drying rates while using Charcoal

The drying rate at D_1 had the highest value of 0.047 kg/min at the first 15 minutes of drying process, it decreased steadily to 0.023 kg/min at 45minutes and maintained same rate through to 60th minutes before it increased to 0.030 kg/min at 75minutes and then drying rate decreases gradually again at 90 minutes through to 135 minutes at a value of 0.003 kg/min, which was the lowest drying rate while using charcoal as heat source (Figure 1). Drying rates at D_2 and D_3 showed the highest values of 0.020 and 0.023 kg/min at 30minutes, the two distances experienced declination

Table 2: Variations in Temperature and Weight of Fish at different Locations within the Kiln

S/N	Time(min)	Oven Temp. (˚C)	Chimney Temp. (˚C)	Fish Weight(kg) D_1 = 215 mm	D_2 = 341 mm	D_3 = 467 mm
1	15	63.5	77.5	4.00	4.18	4.30
2	30	72.5	70.5	3.60	3.8	3.9
3	45	82.5	64	3.25	3.6	3.75
4	60	92.5	71.5	3.10	3.45	3.7
5	75	102.5	80	2.95	3.3	3.6
6	90	112	88	2.75	2.95	3.25
7	105	123	93.5	2.50	2.65	2.95
8	120	139.5	100	2.30	2.45	2.8
9	135	153.5	107.5	1.85	2.20	2.63
Mean	75.00	104.60	83.61	2.92	3.18	3.43
St. Dev	41.10	30.30	14.62	0.66	0.66	0.56
Coef Var	54.77	29.00	17.49	22.65	20.73	16.26
Minimum	15.00	63.50	64.00	1.85	2.20	2.63
Maximum	135.00	153.50	107.50	4.00	4.18	4.30
Skewness	0.00	0.29	0.37	0.03	-0.07	-0.07

Replicate = 2   Heat source = Gas D_1,D_2,D_3 = distances from heat source

in the drying rates to the 45th minutes of the drying process, however, D_3 declined further to 0.010 kg/min, while D_2 increased to 0.017 kg/min at 60 minutes (Figure 1). From Figure 1, it is generally observed that drying rates for all distances D_1, D_2 and D_3 at 105th and 120th minutes have the same values of 0.017, 0.017and 0.013 kg/min respectively.

Drying rates while using Gas

Figure 2 presented the drying rates patterns across the distances of D_1, D_2 and D_3 from heat source, while using gas to dry fish in the kiln. The maximum and minimum drying rates occurred at 15th and 60th minutes and were observed as 0.067 and 0.003 kg/min for D_1 and D_3 respectively. Drying rate at D_1 maintained highest values at 15th, 45th and 135th minutes of drying process, and had equal dry rates of 0.027 kg/min with D_3 at 30 minutes, 0.010 and 0.013kg/min with D_2 at 60 and 70, and 120 minutes (Figure 2). Generally, it can be deduced that the drying rate is parabolic in nature throughout the drying process, and the lowest drying rates across the distances were recorded at 60th and 75th minutes (Figure 2).

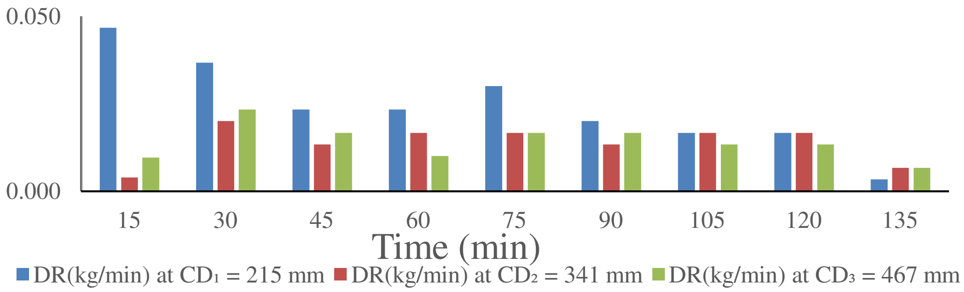

Fig. 1: Drying Rates at Tray Distances from Charcoal Heat Source

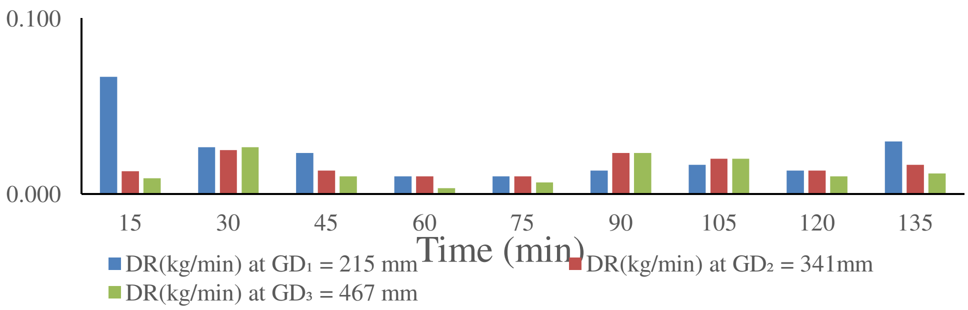

Fig. 2: Drying Rates at Tray Distances from Gas Heat Source

Reduction in Body Mass of Fish

Body mass reduction (BMR) ranged from 2.37 to 3.13 kg for gas heat source and 2.25 to 3.25 for charcoal heat source (Figure 3). At D_1, D_2 and D_3 for gas: charcoal heat sources, the percentages of BMR are 63.0%: 65.0%, 56.0%: 49.0% and 47.4%: 45.0%. It was noted that BMR decreases as tray distance was increases from the two heat sources. Also, it could be observed that, except at D_1, BMR were higher in gas dried fish as compared to charcoal dried ones (Figure 3). The nature of the observed BMR could be as a result of steady temperature increase in gas heat source with time increase as compared observed temperature fluctuation in Tables 1 and 2

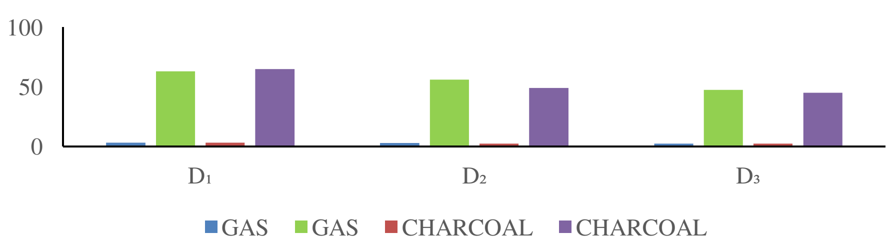

Fig. 3: Body Mass Reduction of Fish at Tray Distances from Gas and Charcoal Heat Sources

Surface Plot of Weight of Fish against Time Taken and Kiln Temperature

Figures 4, 5 and 6 presents surface plots of body mass reduction of fish at distances 125 mm, 341 mm and 467 mm away from heat source while using both gas and charcoal with kiln temperatures ranged from 63.50 to 153.50 ˚C and 138.00 to 261.00 °C respectively, and this was corresponded to the duration of 135 minutes of drying process. Over the period of 135 minutes of drying, it was discovered that the weight of fish at D_1, D_2 and D_3 for gas / charcoal heat sources had reduced significantly from 5.00 kg to 1.85 / 1.75 kg, 2.20 / 2.55 kg and 2.63 / 2.75 kg respectively.

Conclusion

Hake fish were subjected to drying in a kiln to determine the effects of distance from heat source and heat source type on drying rate and body mass reduction of fish samples at each distance level. It was observed from the results obtained that charcoal did not supply steady heat to the kiln but at fluctuating level with increase in time. Hence the charcoal needed to be loaded regularly to achieve the required temperature in a steady measure for appropriate fish smoking. On the average, the study revealed that heat generated by charcoal source was higher than gas source, yet body mass reduction was only higher on the first level tray while using charcoal source as compared to gas source in the second and third levels trays. The need to rotate trays across the levels in a spiffy time is indispensable as the result shows non-homogeneity in drying across the tray levels.

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Gas Charcoal

Fig. 4: Response of Fish Weights (kg) to Relationship between Kiln Temperatures (°C) and Time Taken (min) at D_1; (125 mm)

Gas Charcoal

Fig. 5: Response of Fish Weights (kg) to Relationship between Kiln Temperatures (°C) and Time Taken (min) at D_2; (341 mm)

Gas Charcoal

Fig. 6: Response of Fish Weights (kg) to Relationship between Kiln Temperatures (°C) and Time Taken (min) at D_3; (467 mm)

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DEVELOPMENT AND PERFORMANCE EVALUATION OF A GROUNDNUT PODS GRADING MACHINE

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Abstract

Groundnuts from Nigeria and most West Africa in the colonial era were mainly exported in-shell because of the difficulty in meeting the standards of the importing countries that were predominantly Europe. This was due to the inability of processing equipment to produce higher percentage of unbroken kernels because of the lower efficiency. The objective of this study was to design, construct and evaluate a groundnut grading machine that would grade groundnut pods into different categories in order to improve the quality and value of the output. The geometric sizes of the groundnut pods such as length, width and thickness of the groundnut pods of the selected varieties were determined. Three commonly grown groundnuts varieties in Nigeria were used to evaluate the grading device. These were SAMNUT 10, 14 and 18. Results obtained showed that three different grade were obtained from SAMNUT 10 while the other varieties, SAMNUT 14 and 18 has two grades each. Three ranges were selected to determine the grades: grade I – 15.81 mm to 18.05 mm, grade II – 12.44 mm to 15.78 mm and grade III – 10.60 mm to 13.30 mm. Results obtained also show that the grading machine has a rated capacity of grading 224 th^{-1}. The estimated cost of the grading machine is thirty seven thousand naira (₦37, 000:00).

Key words: Groundnut pod, grading, geometric dimensions, varieties

1. Introduction

Nigeria's economy was mainly dependent on agriculture prior to the oil-boom. Successive governments at both levels in Nigeria earned their means of national development from the export of major crops including groundnut until the advent of petroleum resources, Davies (2009). The essential position of agriculture as a source of raw materials for key industries and a major foreign exchange earning has further added to its preeminence (Echekwu and Emeka, 2005). Groundnut (*Arachis hypogaea* L.) was regarded as one of the most important oilseed crop globally (El-Sayed *et al*. 2001). Nigeria was the largest groundnut exporting country in Africa in the pre-colonial era and shortly after independence. Groundnut processing and trade were, therefore, major sources of employment, income and foreign exchange in Nigeria and most West African countries (Ntare *et al.* 2008). However, groundnuts exported into Europe during the years of bumper harvests from this region was done majorly in-shell thereby increasing export cost since more space was needed while shipping. This was because of high incidence of aflatoxic contamination on decorticated kernels that is carcinogenic. Groundnut exporters to set strict standards for aflatoxic contents due to health concern (Whitaker *et al.* 2005). This results in reduced the net profits for the farmer and produce agent, thus necessitating the need for improved processing methods.

A grading factor was introduced for a more competitive export of shelled and unshelled groundnuts such that the standards of the importing countries has to be met. Agricultural products were then graded mainly on the basis of their physical characteristics (Davies (2009). These include size, weight, moisture content, texture, colour, shape and foreign matter where grading by size and weight are the most widely adapted methods, Chapin and Thomas (2004). The purpose of this grading is to maintain the quality of the product by removing destructive elements into homogenous lots based on the fixed grade standards agreed by the importing countries. The objective of this study was, therefore, to establish a grading standard for processed domestic groundnuts in order to improve its quality and hence, producing groundnut for acceptable grade of exportation to enable them meet international market standard for increased foreign exchange for the country. This would eventually have influence on rural employment, trade and purchasing power and strengthen the economic capacity of the smallholder farming families.

2. Materials and Methods

A groundnut pods grading machine used in the study to sort groundnut pods into various grades was designed, constructed and evaluated.

Determination of volume of the grading machine

The volume of the upper tray that also serves as the hopper of the grader is the ratio of the mass of the groundnut fed to the bulk density of the groundnut pods was determined from equation 1 as suggested by Grossman and Reinsch (2002):

$$V_h = \frac{M_{gp}}{BD_{gp}} \tag{1}$$

where: V_h = Volume of the hopper, m^3; M_{gp} = Mass of groundnut pods, g

BD_{gp} = Bulk density of groundnut pods, given as 336 $\frac{kg}{m^3}$

The weight of groundnut pods that would fill the tray was determined to be 3.732 kg, thus, substituting this in equation (1);

$$\therefore V_h = 1.11 \times 10^{-2}\, m^3$$

Shaft design

The shaft of the grading machine is a made of steel rod which provides oscillatory motion (Figure 1). It is supported on a pair of antifriction bearing fastened to the main frame. The material used for the shaft is a steel rod chosen because of its strength. Its overall length is 370 mm with 200 mm distance between the centerline of the two roller bearings. At the extreme end of the shaft is a 160 mm diameter flywheel that also serves as a sheave for power transmission supplied by the prime mover. The approach most often used for shaft design and analysis is the maximum shear stress theory of failure given in equation 2 as suggested by Ryder (1992):

$$d^3 = \frac{16}{\pi\sigma} \sqrt{(K_b\, M_b)^2 + (K_t\, M_t)^2} \tag{2}$$

where:

d = diameter of the shaft, mm

,K_b = Combined shocks and fatigue factor applied to bending moment, Nmm

K_t = Combined shocks and fatigue factor applied to torsional moment, Nmm

σ = Allowable (working) stress, Nmm^2;

M_b = Bending Moment, Nmm , M_t = Torsional Moment, Nmm

Since groundnut pods to be graded are gradually fed into the grading device through the upper tray, K_b and K_t are respectively given as 1.5 and 1.0 (for gradually applied load) by ASME code (Hall and Holowenko, 1991). The allowable stress of mild steel is 55×10^6 N/mm^2 for shafts without keyways with factor of safety considered between 3–12. To determine bending moment, M_b; the shaft was supported between two bearings at a distance of 200 mm. The bending moment of the shaft that would be exerted by the load it is subjected to is given by Ryder (1992):

$$M_b = \frac{WL^2}{8} \quad (3)$$

where: W = Weight of groundnut in − shell causing bending, N ,
L = Length of shaft between bearings, mm

$$\therefore M_b = 0.18305\ Nm = 1830.50\ Nmm$$

The torsional moment, M_t, acting on the shaft is calculated using Equation 4 (Ryder, 1992):

$$M_t = \frac{9550P}{2\pi n} \quad (4)$$

where:

P = Power supplied, kW;
n = Rotational speed, rev/min

The prime mover used as source of power has 5 kW as its capacity and a speed of 1400 rpm. But 1 kW = 1.34 hp;

$$\therefore M_t = 7.2776\ Nm = 72776\ Nmm$$

Thus:

$$\therefore d = 9.3 \times 10^{-8} \times 7.5522 = 6.9968\ mm$$

The main shaft diameter for the grading machine was, therefore, considered as 10 mm being the nearest recommended shaft diameter.

Determination of sheaves speed

The speed of the grader sheaves can be computed using equation 5:

$$[S_{dv} \times D_{dv} = S_{dr} \times D_{dr} \quad (5)$$

where:

S_{dv} = Speed of the driven sheave, rpm;
S_{dr} = Speed of the driving sheave, rpm
D_{dv} = Diameter of the driven sheave, mm;
D_{dr} = Diameter of the driving sheave, mm

Thus, from equation 5, the speed of the shaft that transmits power to the grading sieves was determined as:

$$S_{dv} = 900\ rpm$$

This speed was confirmed with a tachometer as suggested by Simonyan. and Oke (2010).

Construction of grading sieves

To construct the grading sieves, physical properties of the groundnut pods were determined. These include shape, size, and moisture content. One hundred pods were randomly selected from each variety, this number would be adequate to give the sample mean close to the entire population mean. The tri-axial dimensions of the groundnut pods namely length (L), width (W) and thickness (T) were measured using a Vernier caliper of 0.01mm accuracy or sensitivity (Mohsenin, 1986; Olaniyan and Oje, 2012 and

Firouzi *et al.* 2009). These were used to calculate the various aperture sizes of the grading screens as suggested by Mohsenin (1986).

Description of the groundnut grading machine

The groundnut grading machine constructed consist of two oblong slotted oscillating sieves, collection trays, an eccentric mechanism and an angle iron frame of 50 x 50 x 5 mm dimensions (Figure 1). Its maximum height is 810 mm. The two oscillating sieves have slot sizes of 16 x 50 mm and 13 x 50 mm respectively that is oscillated by an eccentric mechanism. The crank assembly is capable of giving a stroke of 25 mm. The grading machine classifies groundnut pods into three distinct grades according to size. Detailed design of the grading machine is shown in Appendix 1.

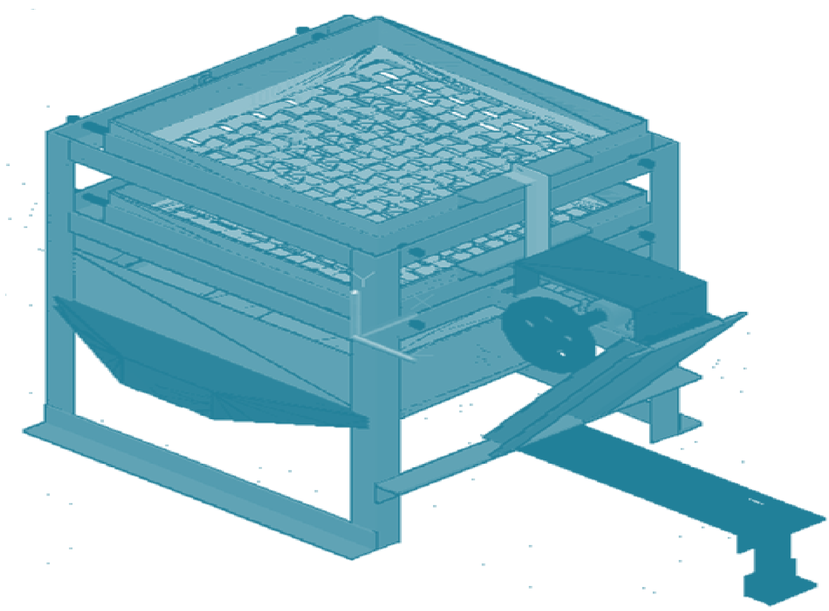

Figure 1: Pictorial View of the Groundnut Pods Grading Machine

Principle of operation of the groundnut pods grading machine

The grading machine accomplishes separation of the pods according to size. Groundnuts pods were fed into the machine through the upper sieve which also serves as its hopper. The pods travel towards the lower part of the machine by gravity through a sieve with diameter greater than pods' major diameter and drop into the lower sieve for further grading. Pods with major diameter larger than the sieve diameter were retained on the sieve. It thus allows pods similar sizes to pass through the oscillating sieves into the collecting trays that were fitted at the front of the grading machine. The pods that are retained on a particular tray determine their grade. The Bill of Engineering Measurement and Evaluation (BEME) as shown in Table 1.

Table 1: Bill of Engineering Measurement and Evaluation (BEME) of the Grading Machine

S/N	Part	Material	Specifications	Quantity	Cost (₦)
1	Collection Tray	Galvanized sheet	2 mm	3	3,000:00
2	Eccentric Mechanism	Spring steel	15 mm θ	40 mm length	2,200:00
3	Sieve	Galvanized sheet	13 mm	1	2,500:00
			16 mm	1	2,500:00
4	Sieve Bottom	Galvanized sheet	2 mm	1	1,000:00
5	Frame	Angle iron	50 × 50 × 5 mm	2 length	4,000:00
6	Pulley	Mild steel	400 mm θ	1	2,500:00
		Cast iron	60 mm θ	1	1,500:00
7	Belt	Flat	B115	1	1,200:00
8	Prime mover seat	Angle Iron	50 × 50 × 5 mm	½ Length	1,000:00
9	Bolt & nuts	Mild steel	12mm	12	600:00
10	Bearings	Roller	15 mm θ	4	4,000:00
11	Paint	-	Green (Oil)	4 litres	1,500:00
12	Labour				9,500:00
Total					**#37,000:00**

3. Results And Discussion

Geometric sizes of groundnut pods

The geometric dimensions of the groundnuts samples determined and used in the design are presented in Table 2. It shows that Samnut 10 has the greatest mean length of 33.33 mm, followed by Samnut 18 with 30.01 mm, while Samnut 14 has the least value of 25.89 mm. The means and standard deviations of width of the respective varieties show Samnut 18 having the largest of 15.11 mm, Samnut 10 with 14.34 and 13.44 mm for Samnut 14.

Table 2: Means and standard deviations of length and width of selected groundnut varieties

Groundnut Variety	Length		Width	
	Mean (mm)	Standard Deviation (mm)	Mean (mm)	Standard Deviation (mm)
Samnut 10	33.22	5.97	14.34	1.45
Samnut 14	25.89	2.00	13.44	0.78
Samnut 18	30.01	1.97	15.11	0.82

The analyses of variance for the mean lengths and widths of the three groundnut in-shell varieties were shown in Tables 3 and 4, respectively. The results revealed that there were no significant differences within the lengths and widths of each variety but there were significant differences among the lengths and widths of the three varieties respectively at 5 % level.

Table 3: ANOVA for mean lengths of the three groundnut in-shell varieties

Source of Variation	Degree of Freedom (*df*)	Sum of Squares (SS)	Mean of Squares (MS)	Observed F	Required F 5%
Blocks	4	9.11	2.29	3.98	3.84
Treatment	2	132.89	66.45	1.99	
Error	8	4.78	0.60		
Total	14	146.78			

Table 4: ANOVA for mean widths of the three groundnuts in-shell varieties

Source of Variation	Degree of Freedom (df)	Sum of Squares (SS)	Mean Square (MS)	Observed F	Required F 5%
Block	4	0.85	0.21	1.91	3.84
Treatment	2	6.30	3.15	28.64	
Error	8	0.90	0.11		
Total	14	8.05			

Width ranges of groundnut pods and choice of screen sizes

Results obtained show that the widths of all the three varieties range from 10.94 – 17.98 mm. From this data, a range of values between 9.95 and 19.05 mm was chosen as a basis for grading the three groundnut varieties. Therefore, the three grades of groundnut pods from this study were: 16.05 – 19.05 mm for grade I, 13.05 – 16.05 mm for grade II, while grade III ranges from 9.95 – 13.05 mm. Two screens were constructed for the grading device from these range of values with the following dimensions: First screen was 50 × 16.05 mm² while second screen was 50 × 13.05 mm². Groundnut pods whose major diameters were above 16.05 mm were retained on the first screen. Pods whose major diameters were less than 16.05 mm passed through the first screen to the second screen whose diameter was 13.05 mm. Here, pods with diameters between 16.04 mm and 13.05 mm were retained and graded as grade II. Finally, pods whose diameters were less than 13.05 mm were collected at the bottom tray as grade III.

Performance evaluation of the groundnut pods grading machine

Table 5 shows the results obtained from grading the three varieties of groundnut pods. During the evaluation process, only Samnut 10 variety had all the three grades. Samnut 14 had grades II and III while Samnut 18 had grades I and II (Figure 2). The results obtained shows that the mean values of grade I samples ranges between 16.48 – 16.98 mm, 14.11 – 14.83 mm for grade II, and 11.84 – 11. 95 mm for grade III. The standard deviations of all the grades of the three varieties were found to be less than one and were noted to be within the acceptable limits as observed by Sykes (2009) that the smaller the standard deviation, the higher the degree of uniformity in the observations and the homogeneity in the series. The grading device has a rated capacity of 224 kg/h.

Table 5: Performance evaluation of the groundnut grader

Groundnut Variety	Grade	No. Observed	Mean	Standard Deviation
Samnut 10	I	100	16.93	0.57
	II	100	14.81	0.84
	III	100	11.84	0.51
Samnut 14	I	-	-	-
	II	100	14.11	0.85
	III	100	11.95	0.69
Samnut 18	I	100	16.48	0.38
	II	100	14.83	0.73
	III	-	-	-

4. Conclusion

A groundnut pod grading machine was designed, developed and evaluated. The grader developed categorized and separated the three varieties of groundnuts into three grades: grade I – 15.81 mm to 18.05 mm, grade II – 12.44 mm to 15.78 mm and grade III – 10.60 mm to 13.30 mm. Of the three varieties considered, only SAMNUT 10 had all the three grades. The finding of this study could be used as a data base for grading pods of different local varieties of groundnuts grown in the country. This is to improve export potential and sustainability of groundnut production, thereby impact on rural employment, trade and purchasing power for smallholder farming families, and improve household nutrition. It will also increase the net income and foreign exchange of such countries.

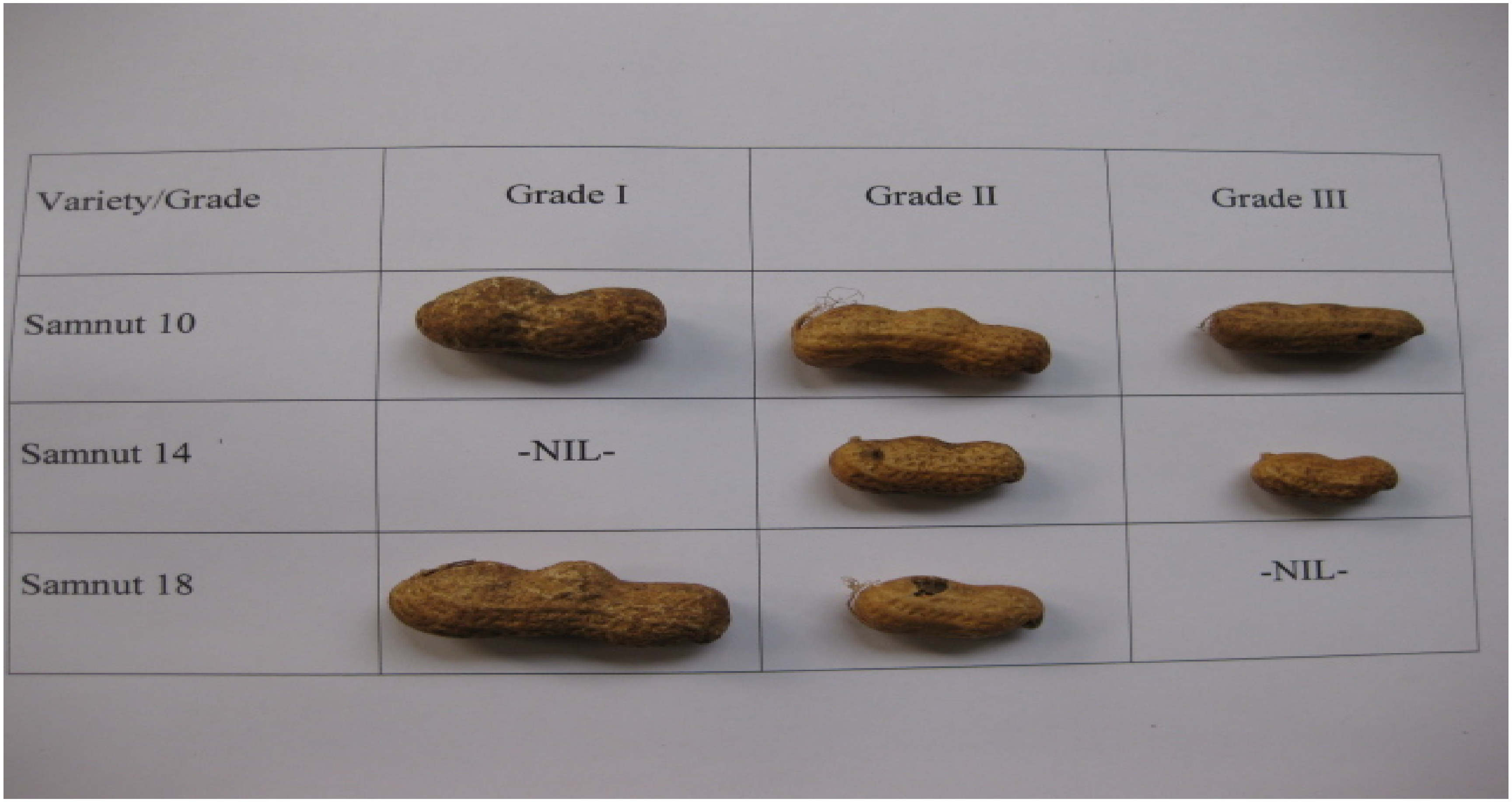

Figure 2: Grades of groundnut pods obtained from the grading machine

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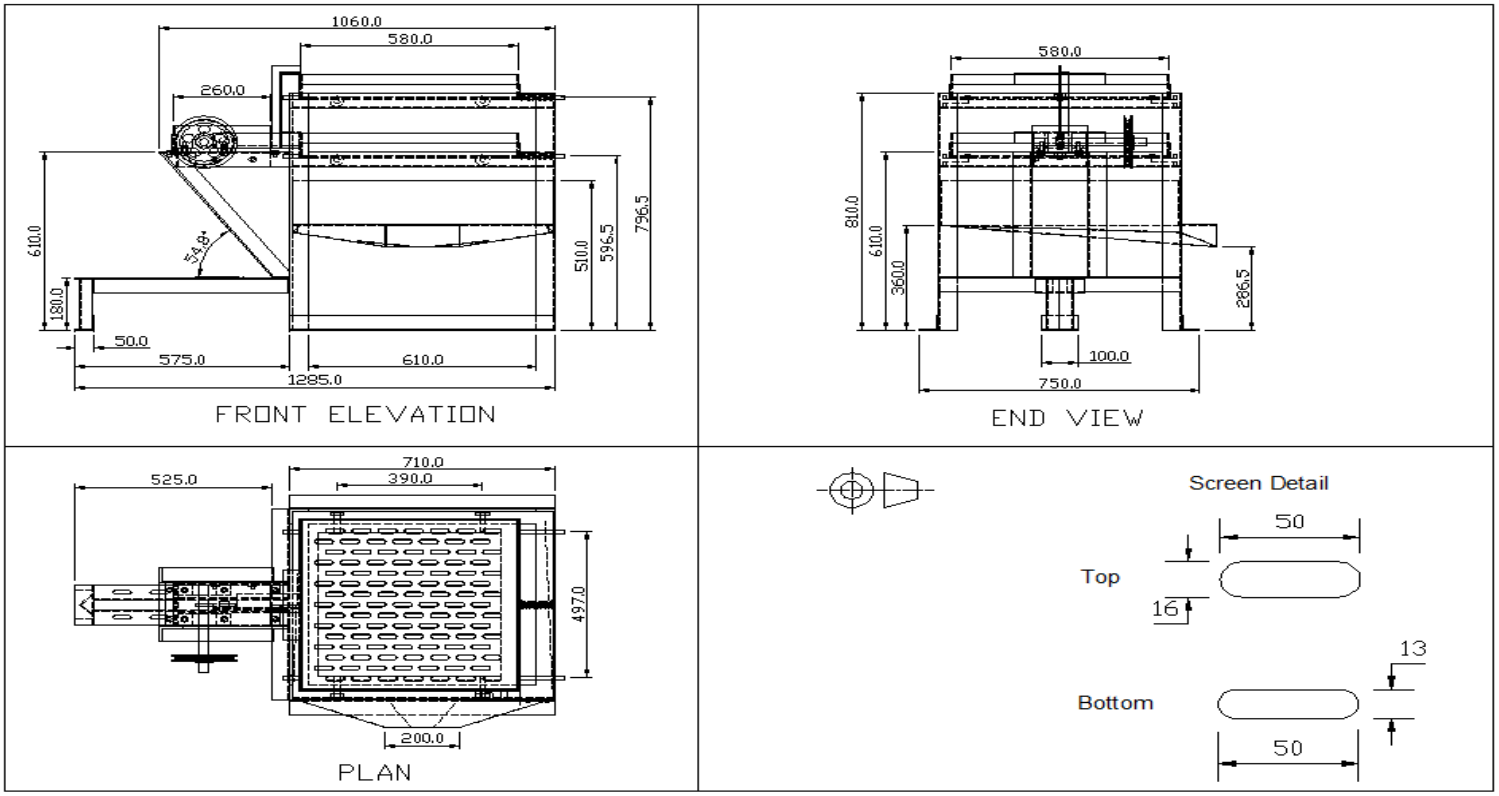

Orthographic projection of the Groundnut In-shell Grader

STRATEGIES FOR IMPROVING THE PRODUCTION AND POST-HARVEST PROCESSING OF RICE IN NIGERIA.

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Absract

Rice is an annual crop and one of the most important staple food crops in Nigeria. The demand for rice has been increasing at a much faster rate in Nigeria and even throughout the World as a whole. However, the issue of low productivity of Nigerian farmers especially in Ekiti State is becoming topical, particularly in rice production. Therefore, this study examined the factors affecting rice farmer's productivity in Ekiti State, Nigeria. Data were collected from 90 respondents in the study area and analyzed with descriptive statistics. Results show that the majority (50 %) of the respondents cultivated 1-3 hectares of rice farm, the mean rice farm size was 2.0 hectares. 25.56 % and 16.67 % cultivated below 1.0 hectares and 4-6 hectares. 2.22 % of the respondents cultivated above 10 hectares of rice farmlands. Most of the respondents (36.67 %) planted both (improved and local) rice varieties. Most (58.89 %) of the respondents used herbicides on their rice farms, 60 % used fertilizer and 70 % used pesticides on their rice farms which could increase their level of production. Therefore, it is recommended that more extension workers should actively be involved in information dissemination on the best way to improve rice production and post-harvest processing of rice in the study area as well as the need to use such methods.

Keywords: food crop, rice, production, post-harvest processing, survey

1.0 Introduction

Rice (*Oryza sativa*) is a main source of nourishment for over half of the world's population, rice is by far one of the most important commercial food crops. Its annual yield worldwide is approximately 535 million tons. Fifty countries produce rice with china and India supporting 50 % of total production. During the last two decades, rice has moved from a ceremonial to a staple food in many Nigerian homes. Ekiti State is one of the major States producing rice in Nigeria. It is blessed with abundant resources in terms of land mass, rich soil, and climatic condition suitable for rice production. Its availability and price have become major determinants of the welfare of the poorest African consumers (West Africa Rice Development Association, 2003).

About 90 percent of Nigerian food need is produced by small-scale farmers cultivating tiny plots of land and depend on rain-fed rather than irrigation systems thereby leading to a shortage in supply-demand relation in rice production (Ogundele and Okoruwa, 2006). These and other reasons have resulted in low agricultural output and farm incomes. Okunola, et. al., (2018) reported that in reality, the demand for local rice is higher in urban areas than in rural areas due to the higher population and its acceptability as a delicacy in social functions and fast food shops. Post-harvest losses are common phenomena in all grain products and it is estimated to occur between 30 – 40 % of total productions of all crops in developing countries. These losses occur right from the field during harvesting and throughout the processing operations.

Ekiti rice, popularly called *Igbemo* is an upland variety and has gained very wide recognition despite the low physical quality of the product. The noticeable problem now is that of processing activities; parboiling, drying, and milling, which are of a small scale where special skills and technologies are lacking. In 2016, the quantity of local rice production in Nigeria was estimated at 4.8 million tons (FAO, 2016). Fasoyiro, et. al., (2012) observed that in Nigeria, rice is mainly produced by small-scale farmers whose products are characterized by low output resulting from production inefficiency, an aging farming population, low technological know-how, and so on. Uduma, et.al., (2016) also noted that the inability of local supply to meet up with rice demand (consumption) has given rise to the high import of rice in Nigeria.

The majority of the African farmers practice subsistence or smallholder farming characterized by low skilled labour force and family units, there is a high incidence of yield gaps, in addition to poor soils and other obstacles to sustainable farming incomes (Gyimah-Brempong, et. al., 2016). Harold and Tabo, (2015) also reported that rice is the single most important source of dietary energy in West Africa and the third most important for Africa as a whole. It is evident from the study that despite the increase in local rice production, there is still the persistence of the shortage of local production compared to the excess demand for the commodity [Gyimah-Brempong, et. al., (2016) and Harold and Tabo, (2015)]. The objectives of this study are to assess rice farmers' perception and knowledge of rice production and evaluate how to improve the post-harvest processing of rice in Ekiti State

2.0 Materials and Methods

2.1 The Study Area

The study area for this investigation is Ekiti State, Nigeria. The State is one of the South-Western States in Nigeria. Ekiti has sixteen Local Government Areas and is located between latitudes 07° 17′ and 08° 06′ North and longitudes 04° 51′ and 05° 47′ East has a land area of 6,353 km^2. The State is bounded to the North by Kwara and Kogi States while it is bounded by Osun State to the West, and Ondo State to the East and South. Ekiti State is a landlocked State; having no coastal boundary.

2.2 Data Collections

The population under study was considered homogeneous. Three Local Government Areas (LGAs) were randomly selected from each of the three Senatorial districts in the State. Cross-sectional data were used and collected with the aid of a well-structured questionnaire, administered to rice farming households. It was collected on the socio-economic and farm characteristics of rice farming households. Primary data was used for this research and a multistage sampling technique was used to select representative households for the study.

The first stage was the purposive selection of nine (9) rice-producing Local Government Areas in Ekiti state. The LGAs are Efon Alaye, Irepodun/Ifelodun, Ido/Osi, Aiyekire, Ijero, Ekiti West, Ileje Meje, Ise Orun, Moba and Emure. These study regions accommodate about 64.2 % of the state populace. The second stage was the random selection of communities in each Local Government Area selected. Two communities were selected from each of the nine Local Government Areas selected, given a total of eighteen communities. The third stage involved the random selection of five (5) rice farmers from each community. In all, a total of 90 respondents were selected for the study. Questionnaires were administered and used for analysis.

2.3 Analytical Techniques

Data collected were collated and analyzed using descriptive and inferential statistics. Descriptive statistical tools such as Tables, Frequency counts, percentages, and mean scores were used to analyze the socio-economic characteristics, shortcomings in the Scheme, and productivity among the rice farmer.

3.0 Results and Discussion

3.1 Production Technologies used by the Rice Farmers

The result in Table 1 shows that the majority (50 %) of the respondents cultivated 1-3 hectares of rice farm, the mean rice farm size was 2.0 hectares. 25.56 % and 16.67 % cultivated below 1.0 hectares and 4-6 hectares. 2.22 % of the respondents cultivated above 10 hectares of rice farmlands. Thus, this implies that most of the respondents are small-scale rice farmers and these small farm sizes make mechanization difficult thereby limiting the output of rice to the subsistence level leaving little for commercial. The mean farm size compares relatively with the finding of Kadiri, et. al., (2014), in their work on Technical Efficiency in Paddy Rice Production in the Niger Delta Region of Nigeria, where sampled farmers had an average of 2.32 hectares. This also corresponds with the findings of Mustapha, et. al., (2012) in which the majority (61.25 %) of the respondents of that study had 1-3 hectares of rice farms.

The range of rice farming experience as shown in Figure 1 below was between 11-20 years which is a relatively long time in rice farming and therefore, should equip them with better knowledge of rice farming. This finding is consistent with the findings of Kadiri, et. al., (2014), who found that the mean of rice farming experience in their study area was 17 years. Experience also revealed that the rice farming business has been long in the area and therefore should, be able to produce enough rice for the ever-growing populace.

Figures 2 and 3 shows the level of machines used and the production technologies adopted in the rice farms in the state. Most (58.89 %) of the respondents used herbicides on their rice farm, and 60 % used fertilizer while 70 % used pesticides on their rice farms which could increase their level of production. All the respondents, as revealed in Table 1 used sickles and sharp knives for harvesting their paddy, and also, they used mortar and pestle in threshing their paddy which may discourage the farmers from cultivating large hectares of land.

Table 1 also reveals that the respondents stored their paddy using bags which is a modern method of storage rather than spreading the paddy on the floor in a room. The majority of the respondents used manual methods (catapults, shouts) in scaring away birds from their farms which are not effective methods in chasing birds away, though they are better than other methods such as scarecrows and cassette.

4.0 Conclusion and Recommendations

This study has thus revealed the problems confronted by producers of Nigerian Rice using nine selected Local Government Areas of Ekiti State. It may be concluded that solutions stated in this study should be of great assistance to the government, policymakers, and researchers and also in tackling the problems confronting rice production in the study area and Nigeria at large.

However, farmers' inability to access credit facilities and inadequate availability of modern machinery have been negatively affecting the production of rice in Ekiti State. Therefore, it is recommended that rice production should be mechanized and the Government should encourage farmers in the study area with the provision of credit facilities and necessary machinery for the production of rice, especially post-harvest processing equipment. The provision of opportunity for training and retraining for rice farmers on modern methods of pest management is equally essential. More Extension workers should be employed and empowered to visit farmers regularly to educate them on new research findings that could promote best practices in rice production.

Table 1: Production techniques used by rice farmers

Characteristics	Frequency	Percentage
Farm Size (Hectares)		
<1	23	25.56
1.1 – 3.0	45	50
3.1 – 6.0	15	16.67
6.1 – 10.0	5	5.56
>10	2	2.22
Farming Experience (Years)		
< 10	33	36.67
11 – 20	45	50.00
21 – 30	7	7.78
>30	5	5.56
Variety of rice planted		
Local	32	35.56
Improved	25	27.78
Both	33	36.67
Rice Ecology		
Upland Rice	42	46.67
Lowland Rice	41	45.56
Both	7	7.78
Use of Harvest and Postharvest Machinery		
Yes	25	27.78
No	65	72.22

Harvesting methods		
Sickle Panicle	15	16.67
Sharp Knife	23	25.56
Combination of 2 or more	35	38.89
	17	18.89
Method used for rice threshing		
Pedal thresher	24	26.67
Trampling	29	32.22
Threshing Flail	16	17.78
Combination of 2 or more	12	13.33
	9	10
Sources of Information		
Radio Television	21	23.33
Internet browsing	14	15.56
Extension Agent/ Fadama	10	11.11
agents	16	17.78
Newspaper	6	6.67
Agricultural Cooperative Society	25	27.78
Friends & Relations	28	31.11
Fellow Farmers	42	46.67
Production Technologies		
Land preparation by machine Land	14	15.56
preparation by hoes and cutlasses	76	84.44
Timeliness in Planting		
Sowing Nursery	84	93.33
Transplanting	29	32.22
Direct Seeding Herbicide	29	32.22
Application Fertilizer	61	67.78
Application Pesticide	53	58.89
Application Manual Bird	54	60
Scaring	63	70
Use of Scare Crow, Cassettes	81	90
Sun- drying	8	8.89
Storage	90	100
	90	100

Long Term Storage Facilities		
Yes	17	18.89
No	73	81.11

Source: Field Survey 2021.

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MACRO- AND MICRO-CLIMATIC INFLUENCE ON MAIZE QUALITY AND INSECT PEST MANAGEMENT STRATEGIES IN SMALL MARKET STOREHOUSES IN NIGERIA

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Abstract

Weather plays a major role in the microclimate of grain storage facilities and could impact the quality of stored grain, most especially in the humid tropics where weather conditions are favorable to insect and mold formation. This study compared the influence of macro and microclimates — temperature and relative humidity (RH) in six storehouses located in three grain markets in Ibadan, Oyo, and Ilorin, Nigeria. The study was conducted from February–December 2016. Traditional Storage Practice (TSP) and Integrated Pest Management (IPM) were used in each of the markets. The average size of each storehouse was 4 m × 2.5 m × 2.5 m and each had twenty-five 100-kg polypropylene bags of maize stacked singly (not nested) in five columns. 15 bags were randomly sampled monthly for moisture content (MC) and insect counts using standard methods. Temperature and RH of the ambient and in-between grain stack were recorded using data loggers. Mean temperatures and RH for ambient, stack, and grain ranged from 29.3–30.8^{0}C and 53.9–59.4% for the storage period. Mean insect count for the six storehouses with IPM and TSP were 1.4 and 7.6 in 700 g per bag, respectively. Ambient conditions correlated with grain stack temperature in all storehouses. MC of stored maize was not significantly affected by the location of storehouses and storage practices. However, insect population was significantly affected by storage practices. Proper grain storage management play a major role in maintaining grain quality during the storage. Commercial grain aggregators are advised to adopt the IPM strategies and ensure regular monitoring of the microclimates of bagged grain to reduce storage losses.

Keywords: integrated pest management, insect infestation, losses, maize, microclimate, moisture content

1.0 Introduction

Grains are regarded as the most important of all agricultural products stored by farmers and aggregators in the tropics and sub-tropical regions of the world (Akowuah et al., 2015). Several types of grain storage systems exist but the method of choice depends on several factors which include the purpose of storage, the volume of grain involved, storage duration and available resources (Okunade, 2013). In developing countries, poor and inadequate storage facilities contribute to slow growth of agricultural development. It has been estimated that 25 to 33.3% of the global grain crop is lost yearly during storage (Ibrahim, 2015). Traditional storage structures are not effective for long term storage of grains due to their structural deficiencies. Improved storage structures such as warehouses with appropriate management techniques have been identified as a suitable approach for reducing grain storage losses among the rural farmers (Mishra et al., 2012).

In Nigeria and Sub-Saharan Africa, grains are usually stored on-farm, in residence, in community or market level storehouses, in large scale warehouses, and sometimes in national grain silo complexes across the country (Adejumo and Raji, 2007 and Adesina et al., 2019). The seasonal state of agricultural production in Nigeria makes grain storage inevitable because market demand is year-round.

According to Pekmez (2016), grain losses (qualitative and quantitative) during storage can be attributed to different factors such as environmental factors (temperature, moisture content of grains, and humidity), storage structure type, length of storage, storage method, and biological factors (insects, pests, microorganisms and rodents). Postharvest storage facilities were identified in a study by Niamketchi (2015) as the major constraint of the grain value-chain in West Africa because the region is characterized with inadequate infrastructure which limit smallholder farmers' ability to store grain crops efficiently. This leads to a significant postharvest losses. Adejumo et al. (2014) also reported that lack of good storage facilities and the high humidity prevalent in the tropics, as it is in parts of Nigeria, cause post-harvest grain losses due to insect activity to exceed 30%.

Warehouses are primarily constructed to provide protection of quantity and quality of stored products (Pekmez, 2016). Generally, small storehouses are the most available storage facilities at the market-level in Nigeria. Jayas (2012) regards a store of grains as an artificial ecosystem in which weather plays a major role in the microclimate within the grain storage facilities. Seasonal variations in the environmental conditions around and within storehouses influence the microclimate of bagged grain. The magnitude of changes in these conditions and the duration impact the quality of the stored grain. (Ileleji et al., 2015). Ileleji et al. (2015) also reported that apart from temperature and relative humidity (RH), the microclimate created by stored grains is affected by solar radiation, precipitation, grain moisture and gases (CO_2 and O_2). However, temperature and RH constitute the main environmental factors influencing macro- and microclimatic condition of storehouses and the stored grains. The temperature and RH affect the equilibrium moisture content of the air surrounding the grains, and this determines storability (Omobowale et al., 2015). Hence, the control of the storage environment is an essential element in grain storage management as it involves, the controls of in-store climate and infestation-pressure which can be achieved by technically sound store design and construction (Shankar, 2014).

According to Johnson and Townsend (2009), there are three ways of preventing multiplication of deterioration agents in stored grain namely: sanitation, inspection and protection. Sanitation involves ensuring that grain to be stored are well dried to low moisture content and cleaned while inspection involves regular monitoring of the stored product in order to take adequate decision if spoilage is noticed. Protection in this concept is divided into chemical and structural protection. Studies have shown that more emphasis is laid on chemical protections which encourage the use of pesticides in grain storage (Erhunmwunse, 2012). The use and abuse of pesticides in grain storage especially at the market level storehouses has been reported to be harmful to human health as many grain merchants fail to follow the instructions on pesticide labels (Ikpesu and Ariyo, 2013).

Strategies for insect and pest management is a major consideration during storage. IPM has been described by USDA-ARS (2018) as a sustainable, science-focused, decision-making procedure which involves the combination of cultural, biological, physical, and chemical tools for the identification, management, and minimize risk from pests and pest management tools and strategies in a way that reduces the general economic, health, and environmental risks. Different researchers have attributed the execution of IPM to be based on some factors such as availability of IPM tools, extension education, level of education, economic and social conditions, environmental awareness, rational thinking, moral values, government policies, consumer preference, and retail marketing (Parsa et al., 2014; Lefebvre et al., 2015; Jayasooriya and Aheeyar 2016, Rezaei et al., 2019).

A typical grain storage structure at market level is characterized by a four - cornered concrete building that provides some level of protection for stored grains from ambient fluctuations. These small warehouses (small storehouses) give room for quality inspection and application of control measures when needed (Danso et al., 2019). Rodent attacks, insect infestation and leakages have been identified as common problems in many store houses in Nigeria. (Igbeka, 2013). Therefore, the primary goal of this study was to examine how structural modifications to storehouses to improve sealing influences the microclimate and grain quality within the structures. In this study, we compared the influence of macro- and microclimate — temperature and relative humidity (RH) of six storehouses using traditional storage practice (TSP) and integrated pest management (IPM) at three grain markets in Ibadan, Oyo and Ilorin, Nigeria.

2.0 Materials and methods

2.1 Study locations and rehabilitation of storehouses

Two (2) storehouses located in three (3) grain markets namely Bodija (Ibadan) located on 7°26′08.3″N 3°54′46.1″ E, Eleekara (Oyo) 7°49′50.7″ N 3°54′39.5″E and Mandate (Ilorin) 8°28′44.3″N 4°30′11.2″E, Nigeria, were selected for this study. The average size of each storehouse was 4 m × 2.5 m × 2.5 m. Storehouses at Oyo (Eleekara) and Ilorin (Mandate) markets had corrugated metal roof and wooden door. The storehouses in Ibadan (Bodija) market had concrete decking and metal doors. One (1) storehouse from each market was renovated (plastering of cracks, replacement of spent corrugated sheets and provision of concrete floor) with a vent equivalent to about 3% of the total wall area. The other storehouses were left untouched under conditions and practices similar to how the grain marketers store their produce in the market typically characterized by poorly sealed roof and doors, with cracked floors and walls (Figure 2-2).

Figure 2. One of the Traditional Storage Practice (TSP) storehouses in the study

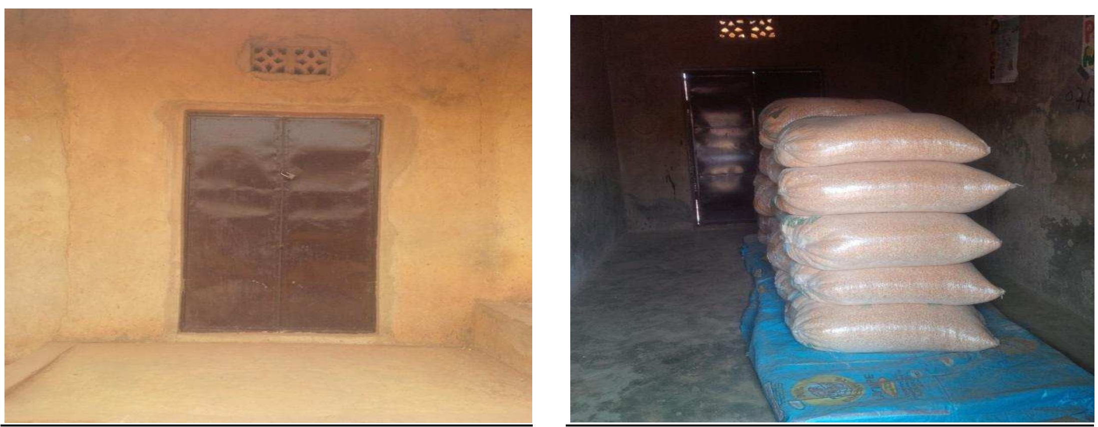

Figure 3. One of the Integrated Pest Management (IPM) storehouses in the study

Figure 2: One of the Integrated Pest Management (IPM) storehouses in the study

2.2 Maize for storage, sampling, and data collection

Maize (SWAN 2 variety) was purchased from Ijaye Farm Settlement in Akinyele Local Government Area, Ibadan Oyo State, Nigeria. The maize which was dried to about 8.2% moisture content (wet basis) was harvested manually, shelled, and cleaned by winnowing after which they were placed in 100-kg polypropylene bags, transported by road and placed on wooden pallets in the storehouses at the markets. Twenty-five 100 kg bags were stored in each warehouse out of which 15 were randomly sampled each month during the study.

Each sampled bag was slightly unstitched at the seam using scissors to create an opening into the bag. About 1000 g maize samples were drawn from each bag using a sampling probe. 700 g of the gabbed samples were used for insect counts. The temperature, relative humidity, and the equilibrium moisture content (EMC) of the air in the interstitial space of the bagged corn were recorded monthly using the GrainMate moisture meter probe (Armstrong et al., 2017; Sesi Technologies, Kumasi, Ghana). The probe was inserted into the bag and the readings were taken after the meter displays a stabilized reading which is about 6 minutes. This procedure was repeated 3 times the mean values and standard deviation were estimated.

2.3 Temperature and relative humidity monitoring in the storehouses

HOBO Pro V2 data loggers (Onset Computer Corporation, Bourne, MA USA) were placed outside of each storehouse and inside the storehouse — in-between grain stacks — to record the temperature and relative humidity at 1-hour intervals. The data loggers were placed in-between the stack at approximately 0.7 m above the floor while the one outside was placed at about 2.5 m above the paved floor. These data were downloaded monthly onto a computer and analyzed along with grain moisture and insect population (number of insect count). Temperature and relative humidity were also measured and recorded separately within the grain stack and inside the grain bag manually with an electronic probe and subsequently referred to as stack and grain temperature and relative humidity, respectively.

2.4 Statistical analyses

Data obtained from field and laboratory experiments were analyzed with SAS Version 9.4 (SAS Institute, Cary, NC). A randomized complete block design (RCBD), with three (3) replications was used. The market was the block or replication TSP and IPM were considered treatments.

Data for dependent variables — MC, number of insects were fitted by a four-level and three-level linear regression model using the first-order function. Macroclimatic condition: ambient temperature and ambient RH; and microclimatic condition: grain temperature and grain RH were the independent variables. Models were generated to predict the MC and insects count using IPMD and TSP for the storehouses. ANOVA, correlation, and regression were performed by General Linear Models (GLM), PROC CORR, and simple linear regression (PROC REG) respectively using 95% confidence interval.

3.0 Results

3.1 Temperature and relative humidity in the storehouses and maize moisture

Mean daily temperature and RH in the storehouses at the three markets ranged between 29.6 to 30.8^{o}C and 53.9 to 59.4 % respectively during the 11 months storage period (

Table 2). The monthly mean temperature and RH levels ranged from 25.7–33.7^{o}C and 36.7–90% respectively across all the storehouses (Figure 4 -5).

The moisture content of stored maize in Bodija, Eleekara and Mandate storehouses ranged between 8.2 and14.1% and 8.5–13.5% for IPMD and TSP practices, 8.4–13.7% and 8.6–13.2% for IPMD and TSP practices, 8.8– 13.2% and 8.9–13.0% for IPMD and TSP practices respectively.

The ANOVA showed significant ($P < 0.05$) regression models, as reflected by small probability values for dependent variables. The regression analysis of ambient temperature, grain temperature, and ambient RH on the insects count across the storage period in Mandate storehouse was not significant. However, regression analysis of stack RH, ambient RH, and grain RH on the insects count for the storage period in Mandate storehouses was significant ($P < 0.05$).

Table 2 The range and mean for temperature, relative humidity (RH) and moisture content (MC) for Bodija, Eleekara and Mandate storehouses using IPMD and TSP practices

Variable	Bodija		Eleekara		Mandate	
	TSP	IPMD	TSP	IPMD	TSP	IPMD
Temperature (°C)	26.6–35.2	25.8–34.2	26.7–33.5	26.7–36.2	25.8–33.2	25.7–32.6
Relative Hum (%)	33.9–77.6	31.7–75.8	33.5–72.3	33.2–71.3	37.2–68.0	37.3–70.0
MC (%wb)	8.1–14.8	8.3–13.9	8.0–14.4	8.0–14.2	8.6–13.6	8.6–19.3
			Mean			
Temperature (°C)	30.8	29.7	30.5	30.5	29.6	29.8
Relative Humidity (%)	59.4	58.6	56.1	57.2	54.1	53.9
MC (%wb)	12.0	12.0	11.5	11.7	11.3	11.4
Insect Count/700g	1	10	2	6	2	7

The mathematical expressions generated from the regressions for the prediction of MC and insects count with IPMD and TSP practices shown for Bodija storehouses (Eq. 1–4), where subscripts in the equations indicate practice type.

$$MC_{IPMD} = 4.96024 + 0.02159(A) - 0.00315(B) - 0.07490(C) + 0.15158(D) \#1$$

$$MC_{TSP} = 5.69614 - 0.02416(A) - 0.00203(B) - 0.05658(C) + 0.14941(D) \#2$$

$$Insect_{IPMD} = 14.65999 - 0.73678(A) - 0.03335(B) + 0.29851(C) \#3$$

$$Insect_{TSP} = -18.28740 + 2.28932(A) - 0.75166(B) + 0.49527(C) \#4$$

where A – ambient temperature (°C), B – ambient RH (%), C – grain temperature (°C), and D – grain RH (%).

The mathematical expressions generated from the regressions for the prediction of MC and insects count with IPMD and TSP practices are presented for Eleekara storehouses (Eq. 5–8), where subscripts in the equations indicate practice type.

$$MC_{IPMD} = 4.78025 + 0.07221(A) - 0.00325(B) - 0.12809(C) + 0.14884(D) \#5$$

$$MC_{TSP} = 6.27329 - 0.10785(A) - 0.01213(B) + 0.02013(C) + 0.15471(D) \#6$$

$$Insect_{IPMD} = -89.57320 + 0.92174(A) + 0.44135(B) + 0.97496(C) \#7$$

$$Insect_{TSP} = -240.82042 + 7.62205(A) + 1.21029(B) - 2.22492(C) \#8$$

The mathematical expressions generated from the regressions for the prediction of MC and insects count with IPMD and TSP practices are presented shown for Mandate storehouses (Eq. 9–12), where subscripts in the equations indicate practice type.

$$MC_{IPMD} = 11.51947 - 0.08667(A) + 0.00014777(B) - 0.16207(C) + 0.12952(D) \#9$$

$$MC_{TSP} = 8.13286 + 0.02994(A) - 0.01002(B) - 0.17068(C) + 0.15074(D) \#10$$

$$Insect_{IPMD} = 6.14826 - 1.17164(E) + 0.52598(B) + 0.51785(D) \#11$$

$$Insect_{TSP} = -16.12074 - 0.57449(E) - 0.20776(B) + 1.40222(D) \#12$$

where A – ambient temperature (°C), B – ambient RH (%), C – grain temperature (°C), and D – grain RH (%), E – stack RH (%).

3.2 Insect count

Highest insect count for Bodija, Eleekara and Mandate storehouses were recorded in December except in storehouse in Bodija with IPMD which had its peak in August (Fig. 3–5). More so the highest number of insects across the six storehouses was 56 per 700 g sampled grains in Bodija storehouse with TSP practice (Fig. 3). No insects were found from February–May 2016 for IPMD practice in Bodija (Fig. 3) and Eleekara storehouses (Fig. 4). Also, Mandate storehouses for IPMD and TSP practices had no insects in the first 3 months of the storage period (Fig. 5).

4.0 Discussion

Grain losses at the market-level storehouses have been attributed to little consideration given to structural protection, climatic influence, and poor storage management (Akowuah et al., 2015; Afzal et al., 2019). Monitoring of temperature and RH fluctuations is inevitable for proper grain storage management in any storage structure, market-level storehouses inclusive (Befidaku, 2014). During the 11-month storage period, temperature in the six storehouses were favorable for insect development. The following observations were discussed with respect to the macro- and micro-climate influence on grain quality (grain MC and insect count) at the study locations.

4.1 Bodija market

In the IPMD storehouse, the monthly mean ambient temperature was high and relatively stable in the first three months (29.0–29.9°C) of the storage period while the mean ambient RH gradually increased (75 to 90%) from February to June 2016, and declined gradually till the end of the storage period (December 2016) (Figure 4). More so, the mean ambient temperature trend gradually declined from April to August, and gradually rose after the August rain break till the end of the storage period. Consequently, the trend observed can be attributed to low rainfall from February to April, and a gradual decrease in rainfall events towards the end of the year (September to December 2016). Interestingly, the mean grain MC gradually rose (8.2 to 14.1%) with a concurrent rise in mean grain RH and mean stack RH (February to September) as shown in Figure 4.

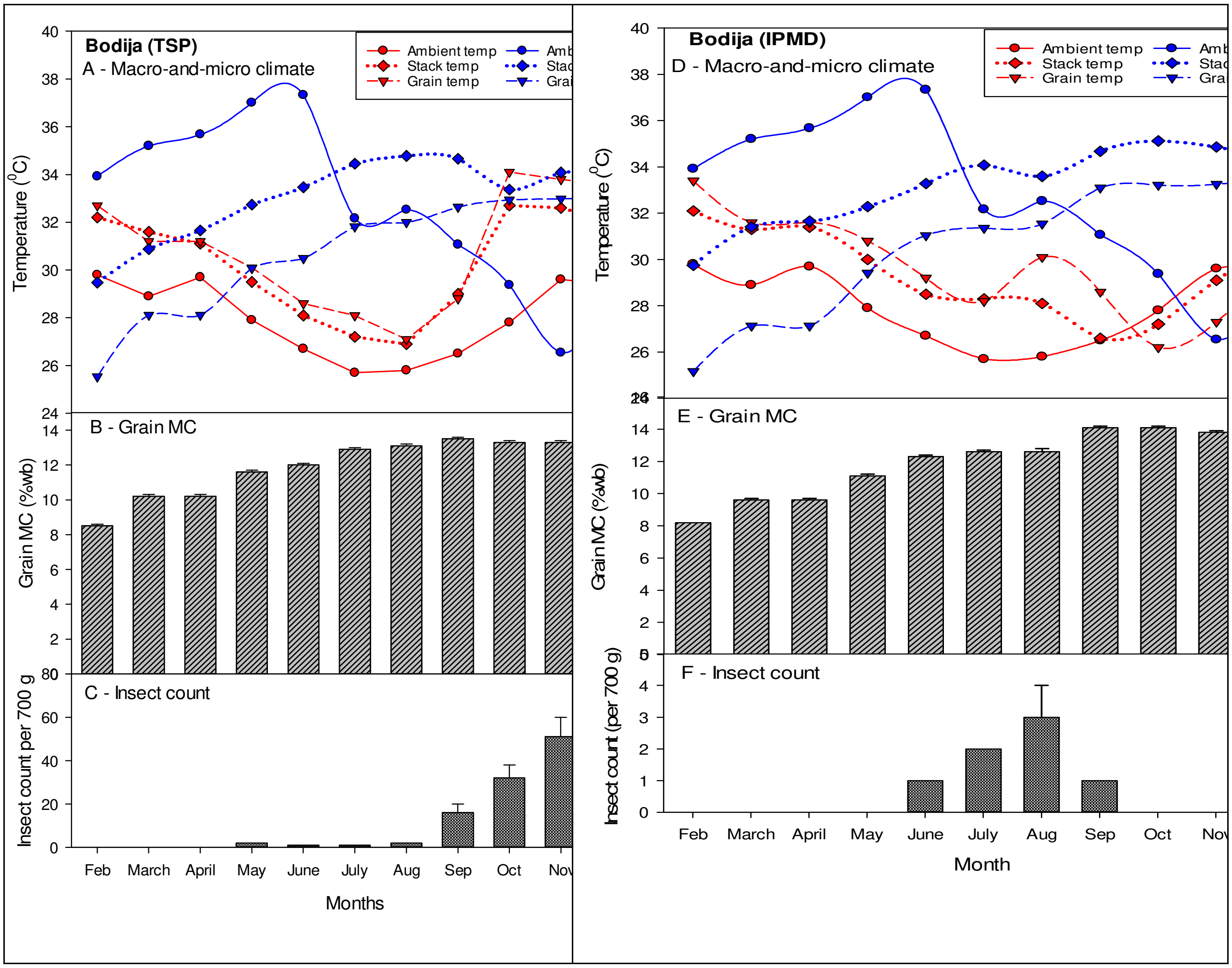

Figure 4. Bodija storehouse: Macro-and-micro climate (A), Grain MC (B), Insect count (per 700 g) (C) for TSP; and Macro-and-micro climate (D), Grain MC (E), Insect count (per 700 g) (F) for IPMD, respectively.

The continuous gradual rise in the mean stack RH levels from March to September (wet season) can be attributed to the ventilation of the warm and humid ambient air in the storehouse causing condensation on the cool wall and floor surfaces. In addition, the last four months of the storage period showed that the mean grain RH and mean stack RH had minimal fluctuations while the mean grain MC was relatively stable (about 14.0%) which may be attributed to the dry season period (Figure 4). This indicates that stack RH and grain RH directly influence the grain MC. This condition observed corroborated with Abass et al. (2017) that grains in a single stack tend to gain or lose moisture to the surrounding air when held for several months. This indicates that RH plays a major role in influencing the microclimate in stored grains thereby contributing to the rate of moisture gain or loss in the grain bags. Bradford et al. (2018) reported that the high RH prevalent in humid climates raises the moisture content of dried commodities stored in porous woven bags, enabling fungal and insect infestations. There were no insects found in the first four months of storage while there was presence of insects (June to September) during the storage period which was generally low (1–3 insects per 700 g of maize) as shown in Figure 4. This can be attributed to the initial low moisture content of the grains (8.6%) as the grains were well-dried to a safe storage level to avoid susceptibility to insect infestation. Despite the absence of insects in the last three months of storage, there was a gradual rise (26.0–29.6 ^oC) in grain temperature and RH levels (70.0–72.1%), while grain MC was relatively stable at about 14.1% (Figure 4). This may indicate the presence of biological activity (fungal) due to the presence of hot spot(s) in the stored grains in the bag. The mean stack temperature followed the mean ambient temperature trend, indicating that the ambient temperature directly influences the stack temperature (Figure 4). More so, the mean grain temperature and RH trends followed the mean stack temperature and RH trends, indicating the stack temperature and RH contributes to the grain temperature and RH fluctuation trends.

Similarly, in the TSP storehouse, the ambient conditions were the same as the IPMD storehouse. The stack temperature levels in the TSP storehouse followed the same trend with the ambient temperature throughout the storage period, which was similar in the IPMD storehouse, however the stack temperature levels in TSP storehouse were generally higher (26.6–32.7^oC) than the IPMD storehouse (26.6–32.1^oC). Consequently, there was better ventilation in the IPMD storehouse than the TSP storehouse which can be attributed to the structural modification in the IPMD storehouse. The absence of insects in the first three months of storage can be attributed to the initial grain MC which was about 8.6% indicating that the grains were well dried prior to storage. Furthermore, most stored grain insects find it difficult to live on very dried grains. It also conforms to already established studies that grain storage in tropical regions can store effectively between 3–4 months if the grain is well dried to a safe storage MC level (Adejumo and Raji, 2007; Adesina et al., 2019). However, with an accentuated steady rise of mean grain RH, there was emergence of insects which gradually increased from 2 to 58 insect counts per 700 g (May to December) with a corresponding and gradual rise in the mean grain MC during the same period (Fig. 3). This aligned closely with the findings from a similar study carried out by Danso et al. (2018) where rise in RH supports increment in insect population. Interestingly, the mean grain MC gradually rose (8.6 to 13.0%) from February to September with an increase in mean ambient RH. However, as the mean ambient RH levels were below 69% (September to December) and continuous ambient temperature rise, there was a rise in grain and stack temperatures (28.5–34.0^oC and 28.6–32.5^oC) with a significant rise in the mean insect counts (18–58 insects per 700 g) as shown in Figure 3. Increased biological activities of insects as a result of insect population growth in stored grains brings about an increment in grain temperature (Jian, 2019). There were no insects found in the first three months of the storage period in both storehouses which can be attributed to the initial conditions of the grains (cleaned and fumigated grains with 8.6% MC), properly sealed bags and cleaned storehouses. On observation in both storehouses, the mean grain temperature and RH generally followed similar trends with the mean stack temperature and RH respectively, indicating that the microclimate of the stacks in the storehouse influences the microclimate condition in the grain bags. This indicates that monitoring the microclimate in the storehouse can give a pre-insight to the microclimate of the grains in bags during the early storage period.

The results for the regression analysis showed that ambient temperature and RH, grain temperature and RH showed good influence on the grain MC (Adjusted R^2 value of 0.9999) with grain temperature and grain RH having the most influence in IPMD storehouse in Bodija market. More so in the TSP storehouse, regression analysis results showed that grain RH had the highest impact, closely followed by grain temperature among the least influence of ambient temperature and ambient RH on grain MC respectively (Adjusted R^2 value of 0.9992). The microclimate conditions in the grain bag will directly have an impact on the moisture content level of the grains in both storehouses. The regression analysis showed that ambient temperature and grain temperature had greater influence with ambient RH on the insect count (Adjusted R^2 value of 0.7941) in IPMD storehouse in Bodija market as compared to TSP storehouse where there was little influence on insect count. Ambient RH played a major role in affecting the outcome in the TSP storehouse which can be attributed to the practice carried out and a possibility of leakage(s) in the roof and crevice(s) which is characterized by most typical storehouses in this market.

Ambient temperature and stack temperature correlated in both storehouses, while there was a negative correlation between the ambient RH and stack RH in both storehouses in Bodija market. This shows that the ambient temperature is a good indicator for stack temperature, however ambient RH is a poor indicator for the stack RH in TSP and IPMD storehouses in Bodija market respectively (Nguyen, 2014). Furthermore, in both storehouses, grain temperatures strongly correlated with stack temperatures, while a strong correlation was found between the grain RH and stack RH respectively. This suggests that the surrounding air in the storehouse should be kept cool and dry always to prevent the presence of high moisture because grains are hygroscopic in nature.

4.2 Eleekara market

The mean ambient temperature trend at Eleekara market was very similar to Bodija market. In the IPMD storehouse, the mean ambient RH gradually increased (65.0 to 88.0%) from February to September 2016, and declined gradually towards the end of the storage period but rose by 10% in December 2016 (Figure 5). In addition, the mean stack and grain RH followed the trend of the ambient RH, however there was a noticeable decrease in the last 3 months of the storage period. Consequently, the trend observed may be attributed to frequent rainfall events in the year (May to September 2016) and gradual decrease in rainfall towards the end of the year (October to December 2016). More so, the mean ambient temperature trend gradually declined from March to August (about 30.0 to 26^{o}C), and gradually rose after the August rain break till the end of the storage period (31.2^{o}C) as shown in Figure 4. The fluctuations in the RH level for ambient, stack and grain conditions influenced the mean grain MC which resulted to a gradual rise in the mean grain MC (8.6 to 13.8%) from February to September, and a decrease in the last three months (13.1 to 12.1%) of the storage period. A reduction in mean grain MC level during the dry season (September to December) was also observed in a similar study carried out in Ghana by Danso et al. (2018). This can be attributed to the increased humidity (64.1 to 88.0%) (Figure 5) at the macroclimate as experienced in the wet season (April to October) and decreased humidity during the dry season period (October to December) with RH less than 80% in the Western part of Nigeria. Interestingly, the mean grain MC trend increased gradually corresponding to the rise in the mean ambient RH and insects respectively, however when mean ambient RH levels were below 87% (September to December 2016) there was no rise in the mean grain MC. A similar trend was observed in Bodija storehouse (IPMD) at mean ambient RH (< 69%). This implies that the ambient RH varies across different locations but plays a similar role in influencing the microclimate in the storehouse hence contributing to the rate of moisture gain or loss in the grain bags. Seed and commodities are hygroscopic, and their moisture content will vary in response to the relative humidity of the air to which they are exposed (Bradford et al., 2016). Bakhtavar et al. (2019) noted that ambient RH and temperature affect seed moisture content and their seed moisture isotherm. Consequently, the presence of insects in the sampled grains were low (< 4 insect counts per 700 g) in the first ten months of storage despite the favourable microclimate conditions (mean grain temperature and RH: 27.8–33°C and 65–88% respectively) for rapid insect multiplication. This can be attributed to the initial grain MC level and the IPMD practice which helped to suppress insect growth rate from February to October. This suggests that the initial grain MC and IPMD practice contributes significantly to the grain quality preservation during the storage period in storehouses at market location. In addition, the mean stack temperature and RH followed the mean ambient temperature and RH trends, indicating that the ambient macroclimatic conditions directly influence the stack microclimatic conditions (Figure 5). Also, the mean grain temperature and RH closely followed the mean stack temperature and RH trends.

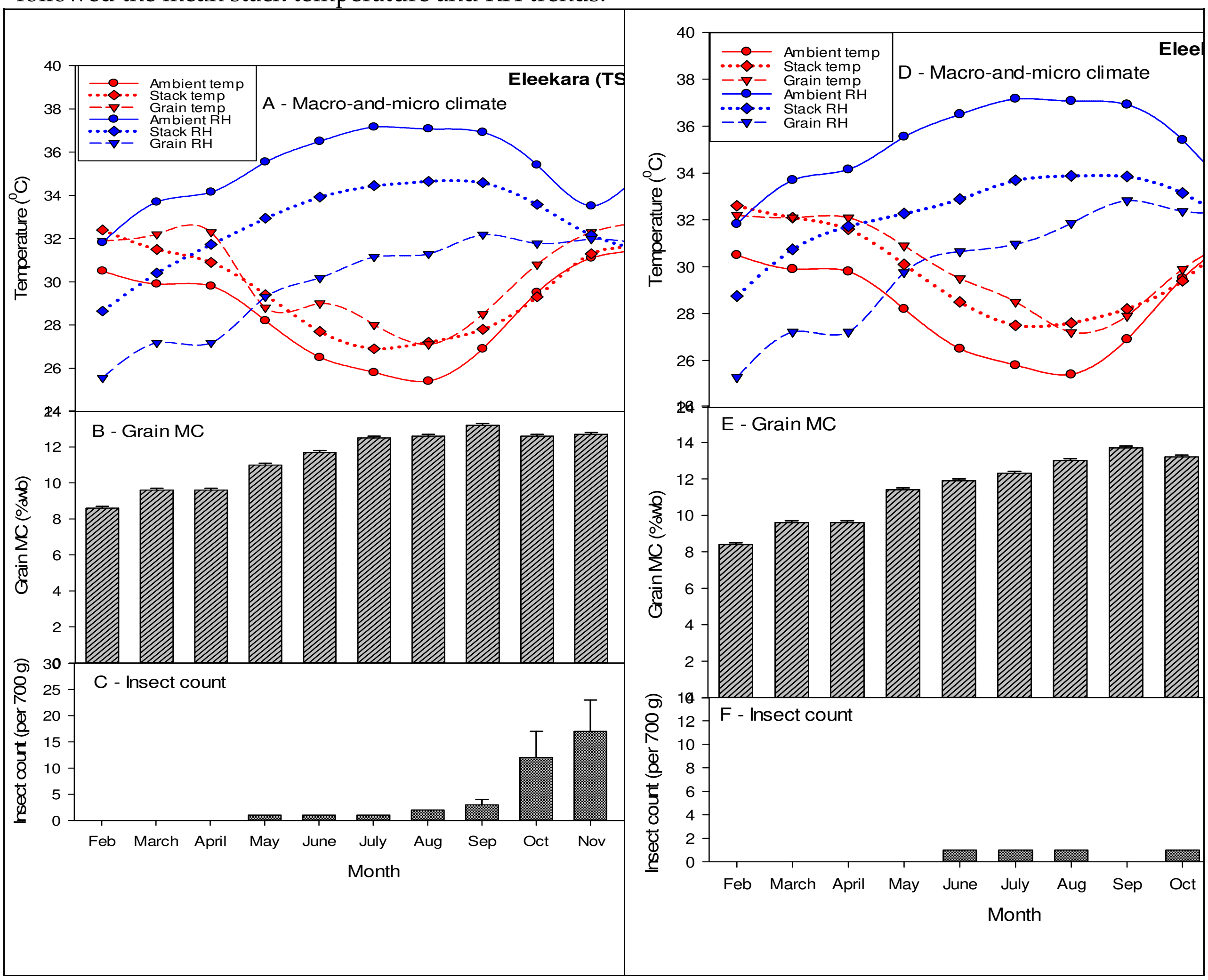

Figure 5. Eleekara storehouse: Macro-and-micro climate (A), Grain MC (B), Insect count (per 700 g) (C) for TSP; and Macro-and-micro climate (D), Grain MC (E), Insect count (per 700 g) (F) for IPMD, respectively.

Similarly, in the TSP storehouse, the mean stack temperature and RH levels followed a similar trend with the mean ambient temperature and RH trends throughout the storage period =, which was similar to the IPMD storehouse. Consequently, it was observed that the grain mean temperature and RH trends also followed the trends of the mean stack temperature and RH respectively, which suggests that the stack microclimate may influence the grain microclimatic conditions. This explains the importance of proper ventilations in grain storehouses to ensure grains are properly preserved over time. The mean grain MC gradually rose (8.6 to 13.5%) from February–September as the mean ambient RH increased (68.0 to 88.0%), indicating that the ambient RH may influence the moisture content of stored grains. There was a rise in grain mean temperature (26.5–31.1^{o}C) corresponding to a spike in the mean insect counts (4–23 insects per 700 g) in the last four months of the storage period. The rise in the grain temperature may be attributed to the increased insect activities compared to the preceding months in the stored grain. This observation is consistent with (Danso et al., 2018) findings which indicated that temperature rise was related to insect activities in the grain bags. Insect counts were relatively low in the first seven months of the storage period, which was similar to the IPMD storehouse.

Ambient macroclimate (temperature and RH) and stack (temperature and RH) correlated in both storehouses in Eleekara market. This suggests that the ambient macroclimate is a good indicator for stack microclimate in TSP and IPMD storehouses in Eleekara market respectively. In both storehouses, grain temperatures strongly correlated with stack temperatures, while a good correlation was found between the grain RH and stack RH respectively. This suggests the need for the storehouses to be kept cool and dry always to prevent the presence of high moisture because grains are hygroscopic in nature.

In addition, the results for the regression analysis which showed that ambient temperature, ambient RH, grain temperature, grain RH showed influence on the grain MC (Adjusted R^2 value of 0.9988) with grain temperature and grain RH having the most influence in IPMD storehouse in Eleekara market. In the TSP storehouse, regression analysis results (Adjusted R^2 value of 0.9975) showed that grain RH had the highest influence on grain MC among other variables — ambient temperature and RH, and grain temperature respectively. This indicates that the grain MC will increase as grain RH increases if the surroundings of the stored grains are exposed to high humidity over time. The regression analysis showed that among the variables of ambient temperature and RH, and grain temperature, ambient RH had a greater influence on the insect count (Adjusted R^2 value of 0.5939) in IPMD storehouse in Eleekara market as compared to TSP storehouse (Adjusted R^2 value of 0.7069) where ambient temperature and RH had more influence on insect count. Most significantly, the influence of RH cannot be overemphasized on the grain MC as well as creating a conducive atmosphere for insects, however this influence can be reduced or slowed down as shown in IPMD storehouse.

4.3 Mandate market

In the IPMD storehouse, the monthly mean ambient temperature showed a steady decline from the the February to July (28.8 to 25.2^{o}C), before gradually rising from August till December while the mean ambient RH was low (about 45%) at February but began to rise and remained slightly stable from July to September before a steep decrease towards the end of the storage period. (Figure 6). This trend was similar to IPMD storehouses in Bodija and Eleekara markets which can be attributed to the seasonal change and rainfall event fluctuations during the year in the Western and North Central part of Nigeria. The trend of the mean grain MC showed that the ambient weather condition variations influenced the pattern of the mean grain MC gradual rise and fall. The mean grain MC experienced two peaks (August and September) at mean ambient RH of 90%, with corresponding ambient temperatures of 24.8 and 25^{o}C respectively. These conditions provide availability of moisture in the surrounding air which can facilitate moisture pickup of stored grains. The mean grain MC gradually increased (8.8 to 13.4%) as mean ambient

RH increased (40 to 90.1%) and insects emerged during the same period (March to August). This may indicate that insects thrive in a moist environment. More so, there was a surgency in the number of insects (18 insects per 700 g) found in December 2016 corresponding to a mean grain temperature of 30.7°C . This indicates the presence of a high insect population and rapid insect activities leading to heat production thereby raising the temperature of the grains in the bag. Stored product insect pests rely on a warm environment to remain active. IPMD practice in the IPMD storehouse was very effective in limiting insect population growth rate as compared to the TSP storehouse in the Mandate market. On observation, the mean insect count trend did not follow the mean grain MC trend. In addition, the mean stack temperature and RH followed the mean ambient temperature and RH trend, indicating that the ambient temperature directly influences the stack temperature. More so, the mean grain temperature and RH trend followed the mean stack temperature and RH trends, indicating the stack temperature and RH can influence the grain temperature and RH.

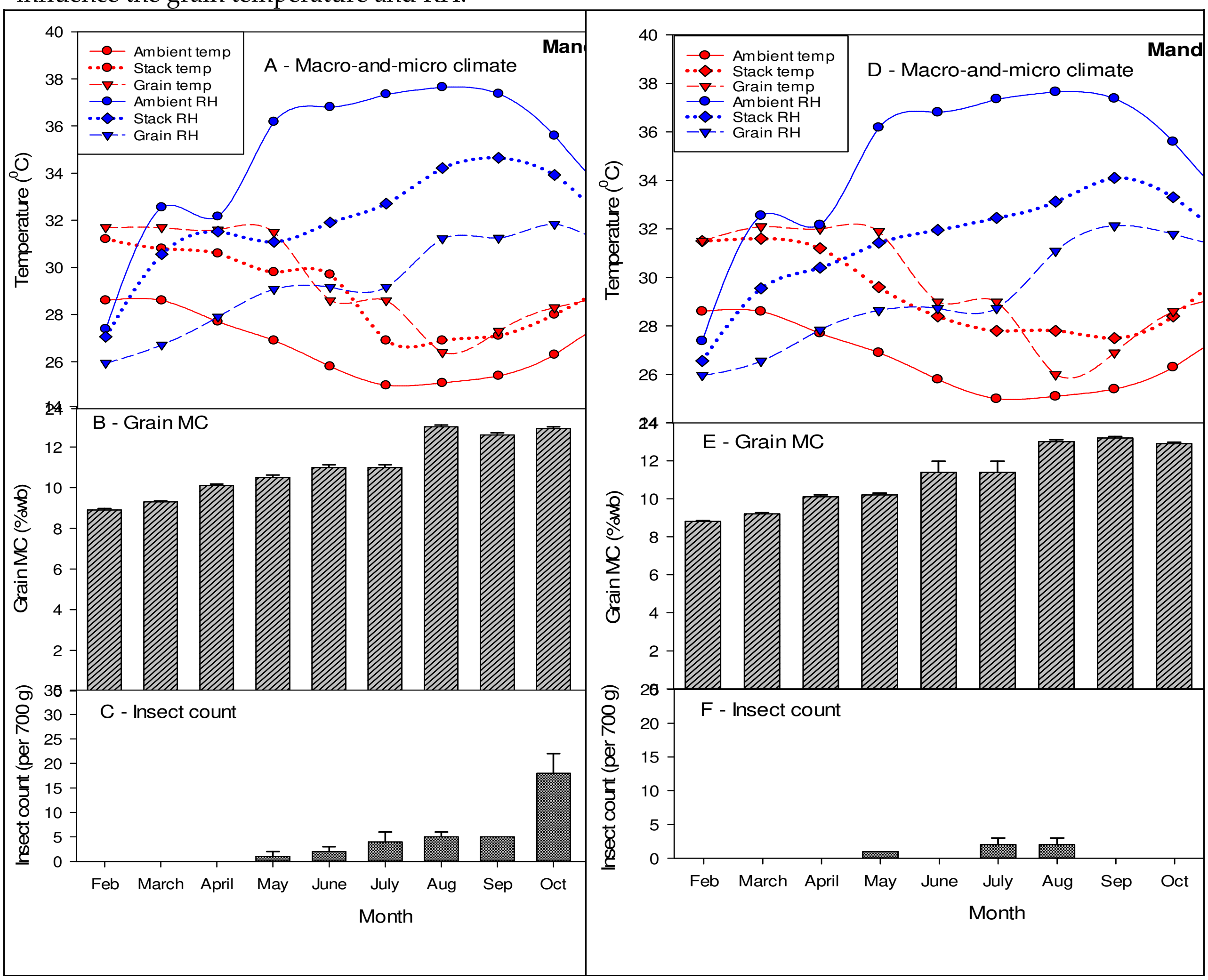

Figure 6 Mandate storehouse: Macro-and-micro climate (A), Grain MC (B), Insect count (per 700 g) (C) for TSP; and Macro-and-micro climate (D), Grain MC (E), Insect count (per 700 g) (F) for IPMD, respectively

In the TSP storehouse, the monthly mean ambient temperature and RH were the same as IPMD storehouse. The trend of the mean grain MC showed that the ambient weather condition variations influenced the pattern of the mean grain MC gradual rise and fall. The mean grain MC experienced two peaks (August and October) at mean ambient RH of 90 and 88.7%, at corresponding ambient temperatures of 25.2 and 26.2^oC respectively (Figure 6). These conditions provide availability of moisture in the surrounding air which can facilitate moisture pickup of stored grains. The mean stack temperature and RH levels in the TSP storehouse followed a similar trend with the ambient temperature and RH levels throughout the storage period, which was similar in the IPMD storehouse. The mean grain MC gradually rose with an increase in mean ambient RH from February to August. However, there was a slight decline (October to December 2016) of the mean ambient RH as well as a slight drop in the mean grain MC. More so, the trend of the mean grain RH showed a gradual steady rise from the beginning (February) of the storage period till the end (December) which could have facilitated the general rise in the mean grain MC. This shows that relative humidity plays a major role in raising the moisture content level of grains. This aligned with Angelovic et al. (2018) findings that ambient fluctuation results in a direct impact on the temperature and RH of stored maize grain in a concrete floored warehouse. Consequently, there was no insect found in the first 3 months of storage, however there was a gradual rise in the number of insects found from May to December (2–25 insects per 700 g). This indicates a rapid insect infestation in the stored grains thereby causing reduction in the quality of the grains. Despite the similar trend of the macro- and micro- climatic conditions of the TSP and IPMD storehouses, insect infestation was more prominent during May to November with TSP practice. More so, December experienced a peak in insect counts (25 insects per 700 g) with corresponding mean grain temperatures of 31.7^oC which was higher than temperatures for stack and ambient respectively. This indicates an increased metabolic activity of the insects with continuous heat production.

Furthermore, ambient macroclimate (temperature and RH) and stack (temperature and RH) correlated in both storehouses in the Mandate market. This suggests that the ambient macroclimate can be a good indicator for stack microclimate in TSP and IPMD storehouses in the Mandate market respectively. In both storehouses, grain temperatures and RH correlated with stack temperatures and RH respectively. Again, this suggests the need for the storehouses to be properly ventilated, kept cool and dry always to prevent the temperature buildup and presence of high moisture in the storehouses because grains are hygroscopic in nature.

The results for the regression analysis showed grain RH had the highest influence among ambient temperature and RH, and grain temperature on grain MC (Adjusted R^2 value of 0.9763) in IPMD storehouse in Mandate market. More so in the TSP storehouse, regression analysis results showed that grain RH had the greatest influence, followed by grain temperature on grain MC respectively (Adjusted R^2 value of 0.9992). These results showed that the microclimate conditions in the grain bag can cause a rise in the moisture content of the grains.

The variables of ambient temperature and RH, and grain temperature were non-significant for the model derived from the regression analysis on insect counts. Similar results were reported by Danso et al. (2018) and Manu et al. (2019) where lack of correlation between the number of insects and temperature was reported. However, the regression analysis using other variables — stack RH, ambient RH and grain RH on insect counts had a significant model ($P < 0.05$) as shown. Furthermore, the regression analysis showed that stack RH had the greatest influence among the other variables on insect count in the IPMD storehouse (Adjusted R^2 value of 0.8402) while the grain RH was dominant in influencing the insect counts at TSP storehouse (Adjusted R^2 value of 0.8251) in Mandate market respectively.

There was no interaction between the storehouse locations (Bodija, Eleekara and Mandate markets) and practices (IPMD and TSP) on grain MC and insect count for the storage period. The main effect of storehouse locations and practices were non-significant on grain MC. Furthermore, the main effect storehouse was non-significant for the insect count, however, the main effect of the practice (IPMD and TSP) was significant on the insects count at $P < 0.05$. This indicated that the type of practices carried out in storehouses with bagged maize could affect the number of insects that may be found during storage. In total, the study also revealed that TSP storehouses had a higher number of insects with an estimated mean of 8 insects per 700 g sampled maize while IPMD had 1 insect per 700 g sampled maize respectively. Based on the results of this study, the best practice in total was IPMD because it effectively limited the total number of insect population at the end of the storage period.

Temperature and RH monitoring in storehouses are crucial to grain MC level during storage period irrespective of the practices employed to prevent problems such as insects and molds formation. Regression equations developed from the data could be used to build a model to predict the stored grain quality outcome at market level storehouses in different locations in the western and North Central part of Nigeria. This will help structural engineers on the appropriate design for storehouses at the market level in the humid tropics. Generally, in the long term the structural defects may be one of the factors that contributed to the poor ventilation in the TSP storehouse thereby creating an atmosphere with a faster avenue for the high insect population at the end of the storage period as compared to IPMD storehouse. The results of this study showed that monitoring of stored grains and carrying out cleaning and sanitation regularly in the storehouses and its environs contributes to a better overall grain condition over a storage period. Based on this study, it was found out that monitoring the microclimate (within the stack) in the storehouse can give a pre-insight to the microclimate of the grains in bags during the early storage period (4–7 months). In addition, proper monitoring of temperature and RH fluctuations alongside MC will help grain merchants and warehouse managers determine when to fumigate or sell off the grain before reducing from food grade to feed grade quality which determines the variation in prices and profit made. Practicing IPM in storehouses can prevent rodent infestations and slow down insect infestation rate over months of stored grains. Therefore, we highly encourage and emphasize good environmental sanitation practices in the grain markets.

5.0 Conclusion

Temperature and RH monitoring in storehouses are crucial to grain MC level during storage period irrespective of the practices employed to prevent problems such as insects and molds formation. Regression equations developed from the data could be used to build a model to predict the stored grain quality outcome at market level storehouses in different locations in the western and North Central part of Nigeria. This will help structural engineers on the appropriate design for storehouses at the market level in the humid tropics. Generally, in the long term the structural defects may be one of the factors that contributed to the poor ventilation in the TSP storehouse thereby creating an atmosphere with a faster avenue for the high insect population at the end of the storage period as compared to IPMD storehouse. The results of this study showed that monitoring of stored grains and carrying out cleaning and sanitation regularly in the storehouses and its environs contributes to a better overall grain condition over a storage period. Based on this study, it was found out that monitoring the microclimate (within the stack) in the storehouse can give a pre-insight to the microclimate of the grains in bags during the early storage period (4–7 months). In addition, proper monitoring of temperature and RH fluctuations alongside MC will help grain merchants and warehouse managers determine when to fumigate or sell off the grain before reducing from food grade to feed grade quality which determines the variation in prices and profit made. Practicing IPM in storehouses can prevent rodent infestations and slow down insect infestation rate over months of stored grains. Therefore, we highly encourage and emphasize good environmental sanitation practices in the grain markets.

Acknowledgements

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DETERMINATION OF SOME ENGINEERING PROPERTIES OF RHOKO BAMBARA NUTS

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Abstract

An investigation was carried out on some engineering properties of rhoko variety of Bambara nuts which are needed for machine/system design construction and fabrication. The engineering properties investigated were both the physical and mechanical properties. The physical properties include seed length, width, thickness, geometric mean diameter, 1000 unit mass, porosity, true density and bulk density. Some mechanical properties investigated were static coefficient of friction and angle of repose. The average length, width and thickness of Bambara nuts grains ranged from 10.5 to 14.64 mm, 9.49 to 11.65 mm and 8.5 to 10.9 mm respectively as the moisture content increased from 10.0 to 14.0 % (db), respectively. The geometric mean diameter increased from 9.64 to 12.54 mm. The one thousand grain mass increased from 502.6 to 801.6 g and the sphericity increased from 0.8332 to 0.8417 with the increase in moisture content from 10.0 to 14.0 % (db). The bulk density decreased from 0.796 to 0.696 g cm^{-3}, whereas the true density decreased from 1.28 to 1.16 g cm^{-3}. While porosity increased from 40.07% to 43.70 % with the increase in moisture content from 10.0 to 14.0 % (db). The angle of repose increased linearly from 24.51 to 26.55 degrees with the increase in moisture content. The static coefficient of friction increased for all surfaces, namely, ply wood (0.38 to 0.66), galvanized iron (0.29 to 0.58) and Aluminum sheet (0.25 to 0.5).

Key words: Rhoko bambara nuts, physiochemical, crude protein, geometric mean

1.0 Introduction

Bambara nut *Vigna subterranea (L)* is an indigenous grain legume grown mainly by subsistence women farmers in sub-Sahara African (Mkandawire, 2007). The crop has advantages over more favored species in terms of nutritional value and tolerance to adverse environmental conditions.

Bambara nut is an annual crop, which resembles groundnut (*Arachis hypogaea L*) in both cultivation and habitat (Shravani, *et al*., 2004). Bambara nut is a completely balanced food because it contains iron 4.9-48 mg/100g, compared to a range of 2.0-10.0 mg/100g for most food legumes, protein 18.0-24% with high lysine and methionine contents, ash 3.0-5.0%, fat 5.0-7.0%, fibre 5.0-12.0%, potassium 1144-1935 mg/100g, sodium 2.9-12.0 mg/100g, calcium 95.8-99mg/100g, carbohydrate 51-70%, oil 6-12%, and energy 367-414 kcal/mg (Vurayai, *et al.*, 2009).

Nigeria produce 100,000 metric tonnes of Bambara nut as reported by (Olapade and Adetuye, 2007). However, Bambara nut is still one of the lesser utilized legumes in Nigeria. It has not been adequately exploited as human food because it is hard to cook, strong beany flavor, poor dehulling and milling characteristic. The freshly harvested pods are consumed cooked, shelled and eaten as a vegetable snack, while dry seeds are either roasted and eaten as snack in a manner similar to peanut when boiled (Bamishaiye, *et al.*, 2011).

The pod of Bambara nut is very hard and the cracking methods are still traditional, these cracking methods vary from locality depending on the quantity produced. Some communities use mortar and pestle to crush the dry pods. Some beat with the sticks on flat ground; others use stones to crush pods on flat ground. The methods have the disadvantage of damaging the seeds, and are slow and tiresome (Ojediran, 2008).

Bambara nut is produce in many parts of the world, these include: Uganda, Tanzania, Kenya, Nigeria, South Africa, Cameroon, Malawi, Swaziland, India, Indonesia, Benin, Togo, Mali, Malysia, Niger, Madagasca, Mauritius, Ceylon, Australia, Brazil, etc. (Shravani, *et al.*, 2004). In Nigeria the most popular producing areas include Kano, Parts of Anambra, Plateau, Sokoto, and Benue, the provinces of Benue, Bauchi, Barno, and Plateau account largely for Nigerians production of 47,000 tonnes from 196,000 areas (Mkandawire, 2007). World production is estimated at 3,300 tonnes annually of which 45 to 50% is produced in West Africa.

The objective of this study is to determine some engineering properties of bambara nut that are relevant to processing. These will provide important information for the design or development of machine/system necessary for handling the crop.

The increase in demand for bambara nut meal and products makes it very important for efficient bambara nut processing machine to be developed. In order to achieve this, proper knowledge of engineering properties of different varieties of bambara nut is equally important. This will help satisfy the demand for bambaranuts in growing feed and food processing industries. The objective of this study is to determine some basic physical properties of rokho bambara nut variety.

Researchers have reported on physical and engineering properties for different seed types such as sunflower (Helianthus annuus L.) (Gupta and Das, 1997), sesame (Tunde Akintunde and Akintunde, 2004; Gharibzahedi et al., 2009), rapeseed (Brassica napus L.) (Cahsir et al., 2005), safflower (Carthamus tinctorius L.) (Baumler et al., 2006), flaxseed (Linnum usitatissimum L.) (Coskuner and Karababa, 2007), soyabeans (Hassan, 2017) and wild sunflower.

Having found that not much work has been done on the physical properties of rhoko variety of Bambara nut to enhance its processing with the attendant benefit to humans, this work was then carried out with the following objectives. To determine some physical properties of rhoko Bambara nut such as axial dimensions, mass, bulk and true density and some parameters calculated were sphericity, surface area, geometric mean diameter coefficient of friction and angle of repose. These properties help to enhance handling (harvesting, cleaning, drying, milling and storing).

2.0 Materials and Methods

2.1 Preparation of the Sample

The test material selected for the study was rokho bamabara nut variety which was obtained from Muda lawal Market in Bauchi metropolis, Bauchi State and was taken to Bauchi State Agricultural Development Programme (BADP) for identification. The experiment on the material was carried out in a laboratory.

Broken, split, spoiled and deformed seeds were discarded before the samples were prepared for the experiment. Sample selection was randomized all through the tests and care was taken to ensure that only good seeds were used. For the variety, three levels of moisture content were taken (10, 12 and 14 %). Values of 10-14 % were selected based on the range of moisture content values in literature. These values are the normal values at which post-harvest threshing operations are carried out. The moisture content of the sample was determined by using oven drying (103±2 °C) method until constant weight was reached. The average moisture content of the bambara nuts was calculated based on dry basis (Kashaninejad *et al.,* 2003). The Bambara nuts was conditioned by adding a calculated quantity of water (equation 2.1), which was mixed thoroughly in the samples and sealed in separate polyethylene bags. The samples were kept in a refrigerator for fifteen days in order to have uniform distribution of moisture throughout (Karababa, 2005).

$$q = \frac{W_i(M_f - M_i)}{(100 - M_f)} \qquad (1)$$

Where: q = additional quantity of moisture (g)
$W_i = wieght\ of\ sampl, g$
M_f = final moisture content (db) (which is to be attained after adding water)
M_i= initial moisture content (db)


Plate 1: Rokho Bambara nut pods plate 2: Unharmed Rhoko bambara nuts

2.1.1 Determination of geometric mean diameter

In order to determine the linear dimensions of the bambara nut seeds, one hundred nuts were randomly selected. For each nut, the three principle dimensions, namely length (major diameter), width (minor diameter) and thickness (intermediate diameter) were measured using a vernier caliper having the least count of 0.001 mm at each moisture level. The length (L) was defined as the distance from the tip cap to kernel crown. Width (W) was defined as the widest point to point measurement taken parallel to the face of the kernel. Thickness (T) was defined as the measured distance between the two kernels faces as described by Pordesimo *et al*. (1990). The geometric mean diameter of the bambara nuts was calculated by using equation (3.2) (Mohsenin, 1980). The linear dimension of the bambara nut is shown in Figure 1.

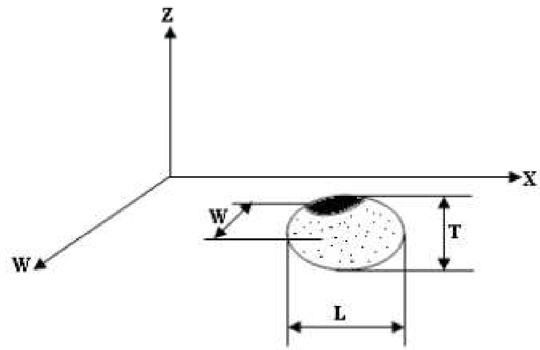

Fig. 1: Characteristic Dimensions of bambara nut

The geometric mean diameter of the bambara nut was calculated using the following relationship (Mohsenin, 1980):

$D_g = (LWT)^{1/3}$ (2)

Where: D_g = geometric mean diameter (mm)

2.1.2 Determination of One thousand grains mass

The one thousand grain mass was determined using an electronic weighing scale having an accuracy of 0.1g.

2.1.3 Determination of bulk density

The bulk density is the ratio of the sample mass of bambara nuts to its total volume. It was determined by filling a 1000 mL container with kernels from a height of about 150 mm, striking the top level and then weighing the content (Deshpande *et al.,* 1993; Gupta and Das; 1997; Konak *et al.,* 2002).

$P_b = \frac{M}{V}$ (3)

Where: P_b = bulk density, (kg/m^3)
M = mass of seeds (kg)
V = volume of seeds (m^3)

2.1.4 Determination of true density

The true density was determined using liquid displacement method. (Mohsenin, 1980) Grain sample of 5g was submerged in kerosene in a measuring cylinder having an accuracy of 0.1 mL, the increased in volume due to sample was noted as true volume of sample which was used to determine the true density of the sample.

$P_s = \frac{(M_s+M_w)}{(V_s+V_w)}$ (4)

Where: P_s = true density (kg/m^3)
M_s = weight of liquid (kg)
M_w = weight of air dry sample (kg)

V_s = volume of liquid (m^3),
V_w = volume of sample (m^3).

2.1.5 Determination of porosity

Porosity is the ratio of volume of internal pores in the particle to its bulk volume. It was expressed using Mohsenin (1980) relationship:

$$\acute{\varepsilon} = \frac{P_s - P_b}{P_s} \times 100 \quad (5)$$

Where: P_s = true density (kg/m^3)
P_b = the bulk density (kg/m^3)

2.1.6 Determination of angle of repose

The angle of repose is the characteristics of the bulk material which indicates the cohesion among the individual grains (Wandkar *et al.*, 2012). The higher the cohesion, the higher the angle of repose. The angle of repose is the angle from the horizontal at which the material will rest in a pile. This was determined by using an open-ended cylinder of 15 cm diameter and 30 cm height. The cylinder was placed at the center of circular plate having a diameter of 70 cm and was filled with bambara nuts grains. The cylinder was raised slowly until it formed a cone on the circular plate. The height of the cone was recorded. The angle of repose, was calculated by using the following formula:

$$\theta = \tan^{-1}(\frac{2h}{d_c}) \quad (6)$$

Where: θ = angle of repose(°)
h = hieght of pile (mm)
d_c = diameter of cone(mm)

2.1.7 Determination of static coefficient of friction

The coefficient of friction of the seeds were determined on plywood and glass surfaces using a tilting table. The angle of inclination of the table to the horizontal at which samples started sliding were measured with the protractor attached beside the inclined plane apparatus (Maduako and Hannan, 2004). Measurements were replicated five times for each sample and the coefficient of friction was calculated from the relation;

$$\mu = \tan \alpha \quad (7)$$

Where: μ = the static coefficient of friction
α = the angle of tilt in degrees.

3.0 Results and Discussion

3.1 Physical Properties of Bambara nuts

3.1.1 Dimensions and one thousand grain mass

The result of Bambara nuts size and mass at three moisture contents (10, 12, 14 %) are shown in Table 1. All the dimensions increased with moisture content in the moisture range of 10.0 %–14.0 % (db). All the dimensional properties were significantly correlated to different moisture content. The result indicates that the length, width and thickness increase from 10.50 to 14.64 mm, 9.49 to 11.65 mm and 9.64 to 12.54 mm respectively. The geometric mean diameter and the thousand grain mass were also found to increase within the moisture range (10.0 to 14.0 %) from 9.64 to 12.54 mm and 502.6 to 801.6 respectively.

Table 1: Principle dimensions, geometric mean diameter, sphericity and thousand grain mass of rhoko bambara nuts

M_c (%)	L(mm) Mean±SD	W (mm) Mean±SD	T (mm) Mean±SD	D_g (mm) Mean±SD	TGM (g) Mean±SD
10	10.5±0.27	9.49±0.26	8.50±0.24	9.64±0.22	502.6±0.2
12	12.34±0.26	10.5±0.21	9.56±0.20	10.93±0.17	604.88±0.59
14	14.64±0.2	11.65±0.2	10.9±0.19	12.54±0.17	801.6±0.40

Mc = moisture content, L = length, W = width, T = thickness, Dg = geometric mean diameter and TGM = one thousand grain mass

Similar investigations have been made to evaluate the mass and dimensional properties and similar results were found by Wandkar *et al*. (2012), Deshpande *et al*. (1993) for a different variety of bambara nuts.

3.1.2 Bulk density, true density and porosity

The bulk density of the variety decreased from 0.796. to 0.696 g cm^{-3}, respectively, as moisture content increased from 10.0 % to 14.0 % (db). The true density was also found to decrease from 1.28 to 1.16 gcm^{-3} with the increase in moisture content from 10.0 % to 14.0 % respectively (Table 2). The reason for the decrease in densities with increase in moisture content is that the volume of the seeds increased when it contains more moisture. Deshpande et al,(1993), Polat et al. (2006), Isik (2007) and Wandkar et al. (2012) also reported the same trend.

The porosity of bambara nuts at the three moisture content was found to increase from 40.07 % to 43.70 % with the increase in moisture content from 10.0 % to 14.0 % (db), Table 2. The similar trend for porosity was reported by (Isik, 2007; Wandkar *et al*., 2012).

Table 2: Bulk density, true density, porosity and angle of repose of rhoko bambara nuts

Mc (%)	ρ_b (g/cm^3) Mean±SD	ρ_t (g/cm^3) Mean±SD	έ (%) Mean±SD	Θ (°) Mean±SD
10	0.796±3.76	1.28±4.76	40.07±0.59	24.51±0.69
12	0.724±4.63	1.17±3.12	40.39±0.66	25.90±0.39
14	0.696±8.74	1.16±5.13	43.70±0.52	26.55±0.70

Mc = moisture content, ρ_b= bulk density, ρ_t= true density, έ = porosity and Θ = angle of repose of Bambara nuts

3.1.3 Angle of repose

The experimental data obtained for angle of repose of bambara nuts is also given in Table 3. The angle of repose increases linearly with the increase in moisture content. The value of angle of repose increases from 24.51 to 26.55 degrees as moisture content increases from 10.0 % to 14.0 % (db). Similar increasing trend was reported by Munde (1997; Hassan, 2017) and Wandkar *et al*. (2012) for green gram and bambara nuts respectively.

Table 3: Values of static coefficient of friction for rhoko bambara nuts against different surfaces

Mc (%)	**Ply wood** Mean±SD	**Galvanized iron** Mean±SD	**Aluminum** Mean±SD
10	0.38±0.026	0.29±0.017	0.25±0.02
12	0.55±0.017	0.49±0.02	0.37±0.10
14	0.66±0.017	0.58±0.026	0.50±0.01

3.1.4 Static coefficient of friction

At the three moisture contents, the static coefficient of friction was determined on three surfaces – ply wood, galvanized iron and aluminum. The result showed that the highest value (0.66) was found against ply wood and least (0.25) for aluminum sheet. As the moisture content of bambara nuts increased, the static coefficient of friction also increased. (Table 3). Similar trend was represented by Polat *et al*. (2006) and Wandkar *et al*. (2012) for wooden material and glass.

4.0 Conclusions

Physical properties of bambara groundnut and other grains and seeds are necessary for the design of equipment to handle, transport, process and store the crop. The physical properties of a variety of *bambara* nuts which is commonly found in Bauchi State, Nigeria were determined; the principal dimensions varied with increase in moisture content, though there was no significant change in the major diameter. This shows that the length of *bambara* nut is negligibly affected by change in moisture content as the nut shrank mainly from the minor and intermediate diameter when the moisture content level was reduced. The value obtained for sphericity indicates the possibility to roll relatively well where necessary. Hopper and other unloading devices need not to be too sloppy because of the relatively low coefficient of static friction of the nut.

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A REVIEW OF GREEN PEA'S FOOD POTENTIAL, AND PROCESSING FOR OPTIMUM STORABILITY

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Abstract

This paper focused on postharvest handling of green pea (Pisum sativum L.). The Green pea is an annual leguminous crop which has a short life span of 3 to 4 days; it is grown and consumed by humans and contains low calories but rich in fiber, micro and macro nutrients. In-depth review of the potentiality of green pea as food, the various pretreatments and processing methods as well as storage methods was done. The short-comings in the existing methods used in the pretreatment and prolongation of the shelf-life of green pea were identified. The knowledge gaps in the reviewed literature were identified as areas for research and development activities that are capable of creating innovative opportunities for jobs in the food industries and in small and medium scale businesses.

Keywords: Green pea, pretreatment, processing, prolongation, food

1. Introduction

Green Pea *(Pisum sativum L.)* is a legume grown and consumed throughout the world and it is widely used in several human diets (Tharanathan and Mahadevamma, 2003; McCrory *et al*., 2010). Green pea is mainly consumed as a green vegetable with its immature pods and seeds. It can be said to be one of the important leguminous crops grown in 84 different countries and constitutes the largest percentage (36%) of total pulse production in the world (Dahl *et al*., 2012). Global pea production has shown a rise for the last 30 years. In 2008, field pea was cultivated in over 10 million hectares worldwide with a total world production of 12.13 million tons (Schatz and Endres, 2009). The crop is an annual vegetable grown largely in countries with cool climate, for example, China, India, France, USA, Kenya and Egypt. In Nigeria it is grown in the middle belt states like Plateau, Benue and Nassarawa areas (Lin *et al*., 2005; Pardeshi *et al*., 2009; Zohany and Hopf, 2000).

The fruit is a typical pod which has four to nine seeds and length of about 5 to 9 cm; it has an inflated shape. The green pea is a seasonal crop, and thrives well during cool seasons. The shelf life is not more than 3 to 4 days after harvest (Madhuri and Tayade, 2019; Tanushare and Saxana, 2017).

Legumes and green pea especially play integral role in sustainability of agriculture by its ability to replenish soil nutrient and maintain soil properties. Peas are highly susceptible to changes after harvest, during processing and storage; they hence require proper handling to maintain their quality (Tanushare and Saxana, 2017; Rohit *et al.*, 2017).

This paper presents a review of potentiality of green pea as food, the various processing and storage methods, and also some identified prospective areas of research and development in relation to postharvest handling of green pea for optimum storability and enhanced quality.

Green Pea Food Potential and Nutritional Value

Green pea is an important food resource that contributes to the nutritional wellbeing of humans, and it is consumed in various diets (Uebersex and Occen, 2003). It is an excellent source of nutrients and contains appreciable proportion of digestible protein (23-25%), carbohydrates (50%), minerals and vitamins (Madhuri and Tayade, 2019; Tanushare and Saxana, 2017). Green pea is also a source of micronutrients and phytochemicals. Their nutritional properties have been linked in the reduction of various cancers, LDL cholesterol, type -2 diabetics and heart diseases (Bassett *et al.*, 2010; Roy *et al*., 2010; Cryne *et al*., 2012; Ldjal and chibane, 2015).

Green pea is considered a potential source of antioxidants because of it high content of carotenoids and polyphenols (Oruna-concha *et al.*, 1998; Chauresi et al., 2012). It is low in fat, high in fiber and contains no cholesterol. Peas are excellent source of vitamin C, vitamin B1 (Thaimine), vitamin B6, B3 (Naicin), B2 (riboflavin), Pro-vitamin A carotenoids (Tanushare and Saxana, 2017). Chuku *et al.* (2019) investigated the mycoflora and nutritional constituents of *P. Sativum* for healthy and spoilt samples and reported the presence of moisture, ash, fibre, lipids protein and carbohydrate in both samples. Highest values were reported for healthy samples; and mineral composition analysis showed the presence of calcium, potassium, sodium, iron and magnesium.

Green pea can be boiled and eaten as a vegetable; dried or prepared as soup and salad. It can also be marketed fresh, canned or frozen for future use (Sharma *et al.,* 2015). The dried ripe peas are consumed whole or made into flour. They can be used in purees and processed products. Dried peas are eaten as dhal, roasted, parched or boiled in some parts of the world (Messiaen *et al.*, 2004). Garg (2015) found green pea powder to contain proximate and mineral properties and that the powder can be used for making Jaggery biscuits. Pea starch has been used to prepare noodles by high temperature extrusion process and this showed superior quality than noodles prepared from lentil starch (Wang *et al.*, 2014). Agnes and Joseph (1986) produced Akla from yellow pea flour and reported some properties of the batter indicating that the presence of hull in the batter increased the specific gravity and decreased the batter volume; and that the moisture content of the batter had a linear relationship with oil absorption of the akla. They also reported that low moisture batter produced heavy textured Akla.

Green Pea Processing

The rate of spoilage and biological degradation of agricultural crops is dependent largely on postharvest handling and storage conditions. Postharvest processes include the integrated functions of cleaning, grading, cooling, blanching, drying, packaging, storing, transportation and marketing. It involves the practical application of engineering principles and knowledge of fruits and vegetables to solve problems (Fasana, 2006).

Fresh vegetables which contain vitamin C starts to degrade immediately they are harvested, because they are perishable in nature and are seasonal, for example, green pea and lettuce (Daniela *et al.,* 2016; Fasana, 2006). To minimize loss of valuable nutrients and general postharvest losses, various methods have been used to process green pea which include: chilling for short term preservation of green pea, freezing, boiling, drying, and blanching (Howard et al., 1999).

Freezing was considered the simplest and natural way to preserve vegetables for retention of quality during long period storage (Cano, 1996). This is because they exhibit better sensory qualities such as flavor with minimal distortion of heat sensitive nutrients (Maity *et al.*, 2011). The problems with this type of processing and preservation method include epileptic power supply (as in developing countries) and deteriorative enzymatic actions on texture, colour, and flavor even at zero temperature (Williams *et al*., 1986). Frozen green pea can deteriorate as a result of inefficient blanching, freezing and improper postharvest handling and storage (Tanushare and Saxana, 2017). Daniela *et al. (*2016) reported the losses of nutrients during prolonged storage at chilling temperature of 4 – 6 ^{0}C and that vitamin C decreased after seven days of storage.

Drying of food preserves it nutrients and protects it by reducing moisture that micro-organisms require to thrive. Microbes need minimum amount of moisture to grow (Pandey *et al.*, 2016). Green pea can be preserved by drying. Dried peas are becoming popular because they have longer life span and palatable; and ease of handling, packaging and storage is also enhanced by reduced weight and volume of the dried pea (Chauhana and Srivastava, 2009; Messiaen *et al.*, 2004; Shukla *et al.*, 2014).

Jayaraman and Gupta (1992) used thin layer drying method to dry blanched and sulphited green pea to retain color, taste and texture of the final product. Drying time was 3 hours to achieve 7 - 8 % moisture content. They also reported that spouted bed drying is more efficient than open sun drying, with a drying rate of 3.5 times the drying rate for open sun drying.

Microwave vacuum drying has been used to evaluate the quality of dried peas. It was found to increase the drying rate to 0.59 l/min compared to the hot air convective drying at 0.20 l/min with minimal deformation in the pea structure (Tanushare and Saxana, 2017).

Radiation processing have also been used to process pea sprout and was found not to affect the quality parameters such as vitamin C content, total carotenoids, color and texture over a storage period of 12 days at 4 and 8^{0}C. The sweetness and softness of pea increased with increase in dose of irradiation after the storage period (Hajare *et al.,* 2007).

Pretreatment of Green Pea

Blanching is a thermal process which exposes plant tissue to heat. Steam or hot water is used at a given time and specified temperature to inactivate enzymes and to reduce microbial activities. The blanched material is rapidly cooled down to minimize the loss of heat–labile components (Luh and Lorenzo, 1988).

Blanching, drying, acid and sodium treatment are postharvest treatment carried out on agricultural produce to enhance its taste and prolong the shelf life. Drying of food preserves its nutrient and protects it by reducing moisture that microorganism require to thrive. Microbes need minimum amount of moisture to grow. Pandey et al. (2016) studied the effect of blanching on drying of green pea at drying temperature range of 60^{o}C to 80^{o}C with pea diameter range of 5 mm to 10 mm and reported that blanching and drying led to a reduction of moisture content at different temperatures of drying. Also, Taiwo and Adeyemi (2009), studied the influence of blanching on the drying of banana slices and reported that the effect of blanching at 60^{o}C for 10 min followed by drying at 50 – 80^{o}C had significant impact on shrinkage and moisture loss.

Severini *et al*. (2015), investigated the effect of different blanching systems and dehydration on dehydration speed, color characteristics and showed that blanching was important. Similarly, Madhuri and Tayade (2019) investigated the effect of drying, blanching and rehydration behavior on the quality of green peas. They used a cabinet tray dryer at temperatures of 50, 60 and 70^oC and blanched at 85^oC for 1 min and reported that drying rate was higher at 70^oC and higher moisture content for blanched green pea. Priyadershini *et al.* (2013) also worked on blanching of green pea treated with citric acid at 85^oC and dried in a microwave at 3 different temperatures and found that blanched samples had shorter drying times than the pretreated and control samples. It was also discovered that high microwave power resulted in a shorter drying time. The blanching temperature was not varied which could result in better sensory qualities of dried green pea.

Doymoz and Kucuk (2017), reported that pretreated green pea subjected to blanching at 80^oC dried faster than the control sample and that pretreated with ethyl oleete (Kingsley et al., 2007; Srimagal *et al*., 2017). Also drying rate increased with increasing temperature. In the same vein, Pandey *et al*. (2016) dried blanched and unblanched green pea using fluidized bed dryer at 60 to 80^oC and blanching temperature of 70 to 100^oC and reported that as the diameter of green pea increased , the drying time also increased and that the moisture content reduced as drying time increased.

In a similar manner, Prakash *et al*. (2019), carried out a comparative study on blanched and unblanched green peas. . Blanching was done at 70 – 100^oC with citric acid (0.1 – 0.2 mg/ml) at different diameter sizes and subjected to drying. The researchers reported that moisture content reduced faster with blanching at a lesser time as compared to without blanching.

Green Pea Storage

Storage of green pea is necessary since it is a short period crop with life span of 3 -4 days after harvest and a seasonal crop of less than 5 months; so as to have it at off season. Some research has been carried out on the storage of green pea.Rahul *et al*.(2015), investigated the storage quality of shelled green peas under modified atmosphere packaging at different storage conditions of T_1 (40 ± 1^0C and 92 ±2 % RH) and T_2 (10 ± 1^0C and 90 ±2 % RH) and stored for 8, 16 and 24 days. The study revealed that shelled green peas can be stored in MAP with 3 perforations (0.4 mm diameter) with temperature range of 4 to 10^oC and relative humidity of 90 -94% for 24 days with marketable qualities.

The effect of storage conditions on quality and shelf life of stored peas was also investigated by Babatola *et al*., (2008) using a deep freezer (0^oC, 95% RH), room refrigerator (12^oC 85 % RH) storage incubator (8^oC, 80% RH) and ambient storage environment (32^oC, 85% RH) and three varieties of peas(green pea *(pisum sativum*), green bean *(phoseolus vulgris*) and runner beans *(phaseolus coccineus)*. They reported that storage conditions in terms of quality preservation was better with deep freezer followed by room refrigerator.

Preetinder *et al. (*2021), used low-dose aqueous ozone treatment and packaging to extend the quality and shelf life of green peas pod under cold storage. They used untreated green pea pods packaged in 3 different packaging films of different thicknesses of 38 μm LDPE, 25 μm PP and 25 μm HDPE stored at 5, 10 and 15$^oC$and relative humidity of 80 ± 5% for 12 days. The researcher also used sanitization effect using sodium hypochlorite solution and aqueous ozone at modified atmospheric packaging and stored at low temperature of 5$^oC$and the result showed a slight change in the biochemical parameters and recorded extended shelf life of 16 days.

Changes that occur in the nutrient content of some green vegetables during storage and thermal processing was studied by Daniella *et al*.(2016).They analyzed fresh , chilled, frozen and boiled broccoli, spinach, green beans and green pea. They reported that there were losses of analyzed nutrients during prolonged storage using refrigeration for 7 days and after thermal processing at time interval of 5 – 20 min, but that total carotenoid and vitamin C were more stable.

Jayaranjan *et al*.(2016) used Glycine Betaine as protection of green peas during blanching at 100^{o}C at 60 s, freeze storage (-20 ^{O}C at 90 days) and they reported that the outcome was most desirable with high level vitamin C and superior green color. The challenge with this method of storage is that the chemical used for preservation could be harmful to human, the cost of maintaining the freezer for 90 days by medium or small scale farmers is exorbitant.

Shortcomings in the Processing and Storage Methods of Green Pea

Green peas are most often frozen or processed in developed countries like in the US whereas in developing countries they are harvested and used mainly for culinary purposes before they attain certain physiological maturity due to inadequate freezing and processing facilities (Basterrechea and Hicks, 1991; Haiying *et al*., 2007). The main shortcoming with freezing in developing countries is the epileptic power supply which can lead to break down from enzymatic action on texture, color, and flavor. Inefficient freezing and improper handling of green pea can lead to rapid deterioration (Daniella *et al.,* 2016; Maity *et al*., 2011). Daniella et al.(2016) also reported losses of nutrients in green pea, green beans and spinach during prolonged storage using refrigeration for 7 days. Freezing is an energy intensive storage method below 0^{o}C and requires high cost infrastructure and uninterrupted power supply to maintain the quality of green pea during storage. Also, freezing can affect the appearance due to freezing injury. The quality of the food is also affected by prolonged freezing (Haiying et al., 2007; Rahul et al., 2015; Babatola *et al*., 2008).

Modified atmosphere packaging (MAP) is a new and current method of food preservation for a prolonged shelf life of respiring products. MAP together with cold storage of vegetables is also considered the best way to prolong their shelf life and maintain other sensory qualities (Day, 1996; Sandhya, 2010; Philips, 1996). The shortcomings of MAP storage methods are that it also requires power to sustain the cold storage facilities; and the storage period does not exceed 24 – 30 days, and concentration of CO_2 in MAP films cause deterioration of the product (Rahul *et al*., 2015).

Irradiation is the application of ionizing radiation on food to improve its safety and extends the shelf life. Irradiation was used to process pea sprout as a means of storage and was found to only last for 12 days at temperature range of 4 to 8^{o}C (Hajare *et al*., 2007). The period of storage does not equate the amount of fund expended.

Conclusion and Recommendations

This review has shown that green pea has tremendous potential in the food and pharmaceutical industries considering its nutritive content which include phenolic and oxidative components if proper postharvest treatment is carried out. Also the review has revealed a good number of processing methods as well as storage methods for shelf life prolongation of green pea, but clarity on effect of such methods on quality characteristics is lacking.

It was also discovered that blanching temperature and time which have significant effect on the quality of the product were not varied which has given rise to the research need for optimization of blanching temperature and time as they affect drying characteristics and functional properties of green pea.

The integration of blanching temperature and time after scientific optimization would go a long way to developing suitable model for green pea pretreatment for enhancement of storage and preservation of this product thereby leading to improvement in rural entrepreneurship. Information on quality, organoleptic and functional attribute of pretreated and stored green pea is lacking, hence giving impetus also for research and development in this area.

Green pea is low in fat and calorie but rich in several nutrients and fiber; therefore acceptability of pretreated green pea for supplementing nutrients in the diets of the people in the urban areas is also an area of attention for researchers.

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AN OVERVIEW OF ENGINEERING PROPERTIES OF EGUSI MELON FRUIT

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Abstract

The determination of the properties of egusi melon is essential for the design of equipment and other facilities for planting, harvesting, handling, and conveying; drying, aeration, storing, and dehulling. Neglecting these properties in design would have a detrimental influence on machine efficiency and might lead to product losses. This paper provides an overview of the physical, mechanical, thermal, and aerodynamic properties of egusi melon as evident in published literatures. It was observed from the study that, although there are many attempts to mechanize egusi melon processing, what is noticeable in most design of these machines is the lack of deeper consideration of some of the engineering properties of the egusi melon. To increase machine efficiency and reduce product losses, the study recommends that the engineering properties be put into consideration in the design of egusi melon processing equipment.

Keywords: egusi, mechanical properties, physical properties, design consideration, melon

1. Introduction

Melon (*Citrullus colocynthis L.*), often known as egusi, is a popular soup spice grown in Nigeria and many other countries in Sub-Saharan Africa. The crop's commercial value is derived from its oil-rich seeds. It is also high in protein and has adequate amounts of the majority of the essential amino acids (Ayodele & Salami, 2006). Egusi oil is a feasible alternative to most vegetable oils because melon farming is inexpensive and the plant is drought-tolerant when compared to most oil crops (Ntui, et al., 2010). Egusi is grown and utilized as food source in most parts of Africa. Melon seed is also an essential component of the traditional cropping system, frequently interplanted with staple crops such as cassava, maize, sorghum, and so on. It is a fast-growing plant that, when correctly established, covers a huge area and so controls weeds, thereby enhancing soil fertility. It has strongly lobed, blue-grey leaves that are alternately oriented (Enoch, et al., 2008).

Basically, egusi processing involves drying, washing, fermentation, shelling and coring as shown in Fig.1. Egusi processing techniques are labour-intensive, slow, tedious, very inefficient, and time-consuming because they are often done by hand. This has had a significant impact on the production and availability of melon seeds. In an effort to increase the production of egusi and its final products, there have been many attempts to mechanize these processes to largely reduce the manual involvement in the processing. For instance, many researchers have designed and fabricated coring machines (Akubuo & Odigboh, 1992; Oloko & Agbetoye, 2006; Osunde & Kwaya, 2012), washing machines (Adebayo & Yusuf, 2015; Omale, et al., 2022); drying machine (Ezeike & Otten, 1991), and shelling machines (Adekunle, et al., 2009; Makanjuola, 1975; Makanjuola, 1978; Sobowale, et al., 2015; Shittu & Ndrika, 2012; Oriaku, et al., 2013; Adedoyin, et al., 2015; Asoegwu, et al., 2015). These machines have helped to reduce labour and rate of spoilage and also increase the shelf-life of melon.

Despite the enormous production capacity and nutritional benefits, poor adaptation of melon processing activities to mechanization has been highlighted as a significant barrier to mass production of melon seeds. (Adekunle, et al., 2009; Oloko & Agbetoye, 2006; Davies, 2010; Asoiro, et al., 2018). It is critical to have a thorough grasp of the properties of egusi melon before building the machinery needed to tackle the challenges associated with traditional melon processing methods. Research into the efficient ways of melon processing is relevant to developing countries where this crop is mainly cultivated considering its nutritional importance in diets of tropical and subtropical countries. However, for an efficient design, the engineering properties of egusi melon need to be put into consideration. This paper, therefore, attempts to review the engineering properties of egusi melon in literature.

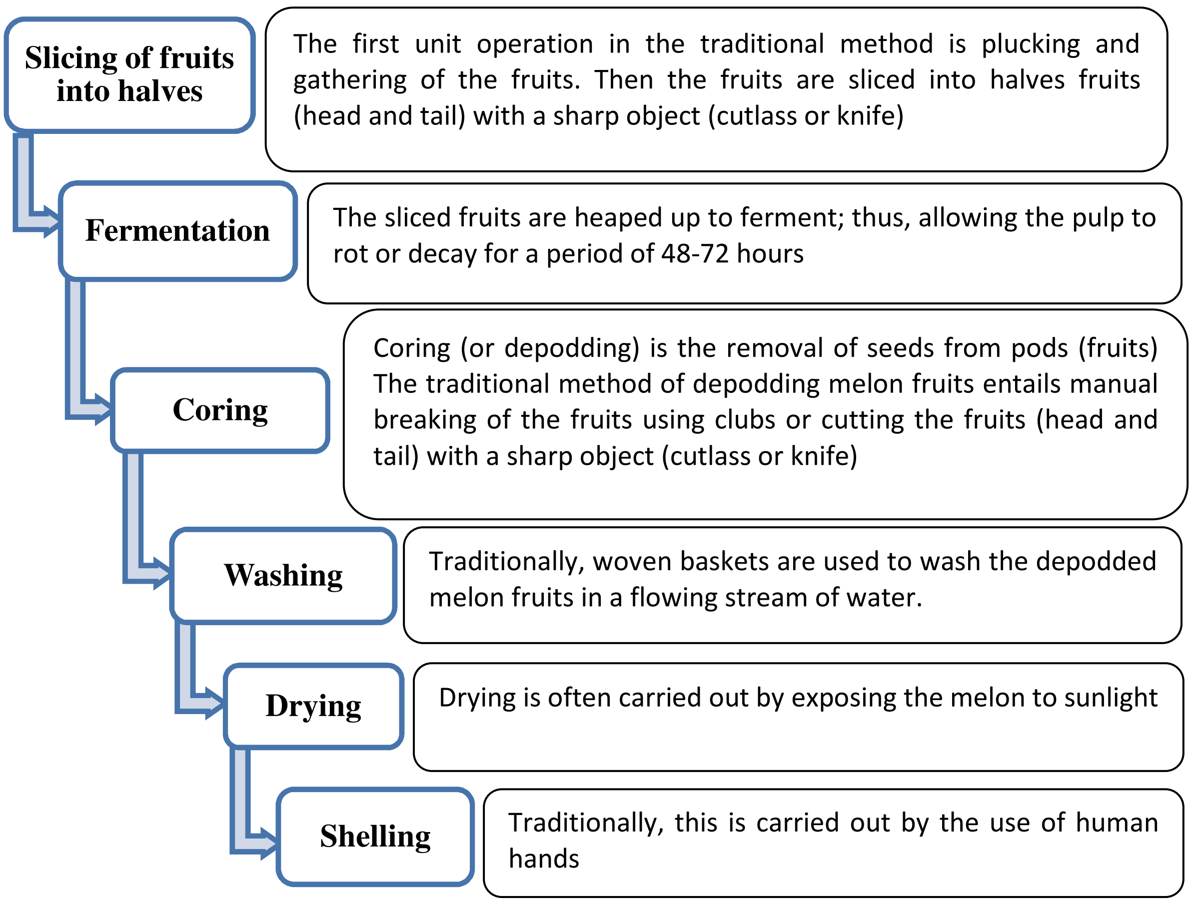

Fig. 1: Unit Operations in the Traditional Melon Processing

2. Engineering Properties of Egusi Melon

The engineering properties of Egusi melon which are highly dependent on the moisture content are crucial for designing machines and equipment for dehulling, storing, drying, conveying, planting, processing, and handling operations (Bande, et al., 2012). Fig. 2 presents the breakdown of some of the engineering properties of egusi melon.

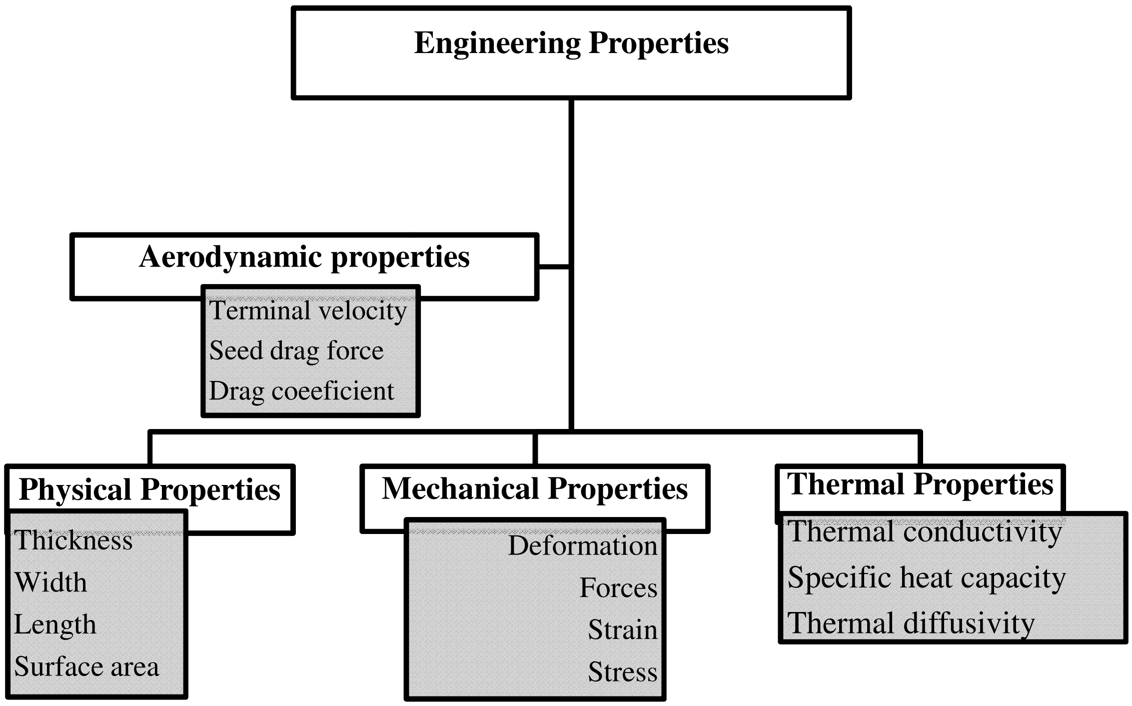

Fig. 2: A schematic diagram of the engineering properties of egusi melon

2.1. Physical Properties and Mechanical Properties

The foremost physical properties of Egusi melon that are dependent on moisture include geometric (sphericity, linear dimensions, surface area, shape, mean diameters), gravimetric (angle of repose, bulk density, mass, porosity, true density) and frictional (static friction coefficient at different surfaces (plywood, glass, galvanized sheet, rubber, etc.) properties. One of the first research on the measurement of the physical and mechanical properties of melon seeds was carried out by Makanjuola (1972). In this work, the three basic dimensions (thickness, width, and length), surface area, and deflection (under breadth- wise bending) of two varieties of melon seeds were measured. The study was centred on the measurement of the properties of kernels and seeds of two species of melon. Empirical equations connecting the three dimensions of the seeds and kernels to one another for the two species of melon and equations estimating the surface areas using either the width or length of the melon seeds and kernels were proposed by the author.

Teotia Ramakrishna (1989) in an attempt to develop and explore a better technique for the separation of melon kernels from the seeds outside the manual method, examined the porosity and densities of kernels, seeds, and hulls of three species of melon as properties. They measured the apparent, bulk and true densities, length, width, thickness, weight, and moisture content were measured. They reported a significant difference between the apparent densities of seeds and kernels for the studied melon species. The highest true density was recorded for the hulls, while the maximum bulk and apparent density were measured for the kernels. The hulls were found to be the most porous of all. Also, the apparent densities of the seeds and hulls were observed to be less dense than water, while the kernels were denser. This implied that a separation tank can be employed to separate the melon kernels from the seeds.

Shieshaa, *et al.* (2007) investigated the impact of moisture content on the physical and mechanical properties of seed melon seeds and kernels. They reported that at a seed moisture content of 9.53% (w.b.), the average length, width, thickness, mass, and hardness of 100 seeds were 12.42, 7.80, 2.37 mm, 0.097g, and 64.8 N, respectively. Corresponding kernel values were 10.5, 6.50, 1.64mm, 0.061g, and 14.0 N. The increase in seed moisture content from 9.53 to 24.08% results in an increase in seed and kernel bulk density from 490 to 600 and 510 to 640 kg/m^3, respectively. However, the real seed density was reduced from 1160 to 1000 kg/m^3. Meanwhile, it grew from 1015 to 1150 kg/m^3 for the kernel. The porosity fell from 58 to 41 and 50, respectively.

Oyerinde, *et al.*, (2020) carried out a study aimed at determining the mechanical properties of two selected varieties (*Bara* and *Sewere*) of melon. Deformation, force, strain, stress, time to failure, time to peak, and young modulus are among the properties determined. They were determined for two different loading orientations (laterally and longitudinally). The obtained data were statistically examined, and the mean difference was tested with a 95% confidence level. For longitudinal orientation, the deformation, compressive force, strain, and stress at the limit of proportionality for Bara are 0.74-0.90mm, 9.13-11.13N, 4.63-5.65%, and 0.06-0.09N/mm^2; for Sewere, the deformation, compressive force, strain, and stress are 1.28-1.69mm, 5.40-6.57N, 8.03-10.55%, and 0.03-0.04N/mm^2; and 1.20-1.58mm, 5.47-8.37N, 7.51-9.85%, 0,03-0.05N/mm^2 respectively for transverse orientation. The longitudinal orientation of Bara has a deformation, compressive force, strain, and stress at peak point of 1.57-.65mm, 35.43-44.91N, 9.81-10.29%, and 0.22-0.28N/mm^2, while the transverse orientation of Bara has a deformation, compressive force, strain, and stress at peak point of 2.20-3.02mm, 22.68-30.35N, 13.77-18.89%, and 0.14-0.19N/mm^2. Omale *et al*. (2022), in an effort to develop a manual egusi (*Citrulus Vulgaris*) washing machine, determined the average length, width, thickness and sphericity of 100 egusi seeds to be 15 mm, 8.8 mm, 2.06 mm and 0.43 mm.

Davies (2010) carried out an experiment to measure physical properties of three varieties of melon seeds at different moisture levels of 5.21%, 6.25% and 6.33% (dry basis). He measured and reported the geometric (thickness, length, width, arithmetic and geometric mean diameter, volume, sphericity, and surface area), gravimetric (1000 seed mass, bulk and true density, porosity, and angle of repose), and coefficient of friction (for concrete, plywood, galvanized metal, and glass) properties of melon seeds (with three varieties) for the different levels of moisture content. In a similar study by Bande, *et al.* (2012), 14 physical properties of Egusi seeds were evaluated at different moisture contents of 7.11%, 14.65%, 28.07% and 38.70%. Their work showed a reduction in the values of the properties with decreasing moisture content, except for the true density, porosity, and sphericity. Correlations with high accuracy were proposed for the prediction of these physical properties as dependent on moisture contents. Many other studies were carried out on the physical and mechanical properties of Egusi melon (Shieshaa, et al., 2007; Okokon, et al., 2010; Oje, et al., 1999).

2.3. Aerodynamic and Thermal Properties

There is paucity of research on the thermal and aerodynamic properties of Egusi melon. The only found one in literature was carried out by Asoiro, *et al*. (2018). They investigated some thermal and aerodynamic properties of melon seed as a function of temperature. The thermal conductivity, specific heat capacity and thermal diffusivity were the thermal properties that were determined. Terminal velocity, seed drag force and drag coefficient were the aerodynamic properties investigated. The results obtained for the terminal velocity of the seed at temperatures of 30ºC, 35ºC, 40ºC, 45ºC, 50ºC, 55ºC, 60ºC, 65ºC, 70ºC, and 75ºC were 7.415, 7.135, 6.32, 9.95, 5.885, 5.62, 5.32, 5.205, 4.88m/s respectively. The reported that these values continued to reduce until 100ºC with a value of 3.37m/s. The drag force of the melon seed attained its maximum value at temperature of 50ºC (1.777N). A minimum value was attained at the temperature of 100ºC (0.343N). At various temperature levels of 35ºC, 40ºC, 45ºC, 55ºC, 60ºC, 65ºC, and 70ºC, values for drag force were 1.472N, 1.349N, 1.275N, 1.079N, 0.981N, 0.883N, and 0.884N respectively. The drag coefficient was at its maximum at temperature of 80ºC with a value of 1.179, and minimum at 30ºC with a value of 0.743. For the thermal properties, the specific heat capacity attained a maximum value of 2.995KJ/Kg/K at a temperature of 30ºC, while it attained a minimum value of 1.596KJ/Kg/K at temperature of 100ºC. The thermal conductivity was maximum at 30ºC with a value of 3.62W/m/K, and minimum at 100ºC with a value of 0.46W/m/K. In the same vein thermal conductivity reduces with an increase in temperature. At the temperatures of 30ºC, 35ºC, 40ºC, 45ºC, 50ºC, 55ºC, 60ºC, 65ºC, 70ºC, 75ºC, and 80ºC, the thermal conductivity values were 3.26W/m/K, 1.545W/m/K, 1.1W/m/K, 1.83W/m/K, 1.725W/m/K, 0.64W/m/K, 0.605W/m/K, 0.555W/m/K, 0.53W/m/K, 0.52W/m/K, and 0.505W/m/K respectively. The thermal diffusivity attained a maximum value at 30ºC ($6.19 \times 10^{-5} m^2/s$) and a minimum value of $1.16 \times 10^{-6} m^2/s$ at 100ºC.

3. Consideration of Engineering Properties in Design

As mentioned earlier, there have been several attempts by researchers and engineers to develop appropriate mechanization processes to ease the processes of egusi melon production. What is noticeable in most designs and fabrication of these machines was the lack of deeper consideration of some of the engineering properties of the egusi melon. This tends to have a negative impact on efficiency and can result in product losses. Where researchers consider the physical and mechanical properties, thermal and aerodynamic properties of the egusi melon are often neglected in their design considerations. Table 1 shows reviews some of the machines developed and the properties considered.

Table 3: Properties of Egusi melon considered in the design of Egusi melon processing machines

S/N	Machine Developed	Properties Considered	Reference
1	Cracking Machine	Physical: Length, width, thickness, surface area, density	Yakum (2020)
2	Decorticating Machine	None reported	Agberegha1, *et al.* (2021)
		Physical: Length, thickness, width	Akubuo and Odigboh (1992)
3	Coring machine	Mechanical: Angle of repose, coefficient of friction	
		None reported	Oloko and Agbetoye (2006)
		None reported	Agbetoye, *et al.* (2013)
		Physical:	Omale, *et al.* (2022)
4	Washing Machine	Length, width, thickness, sphericity	
		None reported	Adebayo and Yusuf

			(2015)
5	Multi-Purpose: Shelling, grinding, oil extraction	None reported	Onwuka and Nwankwojike (2015)
6	Drying machine	None reported	Ezeike and Otten (1991)
		Physical: diameter, projected area, volume, weight, density	Odigboh (1979)
7	Shelling/Dehulling machine	Mechanical: Angle of repose, coefficient of friction	
		None reported	Adekunle, *et al.* (2009)
		None reported	Sobowale, *et al.*, (2015)
		None reported	Adekunle, *et al.* (2009)
		None reported	Oladimeji, *et al.* (2019)
		None reported	Abidemi and Fashina (2014)
		Physical: Length, width, thickness, mean diameter, sphericity, surface area, volume Mechanical: Angle of repose, coefficient of friction	Shittu and Ndrika (2012)

4. Conclusion

This paper reviewed some literatures of researches done on the engineering properties of egusi melon. Although there is no paucity of research on the physical and mechanical properties of egusi melon, implementation of these properties in the design consideration of egusi melon processing machinery seem to be lacking. There is also dearth of research on the thermal and aerodynamic properties of egusi melon. Determination of properties of egusi melon is essential for design of equipment and other facilities for planting, harvesting, handling, and conveying, drying, aeration, storing, and dehulling. Neglecting these properties in design would have a detrimental influence on machine efficiency and might lead to product losses. Therefore, it is pertinent that the engineering properties are put into consideration in the design of egusi melon processing equipment.

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DETERMINATION OF PHYSICAL PROPERTIES OF EGUSI-MELON FRUIT

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Abstract

The post-harvest processing of melon fruit has largely been done by hand, and the little equipment that is now in use performs inefficiently. In order to improve the design and production of high-performance melon processing equipment, it is necessary to ascertain the physical characteristics of melon fruits and seeds. The physical characteristics for fruit sizes that were determined in this study were weight, volume, and major and minor diameter. The mean weight and volume obtained from the study were 1600 g and 1750 cm^3, respectively, whereas the mean values for the main and minor diameter were 151 mm and 144 mm, respectively. At 15% moisture content, the seeds' major, intermediate, and minor diameters were 19 mm, 17 mm, and 9 mm, respectively. These findings might be used to design the hopper opening for the melon fruit seed extractor, the sizes of the shearing and crushing mechanisms, and the screen perforation.

Keywords: melon fruit, physical properties, major and minor diameters, design

1. Introduction

Melon (*Colocynthis citrullus L.*) is popular in Nigeria because of the edible seeds which have been used in preparation of local soup. It is one of the members of the family Cucurbitaceae which has bitter fruit pulp. Basically, they are small or large seeds, the seed coat may be thin, thick or encrusted with flat or moulded edge (Oyolu, 1977). Melon fruit is slender, hairy and grown annually with a very extensive and superficial root system. The stems are rather thin, angular, grooved and 1.5 to 5 meters long, with white hairs. The fruit is hard, bitter and inedible. Statistics shows that 100 000 and 488 000 metric tons of melon were produced in Nigeria in 1992 and 1997, respectively (Federal Office of Statistics , 1998). In the eastern part of Nigeria, the seed are sometimes boiled and eaten as snacks. The seeds are rich in oil (30-50%) which is comparable to other oil palms (Ayodele & Salami, 2006) and the oil contains a high level of saturated fatty acids (Adeniran & Wilson, 1981). Several varieties are grown in Nigeria and are locally referred to as egusi. Domestic use of melon oil includes soup cooking and frying while industrially it can be used for production of soap, pomade, metal polish, lubricant, adhesive, candles, feed for cattle, poultry, pigs, sheep and goats.

Physical properties such as shape and sizes, density, volume, weight, etc. are required in the design of processing equipment. These properties are important in the study of size reduction (milling) of agricultural materials. Shape and size are generally required for satisfactory description of the agricultural materials. There are various methods of determining shape and sizes of agricultural materials as outlined by Mohsenin (1970); some of which includes:

i. Use of chartered standards

ii. Use of resemblance to geometric shapes
iii. Use of overhead projector/shadow graph
iv. Measurement of dimension on three mutually perpendicular axes.

Measurement of dimension on three mutually perpendicular axes appears to be the most widely used in literature. In determining the principal dimensions, viz major, minor and intermediate diameters on three mutually perpendicular axes of shea nut, milled and polished rice grains, and thevetia nuts, Olaniyan and Oje (1999) used a pair of vernier callipers. Gupta and Das (1997) and Olajide and Ade-Omowaye (1993) however, used micrometres to measure the three principal dimensions of sun flower seeds and locust bean seeds, respectively. Jain and Bals (1997) on the other hand, used a dial gauge for peal millet grains. For shape, Oje (1993) pencil-traced the edges of thevetia nuts, then the projected and the diameter of circles inscribing and circumscribing the projected areas were measured.

Volume and density also play important roles in the design of agricultural equipment. Methods for determination of volume and density as listed by Mohsenin (1970) include:

1. The use of platform scale
2. Air compression pycnometer for solid particles
3. Resemblance to a geometric shape e.g., fresh egg is assumed to be prolate spheroid shape, hence, the volume is calculated from Eq. 1.

$$V=\frac{4}{3}ab^2 \qquad (1)$$

4. Water displacement method for non-water-soluble objects.

Oje (1993), and Olajide and Ade-Omowaye (1999) used water displacement method for the determination of volumes and densities of thevetia nuts and locust bean seeds, respectively. This involves immersing the materials in water contained in a measuring cylinder; the level rises and the difference in the final and initial reading gives the volume of the material. Gupta and Das (1997) used balance and air comparison pycnometer (Beckman, model 930) to determine the volume and bulk density of sun flower seeds. Jain and Bals (1997) used the principal dimensions of pearl millet to calculate the volume using Eq. 2.

$$V_t=\frac{\pi D^2 D_2^2}{6(2D-D_2)} \qquad (2)$$

Methods for determination of surface areas of agricultural materials such as leaf, fruits and eggs as listed by Mohsenin (1970) include:

i. Peeling fruits in narrow strips and the planimeter sum of the areas of traced of the strips gives the surface area
ii. Use of shadow graph
iii. Covering the surface of the materials (e.g., egg) with strips of narrow masking tape and the areas of the tape is then traced
iv. Measuring the principal dimensions used for the assumed geometric shape to calculate the surface area

v. Coating the surface of the sample with paint and contact on a flexible paper and edges traced. The planimeter sum of the traces gives the surface area.

Oje (1993) used the last method stated above, but pencil-traced the traced edges of flexible paper on graph paper and counted the squares within the traces mark. Olajide and Ade-Omowaye (1999) determined the surface area of locust bean seed by analogy with a sphere of the same geometry mean diameter and calculated the surface area using Eq. 3. Jain and Bals (1997) used Eq. 4 to calculate the surface area of pearl millet.

$$S = \pi Dp^2 \quad (3)$$

$$S = \frac{\pi D D_1^2}{(2D - D)} \quad (4)$$

This study is undertaken to determine some physical properties of melon fruits considered important for its processing, and to provide researchers, industrialists and farmers with sufficient information for successful design and construction of melon fruit processing equipment.

2. Materials and Methods

One hundred (100) matured melon fruits were randomly picked from farmers' fields in Nasarawa town, Nasarawa Local Government Area, Nasarawa State in Nigeria. They were grouped into five according to size with the biggest designated as group A and the smallest size as group D. Measurements of dimensions on two axes: major and minor diameters were determined using a pair of Vernier callipers with at least count of 0.01 mm. Volumes of the fruits were determined by water displacement method. The mass of each fruit was determined using electronic weighing balance with a least count of 0.1 g. The density was determined using Eq. 5.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad (5)$$

3. Results and Discussion

The physical properties of the melon fruits are contained in Tables 1 and 2 below. Table 1 showed the mean physical properties according to the groups. The major diameter increases with decrease in size while the other properties, minor diameter, weight, volume and density increases as the sizes reduces.

Table 1: Mean Physical Properties of Egusi Melon Fruits

Group	Sample	Major diameter (mm)	Minor diameter (mm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)
A	25	2.666	142.00	1331.25	15050.00	0.0882
B	25	2.608	112.75	681.25	7062.50	0.0973
C	25	3.454	103.625	483.75	4887.50	0.0988
D	25	3.369	91.125	340.00	3525.00	0.0742
E	25	3.214	75.125	186.25	1612.50	0.1161

Table 2: Physical Properties of Egusi Melon Fruits

	Major diameter (mm)	Minor diameter (mm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)
Sample	100	100	100	100	100
Max	4.97	151	1600	17500	0.1218
Min	1.121	72.5	175	1450	0.01
Mean	3.06205	104.925	604.5	6427.5	0.09489
SDEV	1.166608	22.77404	407.489	4740.582	0.022165

Table 2 present the maximum, minimum, mean and standard deviations of the properties investigated. The major diameter ranges between 66 mm and 144 mm while the minor diameter was from 73 mm to 151 mm. The volume of the fruit ranges between 1500 cm^3 and 17500 cm^3. The density of the fruit ranges from 0.0914 g/ cm^3 to 1.067 g/ cm^3. The mass of the fruit ranges between 175 g and 1600 g.

The results obtained were similar to the work of Barde et.al., (2012) that researched on melon fruits but the differences can be attributed to varieties. Based on the results, the opening of the hopper (feeding) should be considered between 144 mm and 151 mm.

4. Conclusion

The research is limited only to the determination of the physical properties of the melon fruits. The purpose was to guide the design of the mechanical processing machine. This is important as it will guide the machine designer in designing to obtain the required output and increase machine efficiency. The research therefore gives all information necessary to design the hopper opening for the melon fruit seed extractor, the sizes of the shearing and crushing mechanisms, and the screen perforation.

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SYNTHESIZING BIO-PARTICLEBOARDS FROM SUGARCANE BAGASSE AND EXPANDED POLYSTYRENE FOAM: AN ASSESSMENT OF PHYSICAL AND MECHANICAL PROPERTIES

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Abstract

As agricultural production keeps surging, it becomes imperative to harness sustainable measures of recycling the growing waste generated towards preserving the environment. This paper presents the production of particleboards from sugarcane bagasse (SB) and expanded polystyrene (EPS) foam and the determination of their physical and mechanical properties. Four particleboard samples namely A1, A2, B1, and B2 were produced from sugarcane bagasse and expanded polystyrene foam (EPS). Samples A1 and A2 were produced from 2mm particle size feedstock (sugarcane bagasse) with a feedstock to binder ratio of 50:50 and 60:40 respectively, while samples B1 and B2 were produced from 1 mm particle size feedstock with a feedstock to binder ratio of 50:50 and 60:40, respectively. The boards were produced using the hot-pressing method and the ASTM D-1037 standard was employed in determining the physical and mechanical properties which include density, water absorption (WA), thickness swelling (TS), modulus of elasticity (MOE), modulus of rupture (MOR) and tensile strength (TS). Although the result of the analysis of variance revealed no significant difference among the tested samples, sample B2 with a feedstock to binder ratio of 60:40 and particle size of 1 mm yielded the best performance. The sample equally met the EN 312 standard for particleboard panels intended for internal use as well as the ANSI A208-1 standard. Hence, the particleboards possess the potential to replace the wood panels for internal use which if adopted would help reduce the rate of deforestation.

Keywords: Particleboards, Feedstock, Binder, Sugarcane bagasse, Expanded polystyrene

1. Introduction

The global surge in agricultural production has increased agro-waste generation. In Nigeria, an average of 55.9 Tg (55.9 million tons) of agricultural waste is generated per year (Iye & Bilsborrow, 2013). However, there is still no adequate technology for utilizing the mammoth agricultural waste generated (Atoyebi et al., 2021), as they are mostly burned or landfilled contributing to the emission of greenhouse gases (Kainthola et al., 2019). Sugarcane is a major sugar crop produced in many parts of the world including Nigeria (Wada et al., 2017). Apart from being cultivated on a large scale, its method of consumption made the waste to be in abundant. The conventional way of waste disposal is a major area of concern in many developing countries (Fayomi et al., 2020; Maraveas, 2020). On that note, a promising and environmentally friendly measure of managing these generated wastes such as the production of particleboards is required (Abdulkareem et al., 2017; Mahieu et al., 2019). Bio-particleboard is a composite material produced from bio-waste with the aid of resins or binders bonded together under heat and pressure (EPA, 2002; Low et al., 2021).

The production of wood-based particle boards is a key factor inducing the rate of deforestation, especially as the demand has increased over the years. The increase in demand is related to the growth in the wood industry which has depleted a lot of forest areas and has compelled manufacturers to seek alternative materials (Oliveira et al., 2016; Mahieu et al., 2019; Iždinský et al., 2020). Out of the ten million hectares of forest land in Nigeria, about 3.5% (350 000 ha) is lost annually through wood collection and other land-use changes (FAO, 2015). As forest cover keeps declining through diverse anthropogenic influences, climate change is becoming more evident (Nyang'au et al., 2019). One vital element in the production of particleboards is the resin (adhesive), as it affects the physical and mechanical properties of the final product (Silva et al., 2021). Most wood-based particleboards are produced with synthetic adhesives which emanate from fossil fuel-derived sources (isocyanate, vinyl acetate, and formaldehyde), and hence cause environmental pollution (Mahieu et al., 2019; Ferrandez-Garcia et al., 2020).

To improve the effective utilization of bio-waste, it becomes pertinent to look into the growing rate of deforestation and its expected environmental impact. On this note, it is imperative to harness agricultural waste for particleboard production (Abdulkareem & Adeniyi, 2017; Fayomi et al., 2020). Overall, particleboards produced from agricultural residues are cheaper, denser, and more uniform compared to conventional wood-based panels (Kevin et al., 2018).

Against this background, this study aims at producing particleboards from sugarcane bagasse and expanded polystyrene (EPS) binder with the potential of substituting wood-based particleboards as an approach to curtail deforestation and mitigate climate change.

2. Materials and methods

2.1 Experimental site

The study was conducted at the Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University, Zaria, Kaduna State Nigeria. The site is located on latitude 11° 10′ N of the Equator and longitude 7° 38′ E of Greenwich Meridian as shown in Figure 1

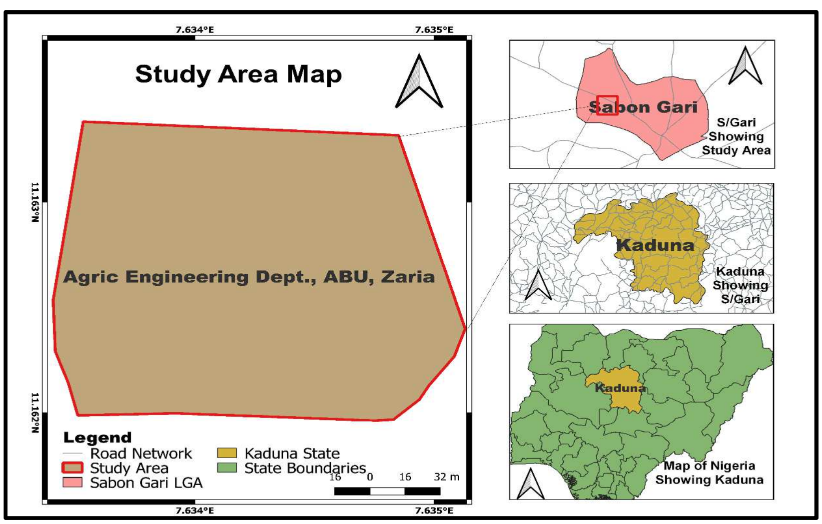


Figure 1 Map of Study Area

2.2 Material preparation

The feedstocks (sugarcane bagasse and expanded polystyrene foam) were sourced locally within Samaru, Kaduna State, Nigeria. The bagasse, which had an initial moisture content of 18% (wet basis) was dried to a moisture content of 11% to enhance the binding process. It was subsequently grounded with the aid of a milling machine and sieved (Figure 2) to 2 and 1 mm particle sizes, respectively. The EPS foam was equally shredded in a shredding machine to a workable size of 8mm.

Figure 2 Material preparation

2.3 Particleboard Production

The production phase typically comprises compounding and compaction. The samples were compounded using a two-roll mill (model RRPMC 5185) machine which was heated to a temperature of 150^{o}C for 30 minutes with front and rear roller speeds of 0.215 and 1.289 rpm, respectively. The EPS foam was first introduced into the machine to attain the molten form after which the bagasse was added. The obtained paste was transferred to a mold plate of 170mm x 125mm cross-section for compaction. A compressing machine set at a temperature of 130°C and heated for about 35minutes was employed for compaction. The compaction was for a period of 15min before cooling. This procedure was repeated on other samples respectively.

Four samples (A1, A2, B1, and B2) as shown in Figure 3 were prepared with a filler to binder ratio of 50:50 and 60:40, and particle sizes of 2 and 1mm, respectively.

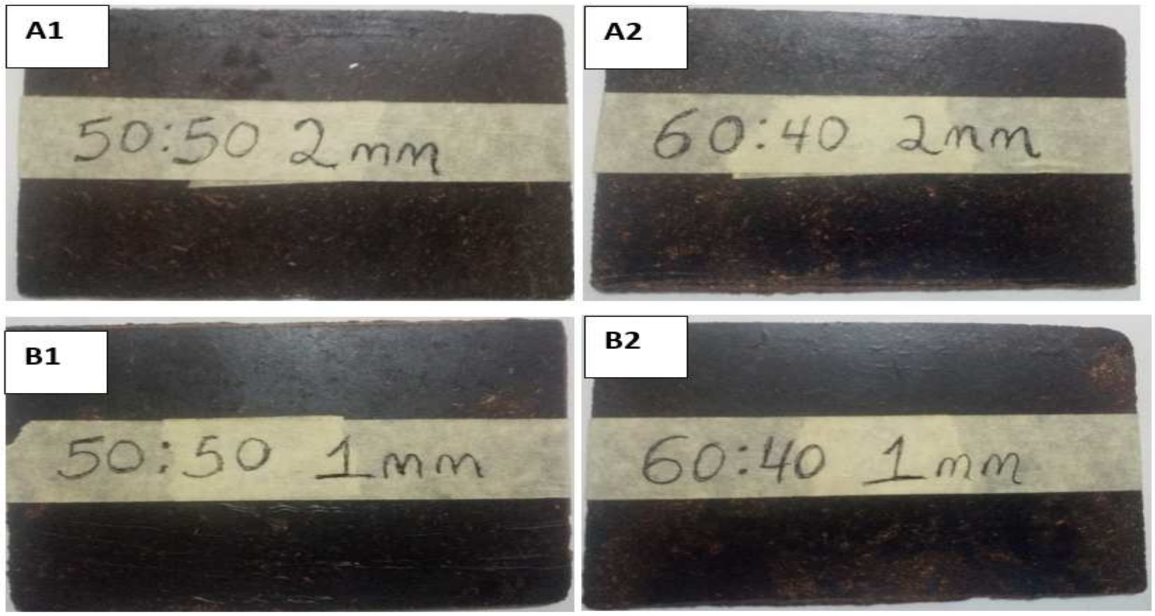


Figure 3 Produced Particleboard Samples

2.4 Determination of physical properties

In determining the physical properties of the particleboards, their dimensions thickness, and weights were first measured with the aid of a tape, a vernier caliper, and electronic scale in three replicates, and the resultant values were used as per ASTM D1037-06a (2006) to estimate the density, water absorption, and thickness values.

2.4.1 Density

The densities of the particleboard samples were estimated using equation 1

$$D = \frac{M}{Lwt} \qquad (1)$$

Where, D = density (kg/m^3), M= Mass of the sample (kg), L= Length of the sample (m), w= Width of the sample (m) and t= thickness of the sample (m).

2.4.2 Water absorption

Water absorption was estimated after 2 hours (WA-2) and 24 hours (WA-24). In determining the values, the samples were soaked in water for 2 and 24 hours, respectively, and the percentage of water absorption was estimated using equation 2

$$WA(t) = \frac{W(t) - W(o)}{W(o)} \times 100 \qquad (2)$$

Where, WA(t) = water absorption (%) at time t, W(o) = initial weight and W(t) = weight of the sample at a given immersion time t.

2.4.3 Thickness swelling

The thickness swelling was computed after 2 hours and 24 hours (i.e. TSW-2 and TSW-24) respectively using equations 3 and 4

$$TSW-2 = \frac{T_{f2} - T_i}{T_i} \times 100 \quad (3)$$

$$TSW-24 = \frac{T_f - T_i}{T_i} \times 100 \quad (4)$$

Where,

TSW-2 = thickness swelling rate after 2 hours of soaking (%), T_{f2} = final thickness (mm) after 2 hours of soaking and T_i = initial thickness (mm).

TSW-24 = thickness swelling rate after 24 hours of soaking (%), Tf = final thickness and Ti = initial thickness

2.5 Determination of mechanical properties

The mechanical properties were determined following the ASTM D1037-06a (2006). The mechanical properties considered in this study are the tensile strength, modulus of elasticity, and modulus of rupture.

2.5.1 Tensile strength and modulus of elasticity

The tensile strength test was carried out using an electronic universal testing machine (WDW 100KN-190536). Three specimens with dimensions of 100 x 20mm were prepared from each sample and shaped as per the ASTM D1037-06a (2006) guideline. Each sample was placed in the machine in a way the jaws can effectively grip the two ends of the samples to aid breakage. Points were marked with a pin on a graph sheet comprising force and extension on the vertical and horizontal axis, respectively, which were slotted into a rotating cylindrical drum based on the extension produced. The point bending test was conducted according to ASTM D790.

Three rectangular samples were tested at support span of 80mm, with the width and thickness measured using a Vernier caliper. Load was applied to the sample with the aid of a hydraulic lever until the material failed. The load of deformation and corresponding deflection before and after failure were recorded accordingly.

The ultimate tensile strength (TS) and modulus of elasticity (MOE) were calculated using equations 5 and 6 respectively,

$$TS = \frac{P_{max}}{bd} \quad (5)$$

$$MOE = \frac{l^3}{4bd^3}\frac{\Delta P}{\Delta y} \quad (6)$$

Where, TS = tensile strength (Mpa), MOE = modulus of elasticity (Mpa), P_{max} = maximum tensile force (N), b = width of the specimen (mm), d = thickness of the specimen (mm),

L = gage length (mm) and $\frac{\Delta P}{\Delta y}$ = slope of the straight-line portion of the load-deformation curve (N/mm).

2.5.2 Modulus of rupture

The modulus of rupture was determined using a 100kN capacity Universal Material Testing Machine with a gauge length of 80mm. Three Specimens with dimensions of 100 x 30mm were prepared from each sample for evaluation of the flexural strength (modulus of rupture). The test was carried out and the modulus of rupture was computed using equation 7;

$$MOR = \frac{3P_{max}L}{2bh^2} \tag{7}$$

Where P_{max} = maximum tensile load (mm), L = length of span (mm), b = width of the specimen (mm), h = thickness of the specimen (mm)

2.6 Statistical Analysis

To determine the most appropriate statistical test for analyzing the data, a normality test was conducted using Shapiro-Wilk's test for normality at a 5% level of significance. Based on the test output which revealed normality, a parametric test using a 2-way analysis of variance (ANOVA) at 5% significance was conducted to test for statistical difference between the means of variations (i.e. 2 levels of particle sizes and binder content). Subsequently, the relationship between the variables was determined using Pearson's correlation analysis. All the aforementioned statistical analyses were carried out with the Stata/SE version 16.1 software

3. Results and discussion

3.1 Result of normality test

Table 1 and 2 shows the result of the normality test for physical and mechanical properties. As presented, all P-values are higher than 0.05, hence, it shows that the data of both physical and mechanical properties follow a normal distribution. Therefore, further analysis involved the use of parametric test.

Table 1 Shapiro-Wilk normality test for physical properties

Variable	Obs	W	V	z	Prob>z
Density	4	0.945	0.629	-0.490	0.688
WA2	4	0.838	1.865	0.877	0.190
WA24	4	0.838	1.865	0.877	0.190
TSW2	4	0.973	0.312	-1.078	0.860
TSW24	4	0.901	1.145	0.165	0.434

P<0.05 = significant difference, P>0.05 = not significant (normal)

Table 2 Shapiro-Wilk normality test for mechanical properties

Variable	Obs	W	V	z	Prob>z
TS (MPa)	4	0.815	2.137	1.120	0.131
MOE (MPa)	4	0.973	0.309	-1.085	0.861
MOR (MPa)	4	0.815	2.131	1.115	0.132

P<0.05 = significant difference, P>0.05 = not significant (normal)

3.2 Result of physical properties

Table 3 presents the result of the physical properties of the particleboard samples. As indicated, data were obtained at variable binder content (50 % and 40 %) and particle size (1 and 2 mm). Although sample A1 had the lowest density (Figure 4), the obtained value agrees with Sugahara et al. (2019) (0.97 and 0.88 g/cm^3) and is better than the values recorded by (Nyang'au et al., 2019) (0.15 - 0.26 g/cm^3). Overall, the density values of all the samples (Figure 4) fall within the high-density particleboard classification according to ANSI A208.1 (1999) (i.e., > 800 kg/m^3). Water absorption was observed only on sample A1 (Figure 5); this was because it has the lowest density value, and hence contains pore spaces that aid absorption within the tested period (2 and 24 hours). The values of thickness swelling TSW (Figure 6 and 7) agrees with the range obtained by Nogueira et al. (2022) as 8 - 16% for TSW-2 and 13 -20 % for TSW-24, and also met the Commercial Standard - 236-6627 which stipulates the value of TSW-24 after immersion not to exceed 35% (Oliveira et al., 2016).

Overall, samples A2 and B2 yielded the maximum density values (i.e., 1.15 and 1.11 g/cm^3) (Figure 4). This depicts that the materials were optimally bonded at a 40 % binder ratio. In the same vein, sample B2 revealed the least (best) thickness swelling at both 2 and 24 hours of immersion with values of 1.25 and 3.44 %, respectively. This is better than the values obtained by Atoyebi et al. (2021) which range from 3.39 – 18.84 for TSW-2 and 6.85 – 22.5 for TSW-24.

Table 3 Result of physical properties

Sample	Binder Content (%)	Particle size (mm)	Density (g/cm^3)	WA-2 (%)	WA-24 (%)	TSW-2 (%)	TSW-24 (%)
A1	50	2	0.95	9.09	18.18	7.32	17.2
A2	40	2	1.15	0	0	14.24	15.51
B1	50	1	1.06	0	0	8.26	11.8
B2	40	1	1.11	0	0	1.25	3.44

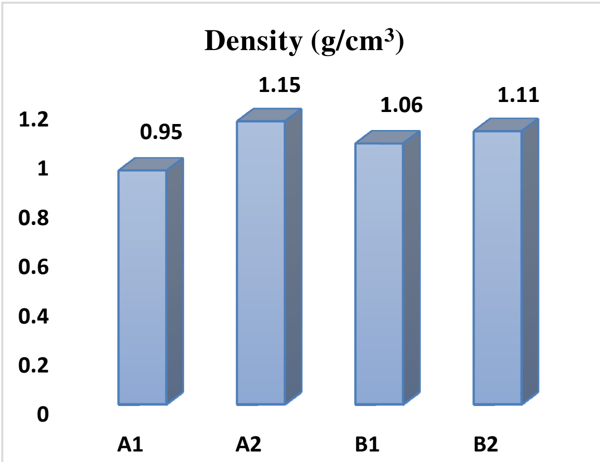


Figure 4: Density of the particleboards

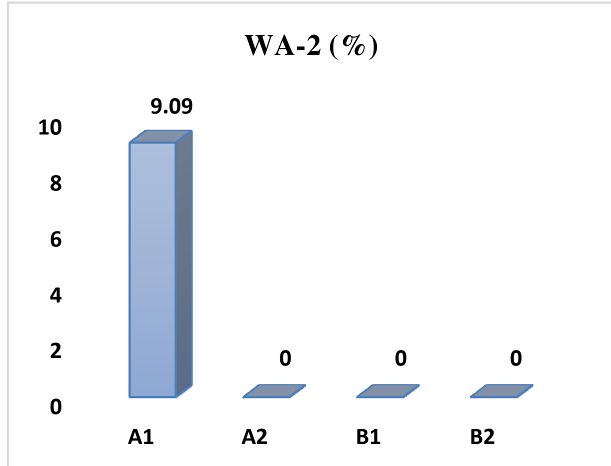


Figure 5: Water absorption after 2 hours

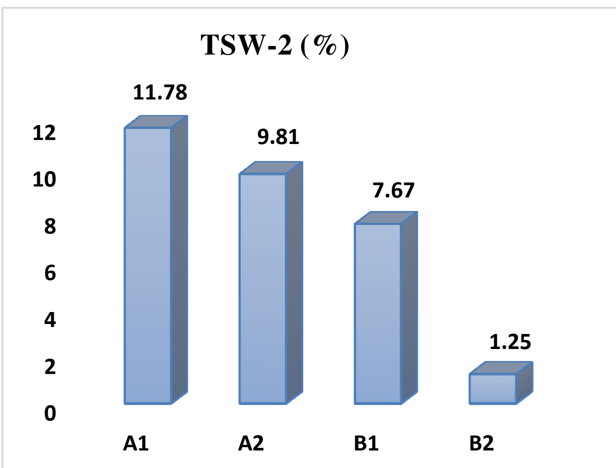


Figure 6: Thickness swelling after 2 hours

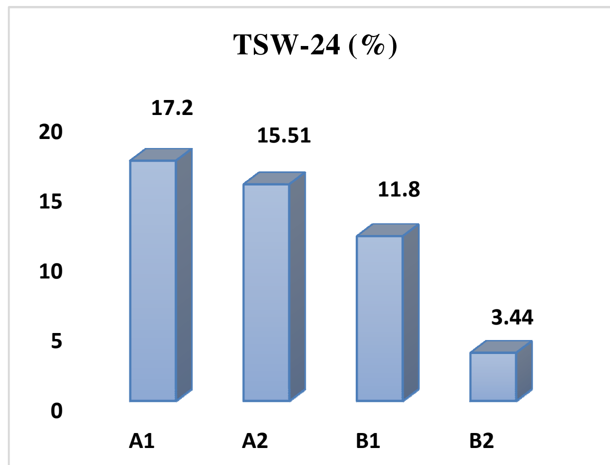


Figure 7: Thickness swelling after 24 hour

3.2.1 Result of descriptive statistics of physical properties

Table 4 shows the descriptive statistical values of the physical properties. The mean density value obtained is slightly higher than the value recorded by (Nogueira et al., 2022 ; Oliveira et al., 2016) as 0.591 to 0.609 g/cm^3, and 0.616 g/cm^3. However, the mean values of thickness swelling at both 2 and 24 hours conform to Oliveira et al. (2016) (6.9 % and 11.6%).

Table 4 Descriptive statistics of the physical properties

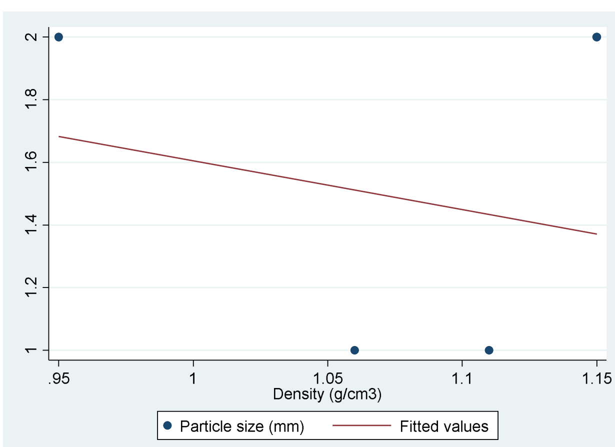
Variable	Obs	Mean	Std. Dev.	Min	Max
Densitygcm3	4	1.067	.087	.95	1.15
WA2	4	2.272	4.545	0	9.09
WA24	4	4.545	9.09	0	18.18
TSW2	4	7.768	5.317	1.25	14.24
TSW24	4	11.988	6.128	3.44	17.2

3.2.2 Correlation between the factors and physical properties

Table 5 presents the result of the correlation between varied factors (i.e. particle size and binder content) and the physical properties. From Table 5, it can be seen that apart from density which yielded a strong negative correlation (i.e., it decreases with an increase in particle size and binder content) (Figures 8 and 10), all other physical properties (i.e., WA-2, WA-24, TSW-2 and TSW-24) showed a positive correlation. Although, in the case of TSW-2, the correlation is weak (Figure 9).

Table 5 Result of correlation between the factors and physical properties

Properties	Particle Size (mm)	Binder Content (%)
Densitygcm3	-0.2335	-0.8338
WA2	0.5774	0.5774
WA24	0.5774	0.5774
TSW2	0.6542	0.0049
TSW24	0.8229	0.4734



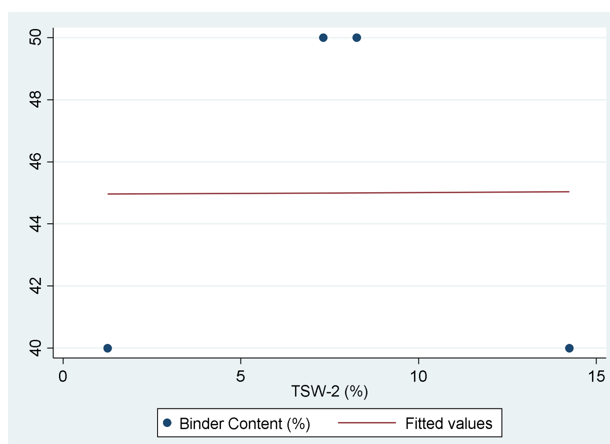


Figure 8: Correlation between particle size and density

Figure 9: Binder content and TSW

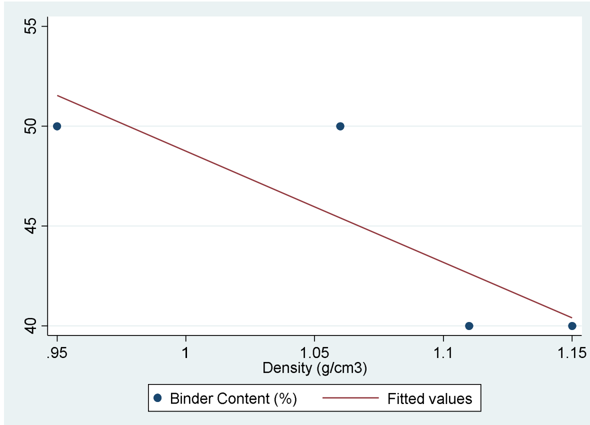


Figure 10: Correlation between binder content and density

3.3 Mechanical properties

Table 6 shows the result of mechanical properties. The result of MOR agrees with Sharma et al. (2021) that recorded a range of 8.81 – 14.43 MPa. Sample A1 and B2 meet the ANSI A208-1 standard for panels which defines minimum values of 1943.8 MPa for MOE and 12.8 MPa for MOR (Oliveira et al., 2016). However, only sample B2 (Figures 12 and 13) met the EN 312 standard which stated minimum values of 1800 MPa for MOE and 13 MPa for MOR for particleboard panels intended for internal use (Oliveira et al., 2016). Sample A1 and B1 yielded the maximum tensile strength (Figure 1) i.e., 20.53 and 21.07 MPa, respectively. This shows that tensile strength increases with an increase in binder content.

Table 6 Result of mechanical properties

Sample	Binder Content (%)	Particle size (mm)	TS (MPa)	MOE (MPa)	MOR (MPa)
A1	50	2	20.53	1964.96	11.339
A2	40	2	14.67	860.813	6.988
B1	50	1	21.07	2138.44	9.469
B2	40	1	15.33	3233.83	25.979

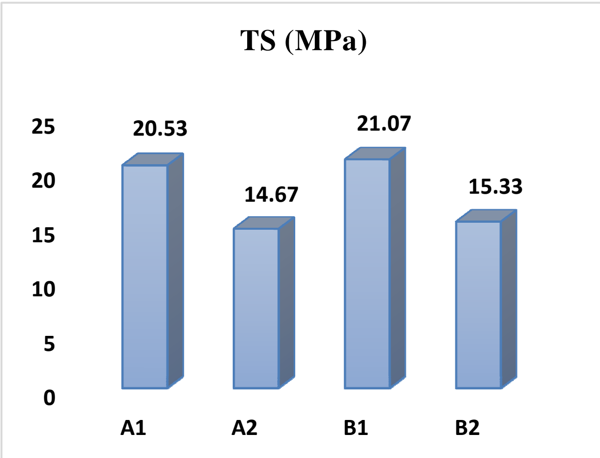


Figure 11: Tensile strength

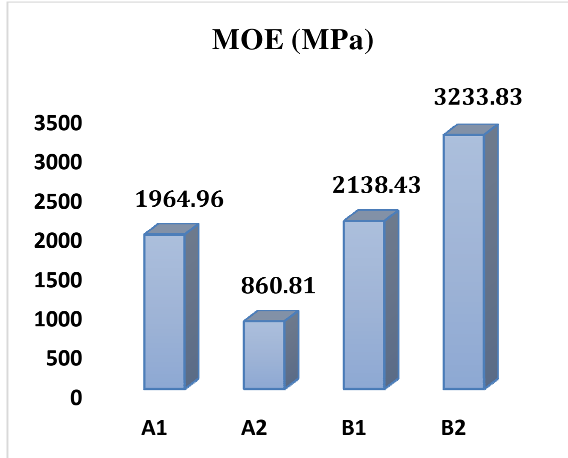


Figure 12: Modulus of elasticity

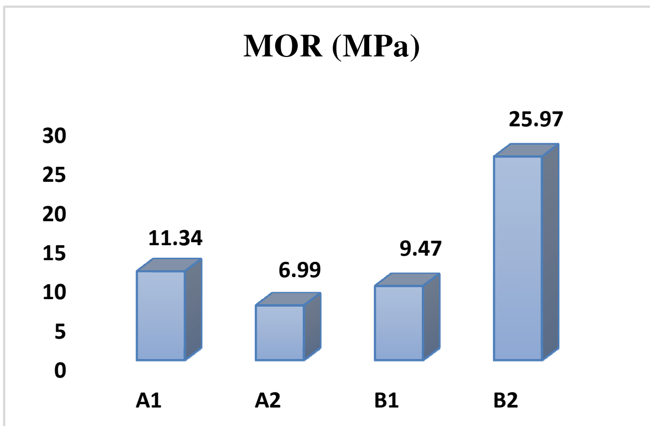


Figure 13: Modulus of Rupture

3.3.1 Descriptive statistics of mechanical properties

Table 7 shows the descriptive statistical values of the mechanical properties. The mean value of MOE and MOR is slightly below the values obtained by Sugahara et al. (2019) as 2420 and 18 MPa, respectively, for particleboards made from sugarcane bagasse and urea-formaldehyde (UF) binder.

Table 7 Descriptive statistics of the mechanical properties

Variable	Obs	Mean	Std. Dev.	Min	Max
TS (MPa)	4	17.9	3.367	14.67	21.07
MOE (MPa)	4	2049.511	971.369	860.813	3233.83
MOR (MPa)	4	13.444	8.545	6.988	25.979

3.2.2 Correlation between the factors and mechanical properties

As presented in Table 8, all the mechanical properties yielded a negative correlation with particle size. However, in comparison with binder content, only the modulus of rupture (MOR) showed a negative correlation as other properties revealed a positive correlation.

Similar to Yunus et al. (2018), both MOR and MOE of the particle boards decrease with an increase in particle size

Table 8 Result of correlation between the factors and mechanical properties

Properties	Particle Size (mm)	Binder Content (%)
TS (MPa)	-0.1029	0.9946
MOE (MPa)	-0.7568	0.0026
MOR (MPa)	-0.5784	-0.4108

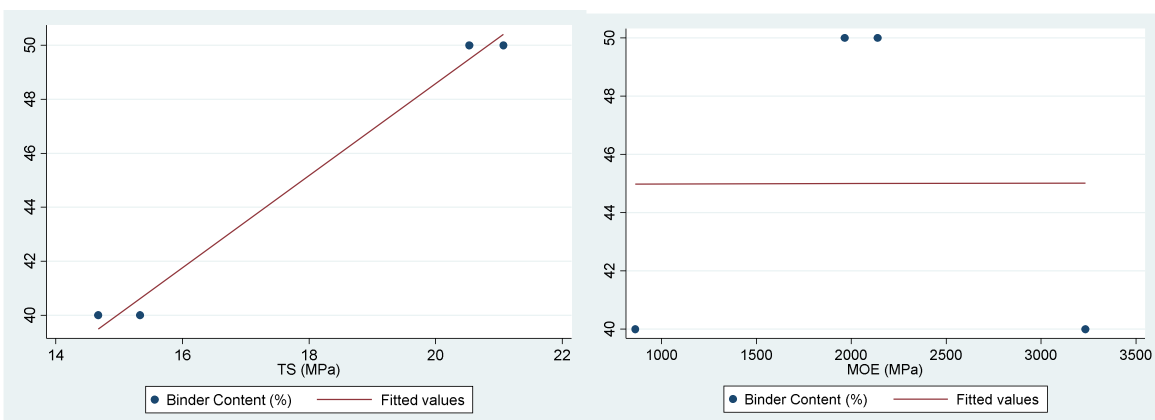


Figure 14: Correlation between binder content, thickness swelling, and Modulus of elasticity

3.1.4 Summary of analysis of variance (ANOVA) result

Table 9 shows the result of ANOVA for the mechanical properties considered. While there are variations in the values obtained, the result of analysis of variance (ANOVA) revealed no significant difference between the mean values of all the measured properties, except for tensile strength where the mean values at variable binder content were statistically different.

Table 9 Result of analysis of variance

S/N	Properties	Prob>F Binder Content (%)	Prob>F Particle Size (mm)
1.	Physical		
	Density(kg/m^3)	0.3440 ^{ns}	0.7220 ^{ns}
	WA-2 (%)	0.5000 ^{ns}	0.5000 ^{ns}
	WA-24 (%)	0.5000 ^{ns}	0.5000 ^{ns}
	TSW-2 (%)	0.9959 ^{ns}	0.5460 ^{ns}
	TSW-24 (%)	0.3730 ^{ns}	0.2322 ^{ns}
	Mechanical		
	TS (MPa)	0.0066*	0.0635 ^{ns}
	MOE (MPa)	0.9975 ^{ns}	0.4535 ^{ns}
2.	MOR (MPa)	0.6640 ^{ns}	0.5625 ^{ns}

* = Significant at $P < 0.05$ ^{ns} = not significant at $P > 0.05$

4. Conclusion

i. Particleboards were produced from sugarcane bagasse and expanded polystyrene foam using a hot compression technique at variable binder content and particle sizes. Four samples tagged A1, A2, B1, and B2 with feedstock to binder ratio of 50:50 for A1 and B1 and 60:40 for A2 and B2; and particle sizes of 2 mm for A1 and A2, and 1mm for B1 and B2 were produced.

ii. The physical properties (Density, water absorption (WA), thickness swelling (TSW)) and mechanical properties (modulus of elasticity (MOE), modulus of rupture (MOR), and tensile strength (TS)) were determined according to ASTM D-1037 standard.

iii. Although the result of the analysis of variance revealed no significant difference among the tested samples, sample B2 with a feedstock to binder ratio of 60:40 and particle size of 1 mm yielded the best performance. The sample equally met the EN 312 standard for particleboard panels intended for internal use as well as the ANSI A208-1 standard.

Hence, the particleboards possess the potential to replace the wood panels for internal use, and if adopted would consequently help in reducing the rate of deforestation.

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DETERMINING THE COMPRESSIVE STRENGTH OF AN ALTERNATIVE TOMATO PACKAGING CONTAINER FOR TRANSPORTATION

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Abstract

Nigeria produces large quantity of tomato fruits predominantly in the north and requires transportation to other parts of the country. Tomato fruits transportation are commonly done using raffia baskets that has rough inner surfaces, non-uniform venting and causes huge postharvest losses during handling and transportation. To reduce the postharvest losses of tomato fruits incurred through an inefficient packaging container during transportation, an alternative tomato packaging container was subjected to compressive test. The test was basically to determine the strength and maximum allowable force the basket can bear, especially, when stacked during transportation. An alternative basket was designed and developed from palm frond with strict compliance with the design specifications – height, base and top diameter of container and cover and the vents for air circulation. The compressive strength of the baskets was then determined using a Denison Universal Testing Machine (UTM) in the mechanical engineering department of Ahmadu Bello University, Zaria. The developed tomato packaging containers were evaluated for compressive strengths for non-destructive and destructive tests. Results revealed that the developed tomato packaging container can bear a maximum load of 2.5 kN (255 kg) and 3.0 kN (306 kg) respectively for non-destructive and destructive tests. This implies that 6 baskets can be safely stacked and transported with minimal postharvest losses. The packaging container was observed to be a better alternative to the conventional packaging containers used in transporting fresh tomato fruits.

Keywords: Baskets, Compression, Tomato fruits, Packaging containers,

1. Introduction

Nigeria is one of the largest producers of tomato fruits in the world and Africa in particular. However, most of the fruits produced encounters considerable postharvest losses, especially during transportation and the packaging containers used for transportation. Transporting fresh tomato fruits is necessitated due to bulk of its production is in the northern part, while consumption and utilization is circulated to other parts of the country by transporting with varying baskets and vehicles. Estimated tomato losses have been collectively put between 40 – 85% and these losses are prominent between harvest, transportation and handling (Idah *et al*., 2007a; Idah *et al*., 2007b; FAO, 2004; Venus *et al*., 2013). Postharvest losses of tomato fruits through handling have been greatly attributed to packaging containers used. Traditional woven raffia baskets are still used in transporting fresh tomato fruits in open truck, sometimes articulated fuel tankers, resulting in great mechanical damage from abrasion, puncture, impact and the likes (Babarinsa and Ige, 2012; Ebimieowei and Ebideseghabofa, 2013). Clement et al. (2009) and Ajagbe et al. (2014) reported that postharvest losses are traced to packaging failures resulting from poor design, inadequate vents, inappropriate selection and use which calls for an appropriate packaging container practically suitable and efficient for packaging, transportation and distribution.

It is on this premise that this study conducted a laboratory compressive test on an alternative tomato packaging container in order to determine their suitability for transportation, especially in terms of strength and stack ability of the packaging containers during transportation.

Girja *et al.* (2009) developed corrugated fiberboard cartons for long distance transport in India. A Compression-drop test was done on the peti box to determine its strength and weakness for long truck journeys. Tests revealed that about 7% produce damage in 20 kg at 12 straight drops was registered during the drop tests. The unsatisfactory results led to the development of another two corrugated fiberboard with specifications: capacities 15 and 20 kg, bursting strength 11 ± 1, number and diameter of ventilations 8 and 24.5 mm. The laboratory and field trial tests pre-conditioned the boxes for 72 hours in a room with relative humidity of 50 % and a room temperature of 23 ^{O}C was maintained. The drop test showed that 4 and 3.5 % was recorded at straight drop while 2.3 and 2.9 % were recorded at 25 ^{O}C angular drop for both boxes. Compression test revealed that both boxes was capable to withstand 250 kg load with 6 mm deformation, though, the damage increases in the number of drops. The boxes are generally acceptable by its users despite the deficiency of use during rain resulting in transporting products in covered van (Girja *et al.,* 2009). Pathare *et al.* (2012) reviewed the design of packaging vents for cooling fresh horticultural produce. The review focused on the studies of vent designs as they affect the rate and homogeneity of airflow relating to tomato fruits cooling process. Report revealed that total opening area, opening size and position has significant effect on pressure drop, air distribution uniformity and cooling efficiency. The study recommended further research directed to detailed models of vented package, complex produce stacking within the package, as well as their interaction with adjacent produce, stacks and surrounding environment.

2. Methodology

An alternative tomato packaging container was design and developed from a raffia palm frond. Some of the design considerations were availability of raw materials, size and shape of the container, pore space, sizes and numbers, weaving style, abrasion resistance, ease of maintenance and the techno-economic factors as detailed in Olanrewaju et al. (2018) and Olanrewaju et al. (2020). Basic parameters as described in the design (height, base and top diameter), thickness with respect to the palm fronds thickness, heat exchange in terms of weaving the basket for both the basket and cover were given due consideration during the development. The developed baskets as seen in Figure 1 was then compressed using a Universal Testing Machine (UTM) to determine the amount of load the basket can bear when stacked on each other during transportation.

Figure1: Finished alternative packaging container

After producing the alternative packaging container called the "intermediate basket", compression tests were carried out to subject it to a destructive and non-destructive compression test. The non-destructive test was done to determine the maximum bearable load while the destructive test was conducted to determine the maximum force that could damage the container. This was done at the strength of materials laboratory in Mechanical Engineering Department of Ahmadu Bello University, Zaria using a Dennison Universal Testing Machine (UTM) (Model 50 ST) as shown in figure 2.

The UTM was switched on and the intermediate basket placed on the UTM table. The non-destructive test was done by measuring the height of the basket and that of the hydraulic lever when lowered were measured. The movable cross head was then gradually dropped using the control lever until it touches the basket placed on the UTM table. The drop head was continuously lowered to apply load to the basket and the corresponding reading taken from the load indicator. Load from the drop head, drop height and the basket heights were frequently monitored until a constant reading was achieved at about 2 cm varying height of the drop head. At this point, a slight crack sound was heard, indicating that the basket was at its yield point, almost approaching its break point. Furthermore, the above process was repeated until the basket on the UTM table bursts into pieces, marking the destructive test. This experimental process is presented in Figures 2 – 3.

Figure 2: The Universal Testing Machine (UTM)

Figure 3: Basket subjected to compression test

The force applied to the basket and as received by the basket were mathematically computed using stress – strain expression as presented in equations 1 to 3.

$$\text{Stress} = \frac{load}{Area} \tag{1}$$

but Area = $\pi h(R + r)$ (2)

Strain = $\frac{Change\ in\ length}{Original\ length}$ (3)

Results and Discussion

Results of the non-destructive and destructive tests carried out on the plastic and intermediate baskets is presented in Table 1. Values of the stress strain were computed and recorded as presented in Table 1 and Figure 4.

Table 1: Results of compressive tests conducted on the intermediate basket

Applied Pressure (kN)	Distance (m)	Duration (secs)	Strain (Non-destructive)	Strain (destructive)
0	0.22	0	0.01	0.01
0.5	0.28	5	0.05	0.05
1.0	0.35	10	0.05	0.05
1.5	0.41	15	0.05	0.05
2.0	0.52	20	0.05	0.05
2.5	0.528	25	0.07	0.07
3.0	0.527	30	0.05	0.04
3.5	0.52	35	0.03	0.03
3.7	0.517	40	0.03	0.02
3.9	0.515	45	0.03	0.01

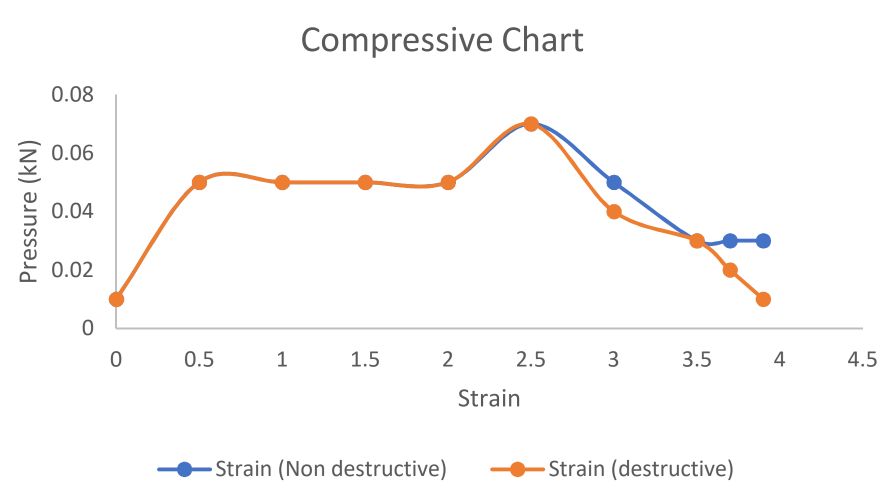

Figure 4: Compressive test of the intermediate basket

As the pressure is applied and increases, the duration of compression also increases and the strain on the basket as well increases. The strain became relatively constant at 0.5 despite a continuous increase in applied pressure. This is as a result of the gradual closure in the pore spaces/vents of the container. Further increase in strain from 0.5 to 0.7 was then experienced until a drop from 0.7 to 0.5 was again experienced. This drop resulted from the palm fronds reaching its elastic limit until uniform values of 0.3 was achieved despite pressure increase. These points are the yield point of the basket material where any further increase in the applied pressure could result to damage of the basket. This is better described in Figure and Table 1. The maximum significant pressure applied was observed to be at 2.5 kN with the highest strain of 0.07, further pressure increase was observed to be insignificant as this tends to destruction of the packaging container. This implies that the packaging container under study can bear a load of 2.5 kN of fresh tomato fruits when packaged and stacked on top of one another without causing permanent destruction to the baskets and mechanical damage to the tomato fruits. The packaging container's ability to bear 2.5 kN pressure also translates to its capability to stack 6 baskets of fresh tomato fruits (40 kg each). However, continuous loading of these baskets results in failure (basket destruction) at 3.5 kN.

Conclusion

The developed tomato packaging container evaluated for compressive strengths revealed that the basket can bear a maximum load of 2.5 kN (255 kg) and 3.0 kN (306 kg) respectively for non-destructive and destructive tests. This implies that stacks of 6 baskets can be safely transported with minimal postharvest losses. The packaging containers developed were found to be a better alternative to the conventional packaging containers used in transporting fresh tomato fruits.

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DESIGN, CONSTRUCTION AND PRELIMINARY TESTING OF A BIOMASS BRIQUETTING MACHINE

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Abstract

In this study, an average cost effective briquetting machine was designed and constructed, capable of producing 25 briquettes of diameter 70 mm and varying heights depending on the composition of the materials used, at a time. The machine was tested using mesocarp palm fibre and palm sludge (which was the binding agent) at various particle sizes which are; particle sizes >4mm, <4mm and <2mm, at binder levels 55%, 65%, 75%, 85% and 95%. The physical properties, behaviours and strength of the briquette was determined and recorded accordingly. On the basis of compressive strength for the initial testing, particles sizes >4mm had a range of 0.45MPa to 0.38MPa for binder level 55%-95%; particle sizes <4mm had a range of 0.11MPa to 0.14MPa for binders 55%-95% while particle <2mm ranged from 0.052MPa to 0.052MPa for binders 55%-95%. The biomass briquetting machine had a production capacity of 1.55kg/hr when tested using the ratio of 100:55, 100:65, 100:75, 100:85 and 100:95 respectively on weight basis, for 10 briquettes produced at a time. The total production capacity for 25 briquettes of palm mesocarp at the same ratio is 3.9kg/hr.

Keywords: Briquetting machine, crop waste, alternative energy source, briquettes.

1. Introduction

Since the energy generated is no longer sufficient for the ever-increased and teaming world population especially in the undeveloped countries, there is great need for adopting and harnessing the various alternative energies sources available (Alonge *et al*., 2002; FAO, 1996). The use of palm kernel shell (PKS) briquette as high grade solid fuel can reduce considerably both environmental pollution emanating from wastes as well as the energy crises in most developing countries (Adeniyi *et al*., 2014).

Agricultural waste such as those from the processing of grains, cereals and cotton, which are left in the field after harvesting can be used to generate energy for domestic cooking, heating and also for drying of crops on the farm (Adekoya, 1998). In 2004, about 77.8 % of the primary energy consumption was from fossil fuels, 5.4 % from nuclear fuels, 16.5 % from renewable resources, of which the main one was hydro (5.5 %) whereas the remaining 11% consisted of non-commercial biomasses such as wood, hay, and other types of fodder, that in rural-economies still constitute the main resource (FAO, 1996 and Anon, 2016). Rural households and minority of urban dwellers depend solely on fuel woods (charcoal, firewood and sawdust) as their primary sources of energy for the past decades (Onuegbu, 2010). Renewable energy technologies are safe sources of energy that have a much lower environmental impact than conventional energy technologies.

Figure 1: **Briquettes being dried**

Briquetting has been carried out on many materials e.g. brown coal (or lignite), biomass wastes and residues. Oil palm mush briquettes obtained from crop wastes can be used as an alternative source of energy (Alonge *et al.*, 2002). Brown coal may contain as much as 60% moisture and often has a low calorific value. To obtain higher-grade product, brown coal can be briquetted by suitable pressure-moulding process (Fabrode, 1998). An assessment of the potential availability of selected residues from maize, cassava, millet, plantain, groundnuts, sorghum, oil palm, palm kernel, and cowpeas for possible conversion to renewable energy in Nigeria has been made (Jekayinfa and Scholz, 2007). Therefore, the objective of this study was to design, construct and test the performance of a biomass briquetting machine.

2.0 Materials and Methods

2.1 Material Preparation

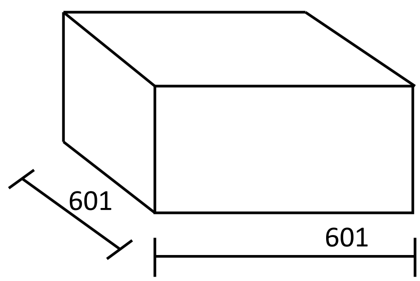
The palm mesocarp fibre (for briquette production) was first dried to reduce the moisture content available after oil extraction. After drying, the fibre was then cut with a pair of scissor to reduce the particle size. The reduced size was then analyzed by sieve and graded into the following groups: sizes >4mm, <4mm and <2mm.

2.2 Biomass-Binder Mixture

Palm fiber sample in three different particle sizes (particle size >4mm, particle sizes <4mm and particle sizes < 2mm) was then mixed with the palm sludge (oil residue from palm oil production) in proportions of 100:55, 100:65, 100:75, 100:85 and 100:95 by weight respectively. The biomass and binder was well mixed without forming a mixture with high moisture content in order not to reduce the density of the briquette. The mixture was fed into the moulds by hand compacted to form the briquettes and ejected after which they were sun dried to constant weight.

2.3 Design Analysis and Calculations

2.3.1 Mould Block



(F.2)

Area = $L\ XB$

= $601\ x\ 601$

= $3.61\ x\ 10^{-1}\ m^2$ (1

Properties of mild steel

Ultimate stress = 400mpa

Yield strength (σ y)

Tensional = 250mpa

Shear = 145mpa

Modulus of Elasticity (E) = 200Gpa

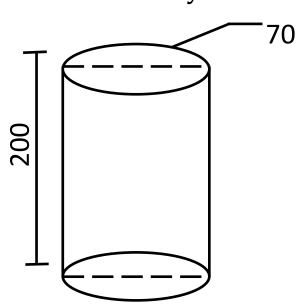
Modulus of Rigidity = 77.2Gpa

Density (ℓ) = 7860kglm³

Coefficient of Thermal Expansion = 11.7Gpa

(Source: Beer *et al.*, 2012)

2.3.2 Mould Cylinder



(F.3)

Ac = πr^2 (2)

r= $35mm$ = 0.035m

Ac = $\pi r^2 = 3.142\ x\ (3.5\ x\ 10^{-2})^2$

= $3.85\ x\ 10^{-3} m^2$

$Total\ Area\ (ACT) = AC\ x\ 25$

$= 3.85\ x\ 10^{-3}\ x\ 25$

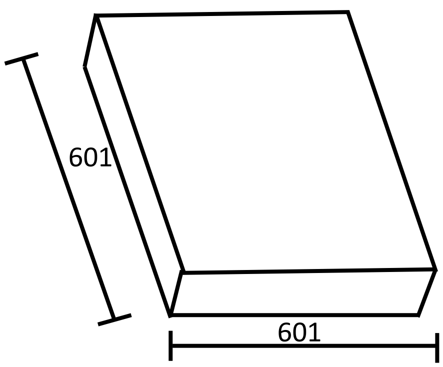
$= 9.62\ x\ 10^{-2} m^2$

Design Pressure = $17.5KN/m^2$ (pressure from the jack acting on the piston)

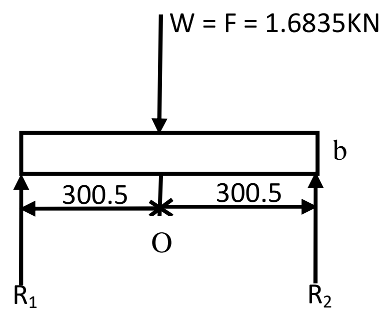
= $17500N/m^2$

Force Applied (F_{CT}) $= P\ x\ A_{CT} = 17.5\ x\ 9.62\ x\ 10^{-2} = 1.6835KN$ (3)

2.3.3 Mould Cover



(F.4)



(F.5)

2.3.4 Under Shearing

$\frac{F_T}{Am}\ x\ \sigma_y$ (4)

Taking moment about R_2

$MO_2 = F\ x\ D$

$= 1.6835\ x\ 300.5$

$= 0.506KNM$

$Am = 601\ x\ b$

$F_T = 1.6835KN$

$\sigma_y = 145MPa$

$Am = \frac{F}{\sigma_y}$ (5)

Substituting eqn.4 into eqn.5

$$0.601\ x\ b = \frac{F}{\sigma_y} \quad (6)$$

$$b = \frac{F}{0.601\sigma_y} = \frac{1.6835}{87.15}$$

$$= 1.93\ x\ 10^{-2}\text{m}$$

Assuming Uniform Distribution

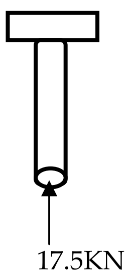
$$BM_{max} = \frac{WL^2}{8} \quad (7)$$

$$W = \frac{F_{CT}}{L} = \frac{1.6835}{0.601} = 2.801KN/M \quad (8)$$

$$BM_{max} = \frac{(2.801)(0.601)^2}{8}$$

$$= 0.1265KNM$$

2.3.5 Piston and Piston Rod

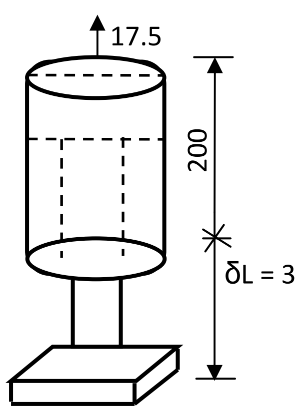


(F.6)

Pressure driving the piston = 17.5KN

Pressure per piston = $\frac{17.5}{25} = 0.7KN$

Force per piston rod = $\frac{1.6835}{25} = 0.06734KN$



(F.7)

Strain = $\frac{Change\ in\ lenght}{Original\ lenght} = \frac{\delta}{L}$ (9)

$\Sigma = \frac{3}{200} = 0.015$

2.3.6 Under Plate

Considering same dimension as mould cover

δ_b = 0.55 x Yield Strength (10)

= 0.55 x 250

= 137.5MPa

Sectional modulus of under plate

$$Z = \frac{L\ x\ b^2}{6} \quad (11)$$

$$Z = \frac{BM_{max}}{6} \Rightarrow a^2 = \frac{6(BM_{max})}{L\ x\ \delta_b} \quad (12)$$

From eqn. 12,

$$a = \sqrt{\frac{6(BM_{max})}{L\ x\ \delta_b}} \quad (13)$$

$$a \geq \sqrt{\frac{6(0.1265)}{0.601\ x\ (137.5\ x\ 10^3)}}$$

$$a \geq \sqrt{\frac{0.759}{82637.5}}$$

$$a \geq \sqrt{9.185\ x 10^{-6}}$$

$$a \geq 3.0306\ x\ 10^{-3} m$$

2.3.7 Description/ Principle of Operation of the Machine

A manually operated biomass briquetting machine was designed and constructed (Fig. 2). The briquetting machine consists of 25 moulds each with an internal diameter of 70 mm and a depth of 200 mm welded to a 6 mm flat mild steel plate at the top and bottom and positioned vertically over equal number of pistons. The pistons were made such that there is a clearance between the piston head and the mould walls to allow the escape of water during compaction and ensure free reciprocation. The opposite ends of the rods were welded on a flat metal plate of 12mm thickness which rests on a 20 tons capacity hydraulic jack. The jack drives the pistons in and out of the moulds during operation. A flat metal plate (A), 12mm thick, is hinged to the mould block (D) to cover the open ends of the moulds (B) during compaction and opened during ejection of the briquettes. When opened, the cover rests on the support (C). The vertical motion of the pistons in the moulds by the under plate (E) and the ejection of compressed briquettes from the moulds are by manual operation of the hydraulic jack (F).

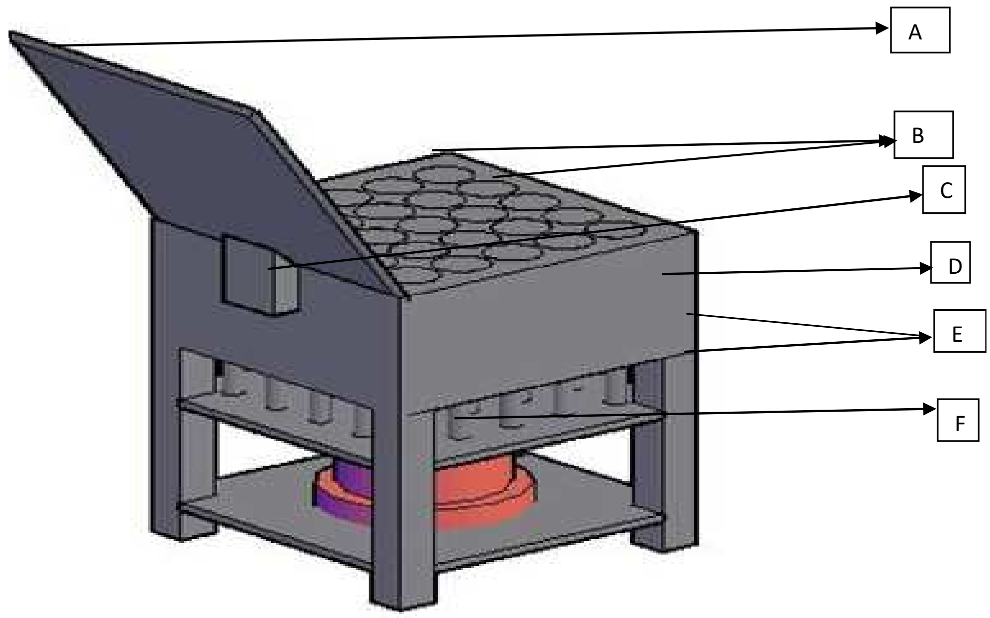


Figure 8: Briquetting Machine

3 Results and Discussion

3.1 Machine Capacity

The biomass compaction time t1, relaxation time t2 and ejection time t3, as well as their percentages of total production time and the corresponding mean mass of the briquettes produced were recorded as shown in Table 1.

Table 1: Production time components of the machine

Time Component	Time (sec)	Total production time (%)
Compaction time t2	65	16.75
Relaxation time t3	300	77.32
Ejection time t4	23	5.93
TOTAL	388	100

Mean mass of briquette produced = 165.6g of 10 briquettes

The machine produces approximately 165.6g of fifteen (15) briquettes in 463 seconds as shown in the table 1. Thus the production capacity of the machine in an hourly basis is 1.55kg/hr for 10 briquettes (i.e. the least production capacity). The relaxation time of the production is most important as it necessary for the loose materials to be held together.

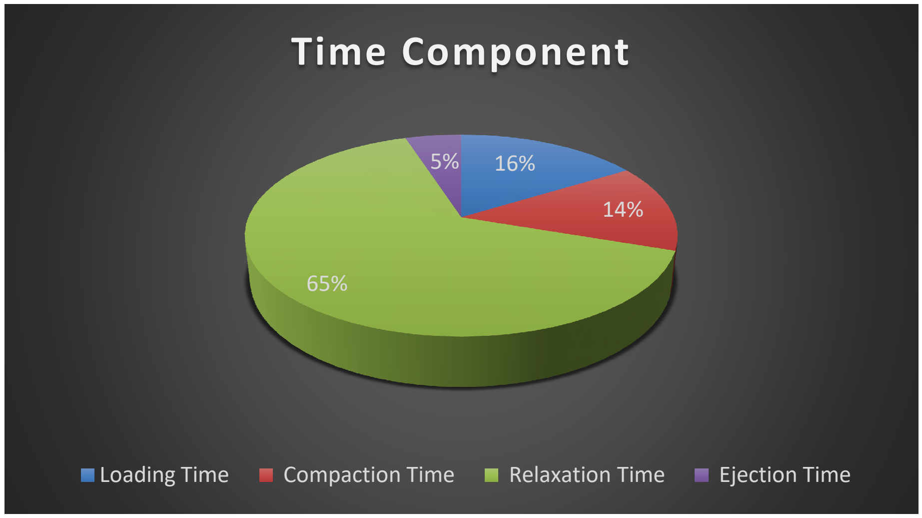


Figure 9: Total production time of machine

3.2 Analysis of the Material

The results of the proximate analysis of the material are shown in table 2.

Table 2: Proximate Analysis of the Material

Parameters	Percentage
Moisture content	5.40
Volatile matter	75.3
Ash content	4.90
Fixed carbon	14.4
Total	100

From literature, the moisture content of biomass should be as low as 10-15% so that there will be complete combustion of the briquettes (Maciejewska *et al*, 2006). Low moisture content of biomass also helps in their storage (prevents rotting and decomposition).

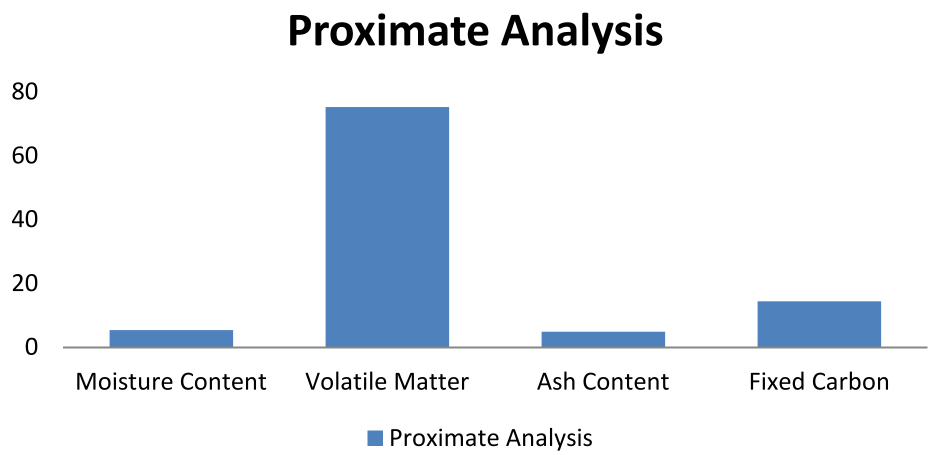


Figure 10: Proximate Analysis

3.3 Physical Properties of the Briquettes

The physical behaviours of the briquettes are as shown in the table 3. The biomass-binder level as well as the particle sizes had a major influence on the briquettes. The compressed density of particle sizes >4mm ranged from 0.394g/cm³ to 0.676g/cm³; that of sizes <4mm ranged 0.410g/cm³ to 0.677g/cm³ ,while the sizes <2mm ranged from 0.438g/cm³ to 0.729g/cm³ all on the addition of binders. The compressed density was greater in particle sizes <2mm which from table 3 indicates its ability to be handled and transported without being damaged. Thus, its tendency to form a compact solid depends on the particle size.

Table 3: Physical behaviours of the briquettes

Particle sizes (mm)	Percentage of binder (%)	Mean initial mass (g)	Mean initial height (cm)	Initial property of handling	Mean final mass (g)	Mean final height (cm)	Final property of handling
>4	55	148.7	9.0	Very difficult to handle	122.4	10.5	Brittle
>4	65	156.05	9.4	Difficult to handle	137.1	9.95	Particle is loose
>4	75	165.95	9.3	Easy to handle	143.95	10.8	A compact solid
>4	85	173.4	9.15	Easy to handle	152.4	10.1	Strong
>4	95	184.0	9.1	Easy to handle	158.8	10.2	Very strong
<4	55	150.1	9.5	Very difficult to handle	123.3	10.5	Brittle
<4	65	158.4	9.3	Difficult to handle	142.8	10.5	Moderately strong

<4	75	169.1	9.2	Easy to handle	147.9	10.7	A compact solid
<4	85	174.7	9.1	Easy to handle	156.5	10.6	Very strong
<4	95	185.2	8.9	Very easy to handle	163.3	10.5	Very strong and transportable
<2	55	150.9	9.2	Disintegrate easily after the first day.	131.8	9.6	Particles are loose and disintegrate gradually
<2	65	160.1	8.75	Disintegrate after 2 days	148.2	9.4	Particles are loose a bit
<2	75	168.7	8.75	Easy to handle	154.6	9.9	A compact solid can b handled
<2	85	176.7	8.6	Can be moved easily	162.7	9.8	A very compact solid and can be transported
<2	95	186.7	8.5	Can be moved easily	168.1	9.5	Very strong and easy to handle

3.4 Effects of Binder Level on the Particle Sizes

The binder levels 55% - 85% had no significant differences on the compressed density of the briquettes but the binder level 95% had a slight difference on the briquettes during testing. Also, in the aspect of strength and handling, the briquettes with binder level 55% started collapsing after 24 hours of drying thus, making it difficult to handle and transport. On the other hand, briquettes with binder level 95% showed superior quality in terms of strength and handling after the first two days of drying.

In terms of height stability, there were significant differences in the compressed and relaxed heights as seen in appendix 3.0. This is because the sludge (binder) used was of a lighter density due to the availability of water during its expansion (i.e. for the first production) but the differences were not significant in the second because the sludge used was thick and with little or no water.

3.5 Compressive Strength of the Briquette

On the basis of compressive strength for the initial testing, particles sizes greater than 4mm had a range of 0.45MPa to 0.38MPa for binder level 55%-95%; particle sizes less than 4mm had a range of 0.11MPa to 0.14MPa for binders 55%-95% while particle sizes less than 2mm ranged from 0.052MPa to 0.052MPa for binders 55%-95%. In the appendix, the actual result is shown for the compressive strength of the briquettes with greater discrepancies in its variation. These (the discrepancies) is as a result of the nature of the binder (fig. 11).

For the second replication, the compressive strength ranged from 0.35MPa to 0.25MPa, 0.28MPa to 0.17MPa, 0.17MPa to 0.14MPa for particle sizes greater than 4mm, less than 4mm and less than 2mm respectively all on the binder levels of 55%-95%.

Thus, it can be concluded that the force taken to crush the briquettes as well as its compressive strength depends on the binder level. The lesser the binder level, the more loose the briquettes become, making it less susceptible to destruction thus, requiring more force for that purpose (fig. 12).

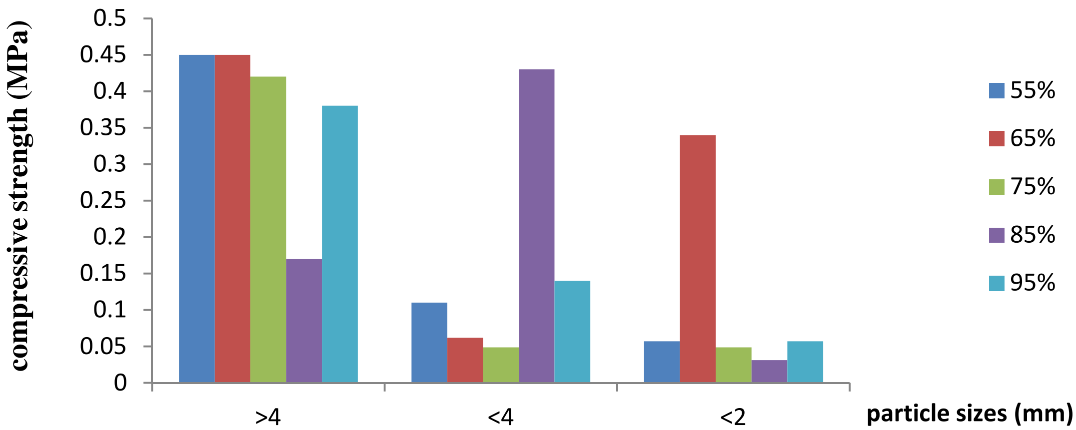


Figure 11: Compressive strength of initial production

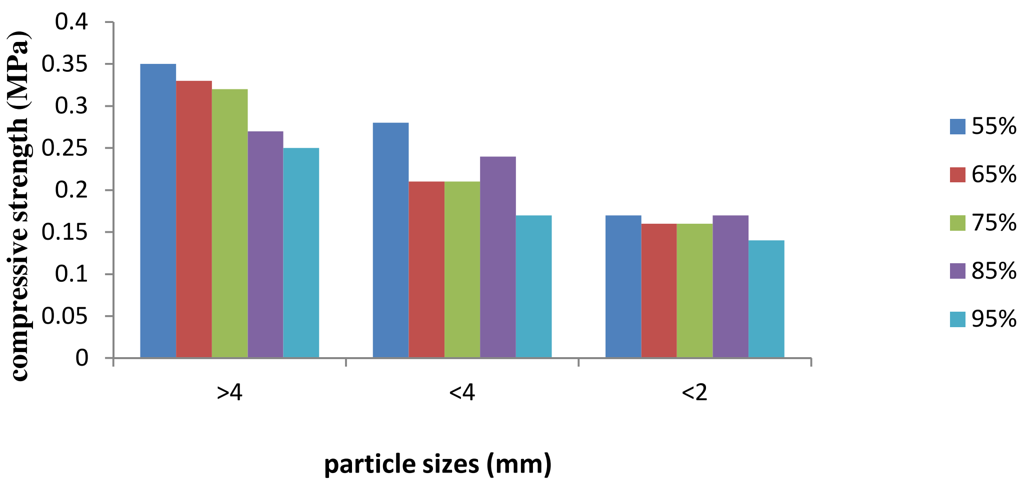


Figure 12: Compressive strength of first replication

4. Conclusions

Based on the results obtained from this study, the following conclusions are made;

1. A manual biomass briquetting machine was constructed and tested using mesocarp palm fibre with its least production capacity being 1.55kg/hr for 10 briquettes.
2. The physical properties of the agro materials are dependent on the particle sizes and also the binder levels.
3. The force taken to crush the briquettes as well as its compressive strength depends on the binder level.

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ENERGY CONSUMPTION AND ANALYSIS OF SACHET AND BOTTLED WATER PRODUCTION AT UNIVERSITY OF IBADAN WATER ENTERPRISES, IBADAN, NIGERIA.

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Abstract

Water is essential for human survival and proper functioning of the human body. Sachets and PET bottles are the most common ways to package water for commercial sales in African countries, especially Nigeria. The production of sachet and bottled water are energy and material intensive, resulting in emissions and plastic wastes that pollute agricultural soil, aquatic bodies, and the atmosphere. It is important to evaluate the amount of energy required to produce sachets and bottled water. The objective of this study was to evaluate the energy consumption of sachet and bottled water production, as well as conduct an energy analysis. Data were collected through repetitive observation from a water production factory located within a university community. Total energy consumption rates were 70 kJ/L and 254 kJ/L with energy ratios of 0.65 and 0.50 for sachet and bottled water production respectively. The energy productivity values were 4.05 L/MJ for sachet water and 0.38 L/MJ for bottled water production. The results depict that the highest energy consuming processes were: the reverse osmosis purification process for sachet water and the PET blowing process for bottled water production. The energy efficiencies of sachet and bottled water production were above average; nonetheless, there was no energy gain during the operations, which was justified because water has insignificant characteristic energy.

Keywords: Energy ratio, sachet water production, bottled water production, energy consumption, electrical energy

1.0. Introduction

Water is essential for sustenance of life and human survival is dependent on intake of water as it is estimated that about 60% of the human body is composed of water. Adequate hydration is necessary for proper functioning of the bodily system via body temperature regulation, oxygen and nutrient transport to cells, lubrication of joints and toxins removal (Dettore, 2006). Despite that about two-third of the earth is covered by water, only about one percent of the water is consumable without treatment (Nwanya *et al.*, 2013). (Dada, 2011) described the concept of packaged water as water packaged generally for consumption in a range of containers including cans, glasses, bottles, sachets and as ice prepared for consumption. In Nigeria, the most frequent methods of water packaging are sachets or plastic bottles. People utilise sachet and bottled water for a variety of activities and situations, including parties, celebrations, thirst quenching, and large-group entertainment (Dunmade *et al,* 2016).

Efficient use of energy is one of the principal requirements of sustainable production and helps to achieve increased productivity and profitability (Singh *et al,* 2002). However, intensive use of energy causes problems threatening public health and the environment. Also, Efficient use of energy will minimise environmental problems, prevent destruction of natural resources, and promote sustainable production (Erdal *et al,* 2007). The best way to lower the environmental hazard of energy use is to increase the energy use efficiency. Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems. Energy analysis together with environmental and economic analyses, are important tools to define the behaviour of a production system (Mohammadshirazi *et al*, 2012). Regardless of the vast field of application, the objective of energy analysis is clear: to reduce energy inputs or adopt alternative and renewable energy sources in production processes (Ortiz-Canavate and Hernanz, 1999).

Gleick and Cooley (2009) reported the total amount of energy needed in a water factory is complicated by many factors, including the location and type of the water source, the distance from the water factory to the consumer, the types of material used in packaging, labels and thermo packaging and many more. The immense majority of single-use plastic water bottles are made out of polyethylene terephthalate (PET) (Maciaszek, 2018). There is an increasing trend in the amount of energy dedicated to most economic production activities; this is a function of the level of development and available technology in countries (Ortiz-Canavate and Hernanz, 1999). Results obtained from two comprehensive life-cycle assessments carried out for the production of PET resins and PET bottles indicate that the energy required to produce PET resin is approximately 23–28 MJ per kilogram of PET resin (Bousted 2005; Franklin Associates 2011).

The challenges facing the water packaging factory in Nigeria includes: high cost of production, unreliable grid supply, high level of workers' incompetence and distribution problems (Nwanya *et al*, 2013). The unreliable power supply is the cause of dependence on generating sets for production which as a result lead to increased cost of production (Akinwunmi *et al*, 2006). The presence of high cost of production issues is ascribed to the inability to accurately predict energy and pool of trained manpower required for a continuous operation which eventually results in poor management of resources (Stratman *et al*, 2004)

The main objective of this study is to perform the energy analysis of sachet and bottled water production. This study is particularly important because there has not been any previous study focusing on energy assessment of sachet water bottled water production in Nigeria.

2.0. Materials and Methods

The study was conducted at the University of Ibadan Water Enterprise, located within the university's campus in Ibadan, Oyo State, southwestern Nigeria. Data were collected through repetitive observation of the production cycles which was an 8-hour period each for both sachet and bottled water sections during May-July 2021.

In this study, the sachet water production unit activities were divided into: water generation, water treatment, water transfer, sachet water production. Water generation entails pumping water from a borehole into pretreatment tanks; water treatment involves primary treatment with resins, activated carbon, and resins, as well as secondary treatment with filter cartridges, ultraviolet tubes, and RO machines; water transfer encompasses all pump transfer activities in between production; and sachet water production entails the liquid filling and sealing machine, as well as bagging and arrangement.

Also, bottled water production unit activities were divided into: water generation, water treatment, water transfer, bottling unit, labelling and packaging. The steam generator aids with labelling as the bottled water moves along the conveyor and the packaging involves using the thermocool machine facilitated by the compressor; and arrangement in stacks is done by personnel. The PET blowing unit activities is divided into PET heating and blowing which is aided by the compressor engine. The unit is a subunit of the bottled water production section on the basis that its products (PET bottles) are utilised in the bottling section.

The energy sources for the production processes at the water factory are the electrical energy and the manual energy of the operator. The energy consumptions were evaluated using the following:

a. Evaluation of the Electrical Energy Input: This is denoted by E_e in kWh and was obtained by multiplying the rated power of the machines and motors, P, in kW with the corresponding operation hours, t. The efficiency, η is assumed to be 1.

$$E_e = \eta \times P \times t \qquad \ldots (1)$$

b. Evaluation of Manual Energy: Bamgboye and Jekayinfa (2006) reported that the physical power output of a normal human labourer in tropical climate is approximately 0.075 kW sustained for 8-10 working hours per day at maximum continuous consumption rate of 0.3 kW and conversion efficiency of 25%,

$$E_m = 0.075 \times n \times t \qquad \ldots (2)$$

Where:

E_m is the total manual energy,
n is the number of persons involved in an operation and
t is the useful time spent to accomplish a given task in hours.

In this study the energy inputs were human labour, water, electricity and plastic packaging (HDPE, LDPE, PP, PET). The energy outputs included water and the plastic packaging. The energy analysis of sachets and bottled water production was carried out in accordance with the energy evaluation system proposed by the International Federation of Institutes for Advanced Study, Energy Analysis Workshop in 1974 (Ortiz-Canavate and Hernanz, 1999).

The energy values of the inputs for both sachets and bottled water production were obtained from relevant literature. The material inputs utilised in sachets and bottled water production at the water factory were: the sachets made from Low Density Polyethylene (LDPE), the shrink rolls and bagging nylons made from High Density Polyethylene (HDPE), the labels and bottle caps made from Polypropylene (PP) and the bottles which were made from Polyethylene Terephthalate (PET). The energy equivalents for PET, HDPE, LDPE and PP as given by Sharuddin *et al* (2018) were 28.2, 40.5, 39.5 and 40.8 MJ/kg, respectively. For the sake of energy analysis, the energy value for diesel is 47.8 MJ/L and for electricity is 12.0 MJ/kWh (Ortiz-Canavate and Hernanz, 1999). The energy equivalent for human labour and water were obtained as given by Mohammadshirazi and Bagheri-Kolhor (2016) to be 1.96 MJ/h and 0.01 MJ/L respectively. The quantity of inputs and outputs used were obtained and documented into Excel spreadsheets. For the human labour energy estimation, the number of workers employed at the various processes as well as the working duration of individual workers were obtained. The energy equivalent of human labour is the muscle power used in the production of sachet and bottled water where the muscle power is the ability to exert an average energy per hour of activities.

For the energy data, the start, end and down times of each of the machines were collected over the period of production for each production cycle. The energy demand is divided into direct and indirect energy. Direct energy includes human labour and electricity, while indirect energy covers the energy embodied in water and plastic packaging used in sachet and bottled water production. Expressions, such as the energy ratio, the energy use efficiency, the energy productivity and the net energy gain (Eqns. 3-6) were given by Mohammadshirazi and Bagheri-Kolhor (2016).

Equations:

a. Energy Ratio = $\frac{Output\ energy}{Input\ energy}$ (3)
b. Energy Efficiency = Energy Ratio x 100 (4)
c. Net Energy Gain, MJ/L = $Total\ output\ energy - Total\ input\ energy$ (5)
d. Energy Productivity, L/MJ = $\frac{Total\ Production,\ L}{Total\ Input\ Energy,\ MJ}$ (6)

3.0. Results and Discussion

3.1. Energy consumption

For the period of observation, the total unit of sachet water produced was 3854 bags (as shown in Table 1), and the total amount of energy consumed was evaluated to be 900.58 MJ, of which 889.47 MJ (98.77%) and 11.11 MJ (1.23%) were electrical energy and manual energy respectively. As shown in Table 2, transfer of water between points had the highest percentage of energy consumption of 290.86 MJ (32.30%), followed by water treatment activities using the RO machine and UV tube with 284.55 MJ (31.60%), while sachet water filling, sealing and bagging accounted for 248.13 MJ (27.55) and finally, water generation with the least consumption of 77.04 MJ (8.55%). The energy consumption per litre for sachet water production was 0.070MJ l^{-1}, whereas Dettore (2006) reported a value of 0.022 MJ l^{-1} for tap water treatment and reusable container, which is around one-third of the energy consumption for sachet water production. This was attributed to the energy-intensive machines required to produce water in sachets as compared with direct consumption of tap water with reusable containers.

Table 1 : Total Energy Consumption for Sachet Water Production

Production activities	**Electrical Energy (MJ)**	**Manual Energy (MJ)**	**Total Energy (MJ)**	**% of Total Energy**
Water generation	77.04	-	77.04	**8.55**
Water treatment	284.55	-	284.55	**31.60**
Water transfer	290.86	-	290.86	**32.30**
Sachet water production	237.02	11.11	248.13	**27.55**
Total	**889.47**	**11.11**	**900.58**	**100**
Percent of total energy (%)	**98.77**	**1.23**	**100**	

Table 2 : Total Energy Consumption for Bottled Water Production

Production activities	Electrical Energy (MJ)	Manual Energy (MJ)	Total Energy (MJ)	% of Total Energy
Water generation	54.00	-	54.00	**1.25**
Water treatment	109.79	-	109,79	**2.53**
Water transfer	196.74	-	196.74	**4.54**
Bottling unit	223.08	7.35	230.43	**5.32**
Labelling	584.13	3.95	588.08	**13.58**
Packaging and arrangement	1463.25	10.90	1474.15	**34.03**
PET blowing	1673.10	5.20	1678.30	**38.75**
Total	**4304.09**	**27.40**	**4331.49**	**100.00**
Percent of total energy (%)	**99.37**	**0.63**	**100.00**	

In the bottled water production section, 948 packs of 75 cl and 320 packs of 50 cl bottled water were produced within the period of observation. For PET blowing, 8483 units of 75 cl bottles and 4175 units of 50 cl bottles were produced. The total amount of energy consumption during this period was 4331.49 MJ with PET blowing operation having the highest consumption of 1673.10 MJ (38.76%) and water generation having the least consumption with 54.00 MJ (1.25%). The input of manual energy (0.63%) was negligible compared to that of the machines (99.37%) used for bottled water production as a result of the automation of the production processes.

The energy consumption for bottled water production per litre for the observation period was 1.24 MJ_{th} l^{-1}, and compared with the range of 5.6-10.2 MJ_{th} l^{-1} reported by Gleick and Cooley (2009), the value is relatively smaller. However, Gleick and Cooley (2009) additionally considered energy for the production of preforms from PET resins, post-production cooling and transport energy for inter-city freight which all accounts for about 92% of the total energy in their report. In addition, Franklin Associates (2009) reported 0.168 MJ l^{-1} for the production of bottled water and 4.325MJ kg^{-1} for PET bottle blowing operation. The energy usage for bottled water production at U.I. Water Enterprises was estimated to be 0.254 MJ l^{-1} and 4.704 MJ kg^{-1} for PET bottle blowing. This discrepancy can be ascribed to the level of automation.

3.2. Energy analysis

For sachet water production (Table), the total energy input was calculated as 247.0 kJ/L and the total output energy was calculated as 159.5 kJ/L. The Energy ratio obtained for sachet water energy analysis was 0.65, the energy efficiency was calculated as 65%, the net energy was -87.50 kJ, and the energy productivity was calculated to be 4.05 L/ MJ. For bottled water production (Table 4), the total energy input was calculated to be 2.771 MJ/L and the total output energy was calculated as 1.387 MJ/L. The Energy ratio obtained for bottled water production was 0.50, the energy efficiency was calculated as 50%, the net energy was calculated to be -1.384 MJ, and the energy productivity was calculated to be 0.36 L/ MJ.

Table 3: Energy Analysis for Sachet Water Production

Items	Units	Energy Intensity (MJ/units)	Quantity (units)	Quantity per litre of Sachet water (L)	Total Energy intensity (KJ/L)	Percentage of the total (%)
Input						
Diesel fuel	L	47.8	18.46	0.0005	22.90	9.27
Human Labour	Hrs.	1.96	41.13	0.0011	2.10	0.85
Electricity	kWh	12.0	200.93	0.0052	62.60	25.34
HDPE	kg	40.5	19.73	0.0005	20.70	8.38
LDPE	kg	39.5	131.04	0.0034	134.30	54.37
Water	L	0.0042	40645	1.0546	4.40	1.78
Total input energy					247.00	
Output						
Water						
i. Sachet water	L	0.0042	38540	1.0000	4.20	2.63
ii. Waste water	L	0.0042	2105	0.0546	0.20	0.13
HDPE	kg	40.5	19.73	0.0005	20.70	12.98
LDPE	kg	39.5	131.04	0.0034	134.30	84.20
Total output energy					159.50	

Total Production = 38540 L

Table 4: Energy Analysis for Bottled Water Production

Items	**Units**	**Energy Intensity (MJ/units)**	**Quantity (units)**	**Quantity per litre of Bottled water (L)**	**Total Energy intensity (MJ/L)**	**Percentage of the Total (%)**
Input						
Human Labour	Hrs.	1.96	101.48	0.0097	0.0190	**0.69**
Electricity	kWh	11.93	1195.58	0.1144	1.3646	**49.25**
PET	kg	28.2	368.12	0.0352	0.9932	**35.84**
HDPE	kg	40.5	64.28	0.0062	0.2491	**8.99**
PP	kg	40.8	36.01	0.0034	0.1406	**5.07**
Water	L	0.0042	10783	1.0316	0.0043	**0.16**
Total input energy					**2.7709**	
Output						
Water						
i. Bottled water	L	0.0042	10452	1.0000	0.0042	**0.30**
ii. Waste water	L	0.0042	330.75	0.0316	0.0001	**0.01**
	kg	28.2	368.12	0.0352	0.9932	**71.60**
HDPE	kg	40.5	64.28	0.0062	0.2491	**17.95**
PP	kg	40.8	36.01	0.0034	0.1406	**10.14**
Total output energy					**1.3872**	

Total Production = 10452 L

Mohammadshirazi and Bagheri Kolhor (2016) reported the net energy gain of 5.92 MJ/L, energy productivity of 0.38 L/ MJ and the energy ratio of 3.14 for the production of a local tea beverage in Iran. Despite having water as the main ingredient (96%) of the beverage production, the discrepancies in the obtained energy output are attributed to other ingredients such as sugar and tea leaves which are high in energy values, resulting in a relatively high energy efficiency as compared to sachets and bottled water production. Ortiz-Canavate and Hernanz (1999) also reported that for the production of bioethanol from sugar beet crops, the net energy gain was 39.2 GJ/ha, the energy ratio was 1.3 and energy productivity of 41.9 L/GJ. Sugar beet crops are energy crops grown for their high energy values, whereas water, which is the raw material for packaged water production, is not known for its energy content and has a relatively infinitesimal energy value, resulting in these huge differences when compared to both sachet and bottled water production.

5.0. Conclusions

Based on the results the following conclusions are drawn:

1. The energy expended for bottled water production per litre (0.262 MJ l^{-1}) was about 12 times more than the energy consumed per litre of sachet water production (0.022 MJ l^{-1}).
2. Sachet water production has an energy efficiency of 65% which is higher compared with that of bottled water production (50 %).
3. In terms of energy efficiency and productivity, sachet water production performed better per litre of product output than bottled water.
4. Negative net energy (NEG) values indicate that some of the input energy was wasted during the production process; this is validated since water as a product has no significant embodied energy.
5. It is shown that the energy ratio can be increased by decreasing energy use, this is achievable through the adoption of energy saving approaches during production.

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EFFECT OF ADDITIVES AND FISH FEED FORMATION ON THE PHYSICAL AND PROXIMATE PROPERTIES OF FISH FEED

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Abstract

This study was conducted to investigate the effect of additives and fish feed formulation on the proximate and physical properties of fish feed, to determine the anti- nutritional factors present in giant cocoyam, two samples were considered which are raw and boiled cocoyam and to evaluate the drying behavior of boiled giant cocoyam which was used in place of maize as a carbohydrate source. The proximate analysis conducted was analyzed and there was a significant difference in the fat and fibre composition of the different feed ratios (1.75^m, 1.55^p, 0.9150^r and 0.8950^r), (4.95^n, 5.35^n, 7.35^q, 7.65^q). The ANOVA indicates treatment effect on anti-nutritional properties of cocoyam showing F-values of oxalate, phytate, saponin and tannin > F criti but in cyanide F-value < F criti, which implies that there is a significant difference between the raw and boiled but boiling of cocoyam and then recommended so as to reduce these factors so that feed will be available to fish. The physical properties of the formulated fish feed showed that ratio A floats 105 minutes, 180 minutes dissolving time and Ratio B and D does not have any floating ability.

Keywords: *Additive, Anti-nutritional properties, Physical Properties, proximate properties, Fish feed.*

1.0 Introduction

Nigeria relied heavily on the importation of supplement domestic production of conventional feedstuffs in order to meet the needs of expanding livestock, poultry and fishery industries (Gabriel et al, 2017).

Fish feed are important part of modern commercial agriculture which is in form of granular or pallets that floats on water providing the nutrition in a stable and concentrated form. This plays an important role in the value chain as it implies important control of the quality of raw materials which is crucial for the food safety as well as efficient high quality food types that ensures optimal growth for different fish species formed under a variety of different condition (Hasan, 2012).

Feed formulation here is the combination of raw materials/feedstuffs to satisfy the already existing nutrient requirements of the species and age of fish. According to Azevedo et al, 1998, formulation of feed must consider price of available ingredient, used and the anti-nutritional factors and palatability of mixtures.

The use of maize as staple food and as a chief energy source in livestock food for man and as a chief energy source in livestock foods has made it to be highly competitive in demand resulting in additional cost constraints, in order to ameliorate this problem alternative sources of energy that are less in demand with relatively lower cost must be exploited because of the frequent drought and locust attack affecting some maize producing areas depending on maize alone as a sole source of dietary energy will be devastating to livestock production (Agwunobi and Essien, 1995).

Maize which is predominantly used for human consumption in Nigeria is not provided in sufficient quantities, the rising prohibitive cost and scarcity of maize have necessitated the need to search for underutilized energy feed ingredients (Jimoh *et al*, 2014).

Cocoyam is a common name for the corns and tubers of several plants in the family Araceae, it is primarily grown as a root vegetable for its edible starchy corn and as a leaf vegetable. It can be consumed in different ways through roasting, cooking, frying, baking, pounding and milling as reported by (Global foodbook.com.) and can be processed into various food products used for industrial and culinary purposes. According to Ekwe *et al*, 2009, cocoyam has mineral starch grains that are easily digestible and as such makes it an ideal source of carbohydrate.

According to Keremiah and Esquire, 2014, there is need to conserve the foreign exchange used in importation by increasing the domestic fish feed production. Therefore there is need for the intensification of the local fish diet formulation in order to boost the current production level of fish feeds (Ahmed and Ibrahim, 2016).

It is believed that local feed formulation will encourage export at maximum returns to the fishery industries and the country (Spinelli, 2014). This take us to the objective of this work is to study the effect of fish feed formulation on the selected physical and proximate properties of the feed.

2.0 Material and Methods

2.1 Description of Equipment and Samples

The study was conducted with some selected and necessary equipment's for feed processing in the laboratory. They include; drying oven, weighing balance, Beaker, Bowl for mixing, aluminum tray, juice extractor, stop watch, hammer mill and gas cooker. The sample include one unconventional material (giant cocoyam) which served as the main component in fish formulation, to replace maize.

2.2 Experimental Design and Treatment

Here two materials; yeast and calcium carbonate was considered in the treatment of mixed feed to aid aeration while it was left for some minute to incorporate air and followed up with pelleting of the dough formed and 50g of the two materials was used at different ratio of feed with the substitute. The study was made up of two (2) treatment; T_1 = yeast and T_2= calcium carbonation at different ratios for cocoyam as shown in Tables 1and 2. The treatment was laid out in a Randomized complete block design (RCBD) and replicated three times.

Table 1: Treatment and ratio of feed with cocoyam.

Treatment	Combination
T_1 Yeast (50kg)	$T_1B_1B_2$
T_2 Calcium Carbonate(50kg)	$T_2B_1B_2$

Where T_1 = Treatment 1, T_2 = Treatment 2, B_1= first ratio of feed with cocoyam, B_2= second ratio of feed with cocoyam.

Table 2: Fish feed formulation using Giant cocoyam as a substitute for maize.

Feed Ingredient	B_1 Ratio 1	B_2 Ratio 2
	Cocoyam	Cocoyam
Cocoyam	1.5	2
PKC	0.5	0.25
Fish Meal	0.3	0.2
Soya bean Meal	1.5	1.0
Groundnut Oil	0.1	0.1
Rice Bran	0.2	0.2
Vitamin and Mineral	0.3	0.3
Wheat Offal	0.5	0.8
Yeast/Calcium Carbonate	0.1	0.1
Total	5kg	5kg

2.3 Drying Procedure

Here drying was done by spreading the sliced cooked cocoyam in a single layer on a rectangular tray or area 0.04155m^2 placed inside an oven. The dryer was maintained at 105^{0}c. here the natural air speed was measured as 0.02mls, the sample was removed and weighed every 20 minutes on a digital weighing balance (scout pro spin 405, made in china) while the dryer was continuous until no noticeable changes in the mass of the sliced material.

2.4 Determination of Physical properties

The physical properties determined were moisture constant, floatability, bulk density, dissolve time, and pallets density and latter subjected to analysis.

2.5 Determination of Anti –nutritional and Proximate Properties:

2.5.1 Determination of Nitrogen Free extracts (NFE): Here at nutrients not accessed by the prior methods it promotes analysis. These are composed mainly of digestible carbohydrate, vitamins and other non-nitrogen soluble organic compounds. It was calculated as:

$$NFE\ (\%) = 100 - (A + B + C + D) \quad (1)$$

A = Moisture content (%)
B = Crude protein content (%)
C = Crude fat content (%)
D = Crude fibre content (%)
E = Ash content (%)

2.5.2 Determination of Ash Content: This was calculated as

$$\% \text{ Ash} = \frac{Wa}{Ws} \text{ X } \frac{100}{1} \quad (2)$$

Where Wa = Weight of ash

Ws = Weight of Original Sample

2.5.3 Determination of Protein Content: This was determined by micro-kjeldhal method which evaluates the total nitrogen content of the sample after it has been digested in sulphuric acid and with a mercury or selenium catalyst.

2.5.4 Determination of Fat and Crude Fibre: The fat was determined with a mixture of chloroform methanol while crude fibre was determined using the equation:

$$\% \text{ Crude Fibre} = \frac{DW-WR}{WP} \text{ X } \frac{100}{1} \quad (3)$$

Where DW = Dry weight of residues before ashing
WP = Weight of sample
WR = Weight of residues after ashing

2.5.5 Determination of Moisture Content: The moisture content was determined by gravimetric method and was mathematically expressed as:

$$\frac{Mw}{Md} \text{ X } \frac{100}{1} \quad (4)$$

Where Mw = Mass of wet sample

Md = Mass of dry sample

2.5.6 Determination Anti-nutritional Properties: Here the following properties**;** Phylate, Tanin, Oxalate, Cyanide and Saponin contents were determined in the laboratory with Munro and Basir (1969) and Fenwick and Oakenful (1981) methods.

3.0 Results and Discussions

3.1 Moisture Content and Drying Time

Figure 2 shows the drying curve of moisture content and drying time of cocoyam. It was observed that the total time required to dry giant cocoyam at 105 C was 400mins which implies that it needs this total time to reduce its moisture content. This could be as a result of higher fibre content of cocoyam which makes it to exhibit longer drying time. It was found also that the drying curve exhibited a steeper slope as it increase the drying rate thus the result of the findings is in line with the report given by Rayaguru and Routray,2012.

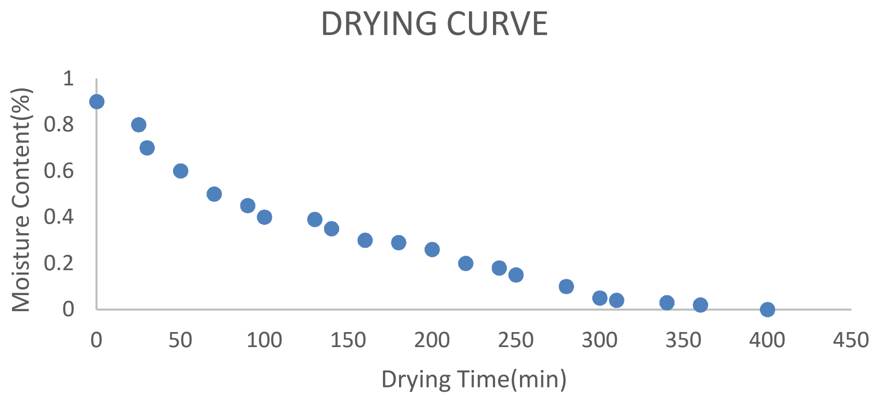

Figure 2: The plot of moisture content and drying time of cocoyam

3.2 Physical Properties of Pelleted Fish Feed

Table 3 describe the physical properties of pelleted fish feed subjected to analysis. It was found that fish feed ratios floatability rate was observed to be high at A and C of the range 105mins and 0.5mins. The dissolving time was at the range 60mins to 180mins for fish feed ratios A to D respectively. The weight was of the range 1.68g to 1.92g for fish feed ratios A to D respectively and the bulk density was of the range 0.7970g/cm3 to 1.36g/cm3 for fish feed ratios A to D respectively. Generally the physical properties of the produced fish feed gave the best ratio of feed considering the generatedvalues.

Table 3: Physical properties of pelleted fish feed.

Physical Properties	Units	Fish Feed Ratios			
		Moisture content (%)	Crude protein content (%)	Crude fat/fiber content (%)	Ash content (%)
Floatability ratio	(m)	105	0	0.5	0
Dissolving Tins	(m)	180	60	60	90
Weight	(g)	1.80	1.68	1.73	1.92
Bulk Density	g(cm^3)	1.36	0.7970	1.25	1.15

Table 4: The mean values of proximate composition of different fish feed ratios

Feed Ratios	Mc	Ash	Fat	Protein	Fish	CHO
A	7.75[a]	6.25[e]	1.75[m]	8.65[w]	4.95[n]	70.65[h]
B	7.78[a]	6.55[e]	1.55[p]	8.85[w]	5.35[n]	70.15[h]
C	8.10[a]	5.75[e]	0.9150[r]	9.25[w]	7.35[q]	68.65[h]
D	8.80[a]	6.00[e]	0.8950[r]	9.05[w]	7.65[q]	67.61[h]

Note: P=0.05; Values with similar letters along the same column are not significant.

Table 5: ANOVA table of the anti-nutritional properties of cocoyam.

SOV	SS	df	ms	f	p-value	f.cal
Phylets	1.521074	1	1.521074	474.668	2.63E-05	7.708647
Oxulate	1176	1	1176	251.2821	9.26E-05	7.708647
Tanin	3.168267	1	3.168267	631.5482	1.49E-05	7.708647
Saponin	16.7334	1	16.7334	669.336	1.33E-05	7.708647
Cyamide	0.070417	1	0.070417	3.474507	0.13577	7.708647

Note: P= 0.05

3.3 Proximate Composition of Fish Feed Ratios

Table 6 Show the mean proximate composition of fish feed ratios. Here it was that the values with similar letters along the same column are not significant and also it was observed from the proximate analysis conducted there was significant differences exist in moisture content, ash, protein, and carbohydrate of ratio A to D respectively, this could be due to the fact that the material were dried to a low level at long duration which indicate that the feed will promote fish growth.

3.4 Anti-nutritional Properties of Raw and Boiled Cocoyam

Figure 3 and Table 5 Shows the anti- nutritional value of raw and boiled cocoyam and the ANOVA table on anti-nutritional properties of cocoyam. It was found in figure 3 that the highest anti-nutritional value for raw cocoyam was observed by oxalate and the least was observed by cyanide of the range 25mg and 3mg respectively while for the boiled cocoyam, the highest anti-nutritional value was observed by oxalate and the least was observed by cyanide of the range 15mg and 1mg respectively. From table 5 showing the ANOVA table of the anti-nutritional properties of cocoyam, it was indicated that the F-value for oxalate, phylate, saponin and tannin are >Fcrit but in cyanide F-value is <Fcrit and from all indication there was significant difference between the raw and boiled cocoyam and the report is in line with the work of Ekwe et al, 2009; Lenu and Adebole 2010.

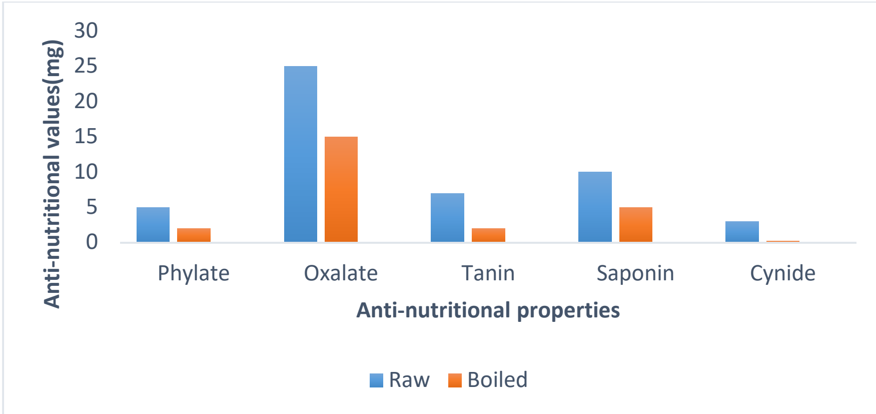

Figure 3: Anti-nutritional properties of raw and boiled cocoyam.

4.0 Conclusions and Recommendations

The effect of additives and fish feed formation on the physical and proximate properties of fish feed was investigated. From the test carried out, it was concluded that the the total time required to dry giant cocoyam at 105 C was 400mins which implies that it needs this total time to reduce its moisture content. From the proximate analysis conducted, it was observed that there was a significant difference in the fat and fibre composition of the different feed ratios. The anti-nutritional properties of cocoyam was F-value >Fcriti for oxalate, phytate, saponin and tannin > F critical but F-value < F critical for cyanide which implies that there is a significant difference between the raw and boiled but boiling of cocoyam and then recommended so as to reduce these factors so that feed will be available to fish. The physical properties test conducted showed that the feed has the best ratio because of its rate of floatability and dissolving. In view of the results, it's also recommended and advised that local feed formulation should be encouraged for maximum export returns to the fishery industries and the country at large.

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.DEVELOPMENT OF NATURAL AND FORCED AERATED STRUCTURES FOR ONIONS STORAGE

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Abstract

Onion is a rich source of vitamins and minerals. It is perishable due to its high moisture content and an increase in relative humidity few months after its harvesting season. Substantial losses have been recorded in traditional storage cribs. This research developed appropriate structures for storage of onion. Four crib-like structure with varied configurations (A, B, C and D) were designed and constructed with dimension 1.2 x 1.0 x 0.8 m and 300 kg capacity. The structures were filled with onions of about 240 kg each. Net bags containing onions of known weight were placed randomly in each of the structure for sampling. The temperatures and relative humidity within the structures as well as the ambient's were monitored during the storage period. The physical, chemical, mineral content and microbial qualities of the stored onions were assessed monthly. The storage duration was 4 months. The temperature in all the structures and ambient ranged from 25.0 – 27.0 ˚C while the relative humidity ranged from 77.0 – 89.1%. Weight loss increased in all the structures throughout the storage period. Structure C recorded the lowest weight loss of 55% among all the structures (A - 65%, B - 74% and D - 65%). Sprouting increased in all structures over the storage period. Structure C had least incidence of sprouting with 8.3% while structures A, B and D had 18.6, 19.5 and 22.2% sprouted bulbs respectively. The chemical and mineral contents of the stored onions were significantly affected by the storage structures and duration of storage ($p < 0.05$). The study showed that forced aeration reduced sprouting. However, there is a need to explore configurations that will as well minimize weight losses. Therefore, we recommend further testing of structure C with modification.

Keywords: Onion, rotting, sprouting, storage, weight loss.

1.0 Introduction

Onion (*Allium Cepa* L.) belongs to family *Alliacea* and originated from South East Asia (Gateri *et al.,* 2018). It is one of the oldest bulb crops known to mankind and consumed worldwide (Banuu *et al.,* 2014). It is an important and popular vegetable crop grown in Nigeria with the bulk of its production concentrated in Northern Nigeria. Sokoto and Kebbi States are among the leading commercial producers of onions (Fumen *et al.,* 2017). Onion is consumed as a spice in dishes for flavor because of the pungent smell of its volatile oil allyl- propyl-disulphide. It is rich in vitamins (A and C), minerals (calcium, sodium, phosphorous) and fiber (Sohany *et al.,* 2016). Onions also have therapeutic properties (Halliru *et al.,* 2019). It contains phenolics and flavonoids that have potential antioxidant, antimicrobial, and anti-cholestrol properties (Anuradha, 2016). Onion is a seasonal and a perishable crop delicate to store due to its high moisture content (Endalew *et al*., 2014). Storage losses in onion can be about 30 to 50% or more if not properly handled. To reduce this loss, many researchers have worked on the effect of curing, storage condition (Nassarawa *et al.,* 2018), packaging (Mahmud *et al.,* 2015, Sohany *et al.,* 2016), storage method and structure type (Soomro *et al.,* 2006, Endalew *et al.*2014, Fumen *et al.,* 2017) on the storability of onions. The studies revealed that properly cured onions require appropriate storage structure with adequate control of temperature and relative humidity for effective storage. Relative humidity is usually high few months after harvest of onions which limits its proper storage and induces price hike in the commodity. Stakeholders in the postharvest value chain of onion have demanded for appropriate technology that will enhance the storability of onions especially few months after harvesting. Therefore, this study aimed at developing appropriate structures for storage of onion and also study their effect on the physical, chemical and microbial qualities of stored onions.

2.0 Materials and Methods

2.1 Design of storage structures

A 300 kg capacity structure was designed considering a bulk density of 550 kg/m^3, a filling height of 0.5 m, and head space of 0.3 m for good ventilation with a width of 1.0 m. using appropriate relationships. Therefore, the design dimensions of the structure are 1.2 x 1.0 x 0.8 m.

2.2 Construction of storage structures

Four storage structure configurations (**A, B, C and D**) each with three replicates were constructed. **Type A** has slated sides and bottom to allow all sides ventilation, **Type B** has slated side and bottom with aspirator to extract heat and moisture, **Type C** has covered sides (up to 80%) and bottom with forced aeration (with solar powered blower) and **Type D** has covered sides (up to 80%) and bottom with natural aeration. The different structure configurations are shown in Figures 1 to 4.

Figure 1: Type A

Figure 2: Type B (with aspirator)


Figure 3: Type C (with blower)


Figure 4: Type D (without blower)

The study site was the technology garden of Nigerian Stored Products Research Institute (NSPRI), Ilorin. The randomization was done in Python® (Table 1) to ensure the storage structures were randomly arranged on the project site.

Table 1: Arrangement of storage structures

D_1	B_2	C_2	D_3
B_1	C_1	A_2	B_3
A_3	D_2	C_3	A_1

2.3 Procurement and storage of onions

Thirty 100 kg bags of Sokoto variety onions were purchased from Sokoto State. The onions were packed in jute bags and transported using an open truck to NSPRI. Onions were cured by spreading on the floor in a well-ventilated room. Rotten and sprouted bulbs were removed from the lot. The curing was done at average ambient temperature of 29˚C and relative humidity of 73% for a period of two weeks.

Bulk storage method was adopted for the study. Each of the 12 structures were filled with 240 kg onion bulbs. Ninety-six net bags were filled with onions, weighed and tagged for destructive sampling. Twelve of the bags were randomly placed in each structure. This was applicable to two of the structures of a particular configuration, while the third replicates were loaded without samples in net bags. The third replicates were put in place to give room for monthly separation of unwholesome onions from the lot to prevent contamination.

2.4 Sampling of onions and monitoring of environmental conditions

Destructive sampling was done by removing two net bags from each structure while bulk sampling was carried out by removing the whole lot. The samples were sorted (rotting and sprouting), counted and weighed and used for physical and chemical quality (weight loss, % sprouting, % rotting, moisture content, total soluble solid and pungency. Sampling was carried out monthly.

Percentage weight loss (% WL) was estimated using Equation 1:

$$\% \text{ WL } = \frac{W1-W2}{W1}\ x\ 100 \qquad (1).$$

where, W_1 is the initial weight of sample and W_2 is the weight at sampling.

Percentage sprout was determined using Equation 2:

$$\% \text{ Sprout } = \frac{No\ of\ Sprouted\ Onions}{Total\ No\ of\ onions\ in\ the\ bag}\ x\ 100 \quad (2).$$

Percentage rot was determined using Equation 3:

$$\% \text{ Rot } = \frac{No\ of\ rotten\ Onions}{Total\ No.of\ Onions\ in\ the\ Bag}\ x\ 100 \quad (3).$$

All chemical qualities were determined according to AOAC (2005).

Temperature and relative humidity within the stored onions and ambient were monitored during the storage using Temtop® data logger and Kestrel® weather station.

3.0 Results

3.1 Air temperature and relative humidity inside and outside the storage structures

The mean temperature and relative humidity in the storage structures and ambient are shown in Figure 5. Steady decrease in temperature were observed in all structures from the first to third month of storage (June to August) while there was a rise in temperature in the following month (September) (Figure 5 A). This may be due to rainfall pattern experienced during this period. The lowest average temperature was recorded in Structure B (25.7 ˚C). The temperature recorded in all the structures (25.4 – 27.0 ˚C) were within the recommended storage temperature (25 – 30 ˚C) for onions by FAO (2003). Relative humidity in all the structures and ambient increases for the first three months (June to August) of storage (Figure 7 B). However, while relative humidity in structure A and D decreased by 3 %, it increases marginally in structure C and was steady in structure B. The recorded relative humidity in all the structures after the third month were above the limit (75 – 85%) as recommended by FAO (2003).

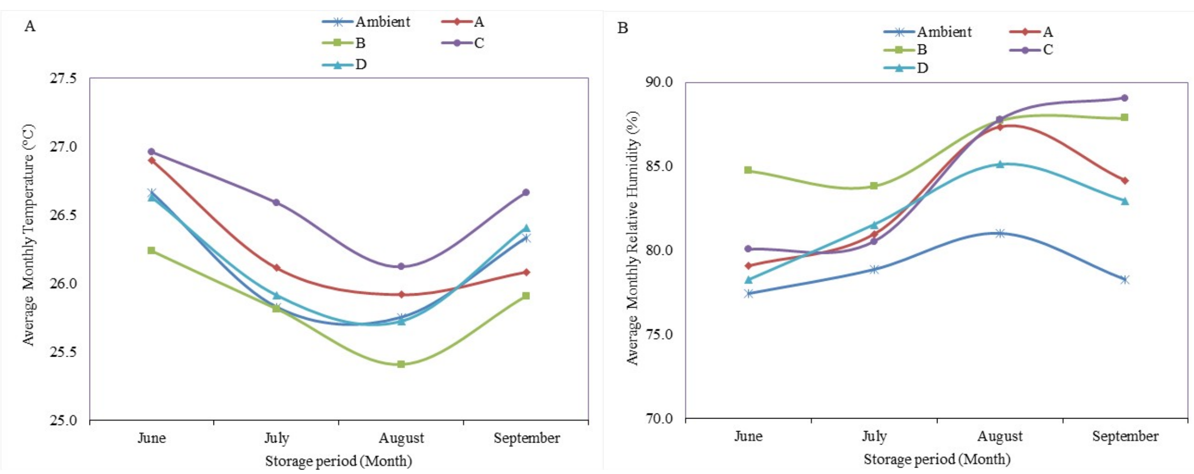

Figure 5: Averaged monthly temperature (A) and relative humidity (B) of the structures and ambient.

3.2 Weight loss of the onion bulbs during the storage period

The mean weight loss recorded during the storage period in all the structures are presented in Figure 6. Weight loss increased with storage period in all the structures. Weight loss in all the structures were not significant different ($p<0.05$) during the first month (May to June). However, weight loss in structure A and D were significantly higher than in structure B and C during the first three months of storage ($p<0.05$). The lowest weight loss was recorded in structure C and the highest in structure B. The observation could be linked to respiration and water loss of the onion during the storage period (Hansen, 1999).

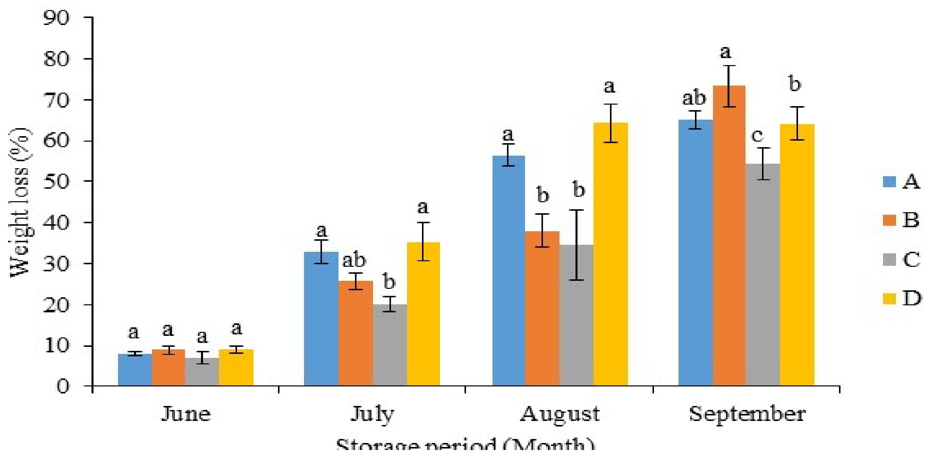

Figure 6: Percentage weight loss of onion bulbs during the storage period

3.3 Effect of storage structures on rotting

No significant differences were observed in the quantity of rot onions after the first three month of storage ($p<0.05$) (Figure 7). However, quantity of rot onion in structure D was significantly higher than the others after four months. The high percentage rot recorded in structure D is attributed to poor aeration in the structure.

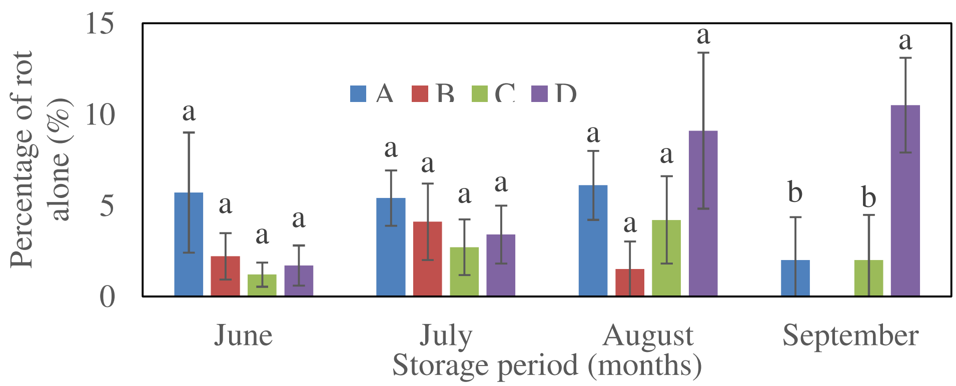

Figure 7: Percentage of rotten bulbs

3.4 Effect of storage structures on sprouting

Sprouting increased in all structures over the storage period as shown in Figure 8. Sprouting observed in the structures were not significant different after the first two months ($p<0.05$). At the end of the storage period sprouting recorded in Structure C was significantly lower than other structures ($p<0.05$). This result is in agreement with Petropoulos *et al*. (2016) that reported sprouting as one of the major factors responsible for losses in onion during long-term storage.

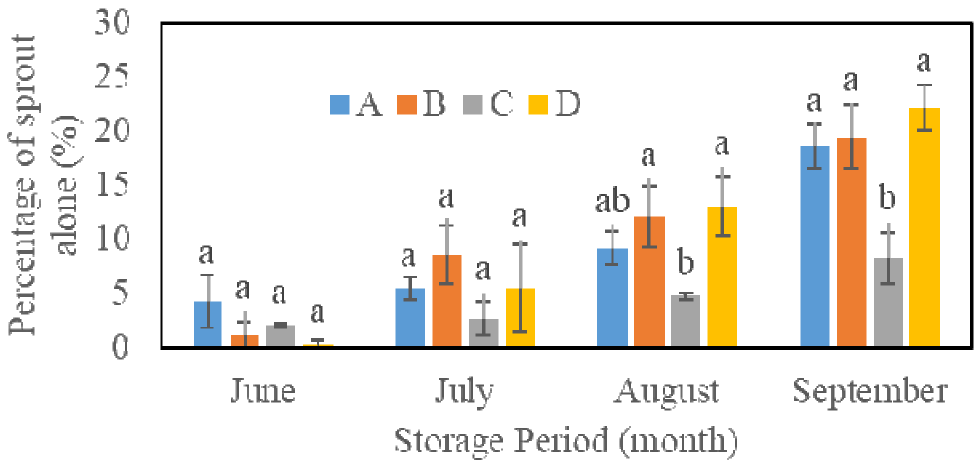

Figure 8: Percentage of sprouting bulbs

3.5 Effect of the storage structures on moisture content

The effect of different storage structures on the moisture content (MC) of the onion bulbs throughout the storage period are presented in Table 2. After one month of storage, MC in all the structures reduced by about 6.5%. In the second month, structure A and B had significantly higher MC compared to C and D ($p<0.05$). Observed values of MC reflected the level of aeration in the structures. However, the higher MC recorded in structure D compared to other structures could be as a result of limited aeration and high relative humidity in the structure.

Table 2. Moisture content (%) of the onion in each of the structure during the storage periods

Structures	Initial	June	July	August	September
A	93.00 ± 0.01^{a}	87.31 ± 0.57^{ab}	87.36 ± 0.23^{a}	82.67 ± 0.32^{a}	74.49 ± 0.32^{c}
B	93.00 ± 0.01^{a}	86.27 ± 1.05^{b}	87.99 ± 0.22^{a}	80.96 ± 0.79^{b}	76.61 ± 0.82^{b}
C	93.00 ± 0.01^{a}	87.73 ± 0.44^{ab}	86.07 ± 0.30^{b}	78.47 ± 0.16^{c}	78.99 ± 0.13^{a}
D	93.00 ± 0.01^{a}	88.75 ± 0.44^{a}	85.57 ± 0.27^{b}	75.34 ± 0.29^{d}	80.18 ± 0.35^{a}

Note: Means ± S.E. values with different letters within a column differ significantly ($p<0.05$)

3.6 Effect of the storage structures on pungency of the onion bulbs

The results of pungency and minerals contents of the onion bulbs at the end of the storage period are presented in Table 3. Pungency was significantly higher in samples stored in structure A compared to other structures ($p<0.05$)

at the end of the four months (Table 3). In addition, pungency reduced by 29%, 33%, 33% and 34% in structures A, B, C and D respectively.

Table 3: Pungency of the onion bulbs in each structure during the storage months

	Pungency (Pyruvic acid) (μmol/g)	
Structures	**Initial**	**Final**
A	88.45 ± 0.17^{a}	62.70 ± 0.14^{a}
B	88.45 ± 0.17^{a}	59.16 ± 0.11^{b}
C	88.45 ± 0.17^{a}	59.30 ± 0.11^{b}
D	88.45 ± 0.17^{a}	58.79 ± 0.08^{b}

Note: Means ± S.E. values with different letters within a column differ significantly ($p<0.05$)

3.7 Effect of the storage structures on total soluble solids of the onion bulbs

Table 4 presents the TSS of onions stored in all structures throughout the storage period. TSS increased with storage time in all the structures. The percentage increases were 62, 73, 68 and 53% in A, B, C and D respectively. This result corroborates the findings of Woldetsadik and Workneh (2010) who reported increase in TSS of onions at the early stage before the end of dormancy period during storage.

Table 4: Total soluble solids content (°Brix) of the onion in each structure during the storage periods

Structure	Initial	June	July	August	September
A	9.27 ± 0.01^{a}	12.07 ± 0.49^{bc}	13.16 ± 0.55^{ab}	14.63 ± 0.57^{ab}	15.05 ± 0.58^{ab}
B	9.27 ± 0.01^{a}	14.97 ± 0.86^{a}	14.63 ± 0.77^{a}	15.61 ± 0.72^{a}	16.07 ± 0.77^{a}
C	9.27 ± 0.01^{a}	12.87 ± 0.30^{b}	13.49 ± 0.35^{ab}	14.98 ± 0.34^{ab}	15.56 ± 0.36^{ab}
D	9.27 ± 0.01^{a}	11.23 ± 0.20^{c}	12.16 ± 0.18^{b}	13.71 ± 0.16^{b}	14.16 ± 0.15^{b}

Note: Means ± S.E. values with different letters within a column differ significantly ($p<0.05$)

4.0 Conclusions

All recorded temperature and relative humidity in the structures were within the recommended values for high temperature storage with the exception of the upper limits of relative humidity within the structures which were slightly higher. Structure C recorded the lowest physiological weight loss and the least loss due to sprouting and rotting at the end of the storage. Due to limited aeration in structure D, there was consistent temperature increase and high relative humidity which encourage microbial activities and is reflected in high percentage of rotting observed in the structure. Structure C reduced sprouting considerably after 4 months. However, as the aim of the experiment is to reduce losses there is a need to modify the structure to achieve the desired weight loss.

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EVOLUTION OF THE THERMAL EFFUSIVITY OF A PRE-TREATED GINGER SLICE IN NATURAL CONVECTION SOLAR DRYER

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Abstract

The objective of this research is to evaluate the influence of blanching on the thermal effusivity of solar dried ginger rhizomes. For this reason, a natural convection solar dryer was assembled and used to dry the blanched and un-blanched 5 mm thick ginger rhizomes slices. Drying took 13 – 16 h to reach equilibrium moisture at a solar radiation intensity of 108 to 635W/m^2. The determined thermal effusivity was in the range of 22.65 to 46 .41 W · S$^{1/2}$ · m^{-2} · K^{-1} for blanched and un-blanched ginger rhizomes at a moisture content of 7.8 to 82.14 %. The very low value of thermal effusivity showed that the drying product can act as a heat sink with the implication of delayed rewetting impact during off-sunshine periods during solar drying.

1. Introduction

The interest generated by greenhouse gas emissions due to the global consequence on the environment has made renewable energy-dependent dryers mostly advocated (Simo-tagne et al., 2019; Ndukwu et al., 2018 a; Nwakuba et al., 2020). In most sub-Saharan African countries, the populaces are subsistence farmers and traders combined. So, they divide their time into going to the farm, processing their farm product and going to the market to sell (Ndukwu et al. 2010). Therefore, the predominately used sun drying methods to dry their product becomes cumbersome for them due to adverse weather condition that makes sun drying require constant attention (Ndukwu et al., 2020a). The reason is that they are required to protect the drying product from occasional rain, pests and rodent attacks. Hence alternative drying methods that will satisfy the drying needs and protect the environment are needed. Among these methods, solar drying is mostly used due to ease of fabrication and cost management (Ndukwu et al., 2020 b, 2021a and 2022 a). Solar drying has the advantage of capacity management based on the size of the enterprise and the locally available material for design (Hawa et al., 2021). Therefore, several designs are available in the literature ranging from indirect, mix-mode and hybrid solar dryers (Langayat et al., 2020; Ndukwu et al., 2018b and 2021b; Nwakuba et al., 2017). They come in active and passive modes. The active mode solar dryer requires a fan or blower to drive the air movement. However, these components add to the cost of the fabrication. Passive solar dryers are cheaper but might take a longer time to accomplish the drying process. However, most solar dryers encounter rewetting of the product at some point depending on the weather condition, especially at the night (Ndukwu et al., 2017). Thus, supplementary energy sources might be required to assist in the drying during off-sunshine periods (Ndukwu et al., 2022 b). Management of this supplementary energy is important to avoid energy wastage which will add to the cost of drying. The rate at which the drying product losses heat to the surrounding will affect the heat retention and the temperature of the air around it. A product that losses heat more rapidly will have the tendency to be cooler quicker and attracts moisture back itself (Ndukwu et al., 2022 c). Hence requires a supplementary heater quicker than the product that retains heat. Therefore, there is a need to understand the thermal effusivity of drying crops in solar drying to gain this knowledge. The thermal effusivity or inertia can be also referred to as the delay factor or conductive capacity. It is a material property that determines the rate the heat absorbed by the product receiving heat is lost to the surrounding air (Jayalakshmy and Philip 2010). This property is inversely related to the thermal impedance. The crop receiving heat during drying will be at a higher or equal temperature to the surrounding air temperature (Ndukwu et al., 2022 d). When the heat source stops, the heat absorbed by the crop will be gradually released (effused) to the ambient air until thermodynamic equilibrium is reached with the surrounding air. The ease of occurrence of this phenomenon determines how quick the product cools and the speed at which the product re-attracts moisture (rewetting). Knowledge of this will help to give an idea of how to manage any additional heat supply. The lower the thermal effusivity, the longer the product surface temperature will take to be thermodynamically at equilibrium with the surrounding temperature (Jayalakshmy and Philip, 2010). Furthermore, the blanching of crops helps to kill the microbes, evacuates moisture from the pores and inactivates the enzymes that produce off-flavours for processed products (Wang et al., 218; Reshmi et al., 2018). Hence blanching has been adopted for much industrial food processing. Therefore, the objective of this research is to empirically study the thermal effusivity evolution characteristics of blanched and un-blanched ginger slices during solar drying process.

2. Materials and Methods

2.1 Description of solar dryer

The solar dryers used for the research are presented in Figure 1. The dryer was designed and fabricated at the Michael Okpara University of Agriculture, Umudike, Abia State. It is an indirect solar dryer with a collector and drying chamber made from plywood. The collector tilted at an angle of 15.47^{O} southward has dimensions of 0.79m x 0.18m x 0.16m with the absorber made of black painted aluminum plate. Copper tubing was coiled from the collector to the drying chamber to assist in heat conduction from the collector to the drying chamber. Two drying trays of 0.30m x 0.35m at a separation distance of 0.22 m from each order were fixed into the drying chamber. Air conveyance through the collector is by natural convection.

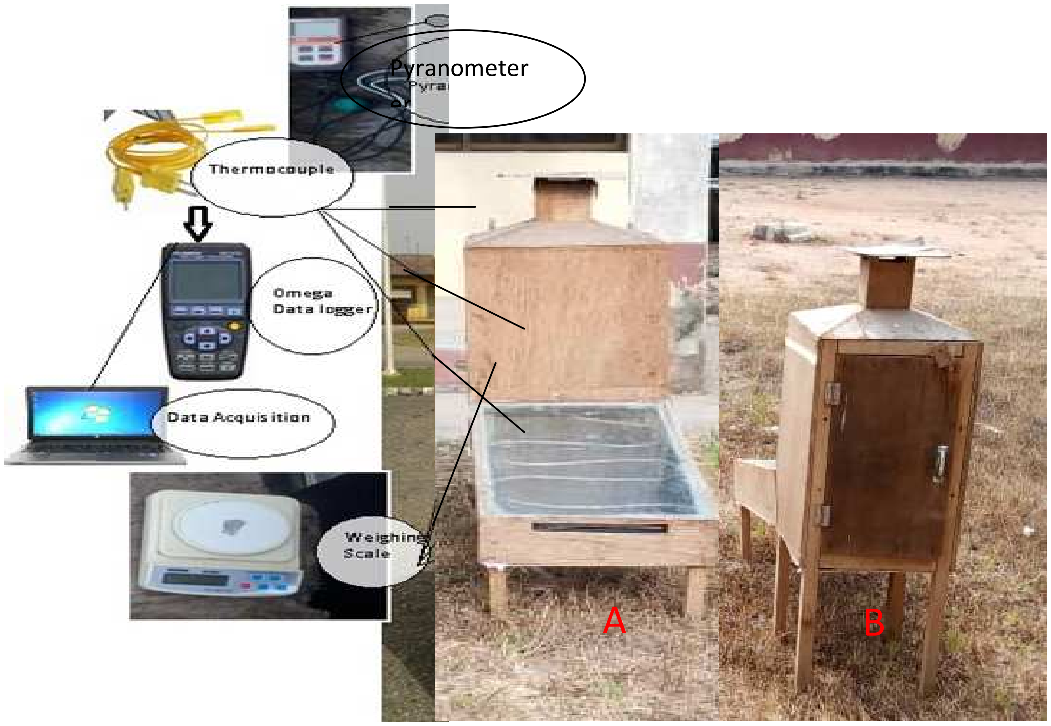

Figure 1: Picture of the solar dryer showing the instrumentations: (A) front view and (B) back view.

2.2 Experimental procedure

The ginger rhizomes used for the experiment were purchased from the local market. The rhizomes were cleaned, washed and sliced into cuboid shapes (12 mm x 10 mm x 5 mm). The sliced ginger rhizomes were blanched in hot (80 ^oC) water inside the water bath for 60 and 90 seconds before allowing it to cool in cold water. Three representative samples of the blanched and un-blanched ginger were placed on the drying trays and allowed to dry to constant mass. Air temperature and relative humidity were measured at three points in the drying chamber and solar collector using the temperature and humidity clock (DTH-82; TLX, Guandong China) and thermocouple connected to a data logger (Omega Stanford USA, HH1147, sensitivity, ± 0.1^{o}C and ± 1 %) while the temperature of the product was measured using EXTECH digital UEi thermometer with a probe (PDT650 made in China). The solar radiation intensity was recorded using an APOGEE pyranometer (Model mp.200, serial number hash 1250 with accuracy of ± 1 W/m^2/day). The weights of the ginger rhizomes were measured with a scale (KERRO model, accuracy of ± 0.01 g).

2.3 Evolution of thermal effusivity

The thermal effusivity depends on the specific heat capacity and thermal conductivity of the material. It is given as follows (Jayalakshmy and Philip 2010):

$$\partial = \sqrt{k\rho_a C_p} \qquad (1)$$

Where C_p is the specific heat capacity and k is the thermal conductivity. The specific heat capacity and thermal conductivity as a function of varying moisture content (X) of food material in solar dryer are given in Equations 2 and 3, respectively as follows (Ndukwu and Bennamoun, 2018b)

$$C_p = 837 + 33.5X \quad (2)$$

$$k = 0.49 - 0.44e^{-0.206X} \quad (3)$$

The moisture evolution of the sliced potatoes was deduced with Equation 4

$$X = X_i - \frac{W_i - W_t}{W_i} \quad (4)$$

3. Result and Discussion

The solar dryer used for the experiment is a natural convection solar dryer. Therefore, the airflow through the collector and drying chamber is controlled by the ambient wind condition. Due to the simplicity of design, this is the most common solar dryer in most developing countries. The temperature and relative humidity evolution of the solar dryer is shown in Figures 2 and 3, respectively. The collector was able to increase the temperature of ambient air in the range of 0 – 9.3 ^oC with an average value of 2.8^oC as the solar radiation intensity varies from 103 to 635 W/m^2 within the period with an average value of 366W/m^2 as shown in Figure 2. The collector was also able to remove moisture from the ambient air as the relative humidity of ambient air decreased in the range of 0 to 16 % with a mean value of 3.5 %. This showed a good transient response of the solar collector to temperature increase.. Figure 4 also showed that 30 seconds blanched ginger dried faster than 60 and 90 seconds while the longest drying time to reach equilibrium drying condition was for un-blanched ginger. While blanching can evacuate the air from the pores and quicken moisture movement to the surface for evaporation as seen in 30 seconds of blanching and un-blanched ginger but a longer period of blanching might lead to moisture absorption which explains the longer period of drying for 60 and 90 seconds compared to 30 seconds blanching. Overall, it took 13 to 16 h to dry the pre-treated and untreated ginger with the natural convection solar dryer under Umudike environmental conditions.

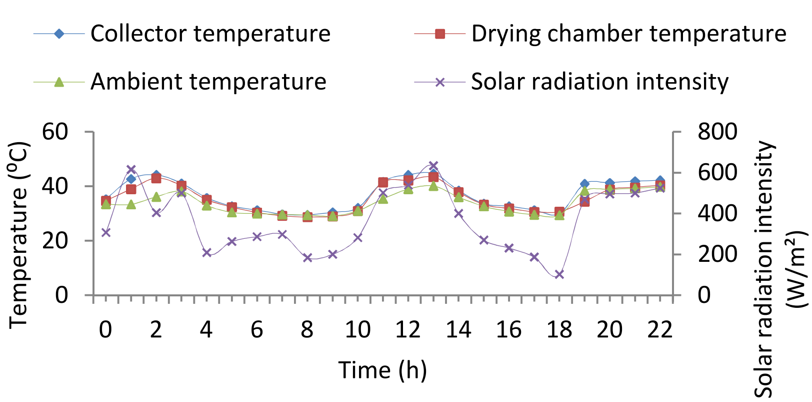

Figure 2: Temperature and solar radiation intensity evolution of the solar dryer

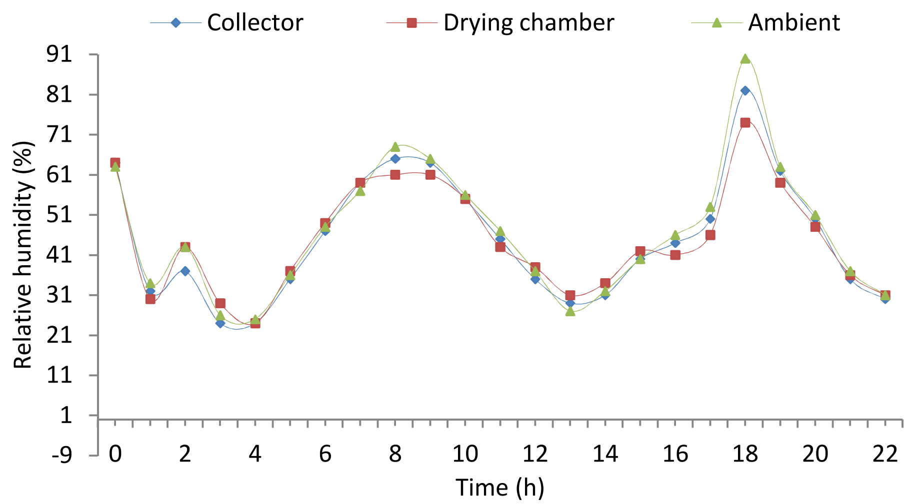

Figure 3: Evolution of the relative humidity

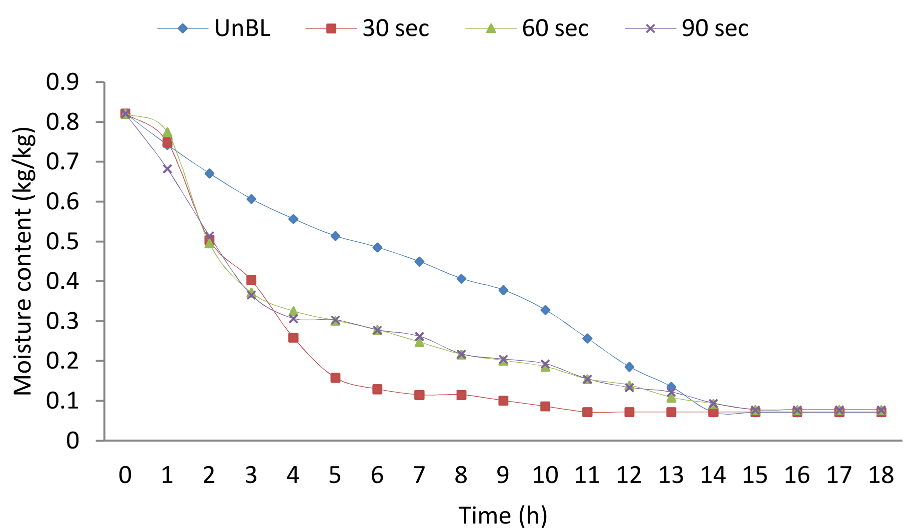

Figure 4: moisture content variation with time

3.1 Evolution of thermal effusivity:

Figure 5 showed the plot of the variation of thermal effusivity with moisture loss during drying. The Figure showed that thermal effusivity increased with moisture increased or decreased with a decrease in moisture loss. The thermal effusivity values determined empirically ranged from a minimum value of 22.65 - 23.20 $W.S^{1/2}.m^{-2}.K^{-}$

[1] to a maximum value of 46.41 $W.S^{1/2}.m^{-2}.K^{-1}$ for initial moisture content. Generally, moisture effusivity was highest for un-blanched and lowest for 30 seconds blanched. as shown. This value is lower than other materials with known standard thermal effusivity like fresh leaves (675W · $S^{1/2}$ · m^{-2} · K^{-1} to 750W · $S^{1/2}$ · m^{-2} · K^{-1}) and water (1600W · $S^{1/2}$ · m^{-2} · K^{-1}), but it is higher than that of agricultural soil (1.38 -4.01 W · $S^{1/2}$ · m^{-2} · K^{-1}). The lower value of the thermal effusivity showed that it will take a longer time for the product to lose absorbed heat and equilibrate with the surrounding. This showed that ginger rhizomes can act as a heat sink during drying. Hence during off-sunshine hours, it will take a longer time to effuse its heat before it can allow rewetting to occur. The lower the thermal effusivity value, the longer the surface temperature will take to equilibrate with the surrounding temperature thermodynamically. The obtained results can help during the modelling of the heat transfer process in the drying chamber. A multiple regression equation of moisture content with the thermal effusivity is presented in Equations 5-8, respectively. The effusivity equations are described by polynomial functions of the second order with R^2 values ranging from 0.94 and 0.99, respectively. The values illustrate a strong correlation with thermal effusivity parameters (as stated in Eq. 1).

$\partial = 94.4\,X - 75.35\,X^2 + 17.49$ $R^2 = 0.94$ (5)

$\partial = 38.84\,X - 4.25\,X^2 + 18.17$ $R^2 = 0.94$ (6)

$\partial = 52.07\,X - 23.72\,X^2 + 19.81$ $R^2 = 0.94$ (7)

$\partial = 54.91\,X - 30.6\,X^2 + 19.67$ $R^2 = 0.99$ (8)

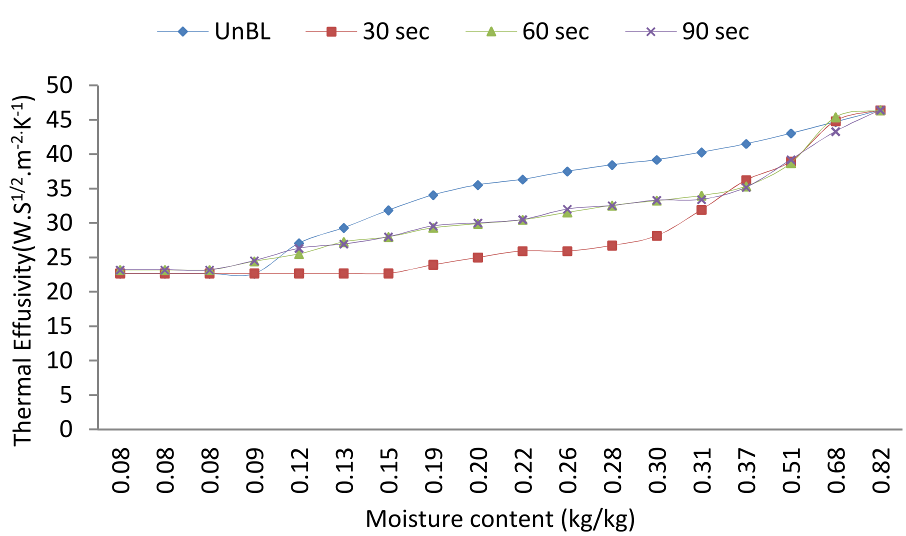

Figure 5: Evolution of the thermal effusivity with moisture content

4. Conclusion

The thermal effusivity of ginger rhizomes pre-treated by blanching in hot water at different time intervals was studied using a natural convection solar dryer. Drying of the various pre-treated ginger rhizomes slices took 13-16 hours to attain equilibrium moisture content under the variable external drying conditions of Umudike South Eastern Nigeria. Thermal effusivity was determined as secondary data from moisture loss data and the obtained values decreased with moisture content as the product dries. The values obtained are very low ranging from 22. 65 to 46.41 $W \cdot S^{1/2} \cdot m^{-2} \cdot K^{-1}$. This showed that crops can act as a heat sink during drying. The polynomial functions showed a high level of association between the moisture content and thermal effusivity with R^2 values of 0.94 to 0.99

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DESIGN MODIFICATION AND PERFORMANCE EVALUATION OF CASSAVA MASH MACHINE WITH RECIPROCATING PADDLES

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Abstract

A machine for gari frying was designed, fabricated and tested. The major component of the machine includes the base fryer, hopper, paddle, shaft, frame, driving mechanism and discharge outlet. The machine is powered by a three-phase (20rpm-100rpm) 1.41kw electric motor (variable speed reduction gear motor) connected to the mains through a control box which controls the movement of the wooden paddles to a reciprocating system. Electricity was used as a source of heat energy required for the gari frying. The time of frying sieved cassava mash was evaluated at four different operating speeds of wooden paddles (10rpm, 20rpm, 40rpm, 60rpm), and three different quantities of mash (5kg, 7.5kg, 10kg), also change in mash temperature and trough temperature with time was evaluated. The optimum speed for the fryer was 20rpm which gave gari of 12.2% final moisture content from the initial moisture content of 40.2% at the twenty-four minutes of frying while frying temperature was 118^0C using electricity as source of heat energy. The throughput capacity and functional efficiency evaluated at an optimum operating speed of 20rpm were 71.6% and 19.7kg/hr respectively. The product (that is gari) obtained at the end of operation was good for human consumption. The two main aims of frying gari (called Garification) were achieved, that is the safe cooking and the reduction of moisture content (MC) to a storage level. The machine can be used by the small and medium scale farmers and it can complement emerging mechanized methods of cassava processing which include: washing, peeling, grating, dewatering, fermenting, press and sieving.

Keywords: Cassava mash, design modification, reciprocating paddle, efficiency evaluation, moisture content, temperature

1. Introduction

Cassava (Manihot esculent a) is a starchy root crop which is an important source of food energy. Cassava belongs to the family of Euphorbiaceous. The two main species of cassava are *Manihot utilissima* (bitter cassava) and *Manihot palmata* (sweet cassava). It has underground roots which can be consumed by man and livestock after processing. Nigeria is the highest cassava producer in the world. Its production was estimated at about 95 million tonnes in year 2013 (Akinbolade, 1986). The total land area cultivated under cassava in the year 2013 was about 3 million hectares. Cassava roots can remain in the ground for up to 24 months (some varieties last up to 36 months), processing or other conditions are favorable. It can grow on marginal lands where cereals and other crops do not grow well. It can tolerate drought and it can grow in low-nutrient soils. In Nigeria, cassava is traditionally peeled and soak for 3 or 4 days, after soaking, dewatering and heated with water twice and pound to make fufu. Another method of processing cassava is by garification through frying.Processing is important because cassava varieties contain cyanide compound and inadequate processing can lead to chronic toxicity

(FAO, 1989). Thus, good processing of cassava will reduce the level of cyanide in cassava and improve its palatability. Processed cassava products are also used as raw materials for a number of medium scale industries in Nigeria (Hahn, 1995). Igbeka (1995) reported that the best quality gari is obtained by local technique, but it is time consuming, uncomfortable and may cause health for the operator.

Efforts should be made to mechanize the garification operation for large scale processing without losing sight of improving the local method. The improvements in garification should be in the areas of ergonomics (sitting position, comfortable work environments and health hazards). Igbeka (1993) carried out studies on the ergonomics of Nigerian women in gari frying. The factors investigated were the comfort, fatigue and arm-reach of the operators as they affected the efficiency of operating three types of traditional gari fryers. It was found that the sitting posture and exposure to excessive heat were the twin factors that affected the arm-reach and comfort of the operator, respectively. Improved designs that reduced heat and changed sitting posture were found to increase efficiency. The objectives of this research therefore are to carryout design modification of cassava mash frying machine with a reciprocating paddle; and evaluate the performance of the modified cassava mash frying machine.

2. Materials And methods

2.1 Principle of Operation

The machine is shown in figure 1, which can complement other machines used in gari processing operation. The trough is thoroughly clean before any operation after which a set of heating element (electric heating plates) is arranged under the trough which is the heat source. This is allowed to heat up for about 10 minutes. The wet mash of known moisture content was put into the upper chamber and the power was switched on, as soon as the power was on, the stop watch was also started. The paddles reciprocated at 50 revolution per minutes while the gari mash is being swept along the length of the trough from one end to the other end.

The reciprocating motion of the paddles allows the simultaneous stirring, pressing and toasting of the mash while starch gelatinization occurs as it moves down towards the outlet. However, the angle of inclination of the frying trough, the intensity of heat in the trough and the initial moisture content are taking into consideration. Plate 1 below shows the gari fryer.

2.2 Design Considerations

In the design of the gari fryer, the following requirements were considered:

i. The strength of the construction materials should withstand the forces acting in the various component's parts of the machine.
ii. Stainless steel would be selected to ensure product quality.
iii. The machine should have higher capacity compared to traditional method of gari fryer.

iv. The machine should reduce the labour requirement drudgery involved in the traditional methods of gari fryer.
v. The simplicity and flexibility of the machine should suit the targeted users

2.3 Design Calculation and analysis

The design calculation required for the Fabrication are listed below.

2.3.1 Determination of Hopper Capacity

The hopper was designed to contain 10 kg of cassava mash at a time and the hopper capacity of the machine is calculated as 0.01470456 m^3 using equation 1.

$$\text{Volume of the hopper} = \frac{A_1H - A_2h_2}{3} \quad (1)$$

2.3.2 Determination of Base fryer Capacity

The capacity of the base fryer is computed as 0.1534 m^3 using the formula below:

$$\text{Volume of Based Fryer} = \frac{volume\ of\ cylinder}{2} \quad (2)$$

$$\text{Volume of cylinder} = \pi^2 h \quad (3)$$

2.3 Determination of Shaft Diameter

The value of calculated shaft diameter is 22.0 mm, but a shaft of 25 mm was chosen. Equation 4 shows the formula Hall et al. (1990)

$$D^3 = \frac{16}{\pi S_S} \quad (4)$$

Where D is the diameter of shaft, K_b is the combined shock and fatigue factor, applied to bending movement, K_t is the combined shock and fatigue factor applied to tensional moment, M_b is the resultant bending moment, M_t is the resultant tensional moment, and S_s stand for Shaft constant given from standard table as 55 MN/m^2. To calculate the torque acting on the shaft, use equation 5:

$$M_t = \frac{\text{power transmitted x 60}}{2\text{x}\pi\text{x}Nb} \quad (5)$$

To evaluate speed of machine shaft (N_b) mathematic model written in Equation 6 was adopted

$$N_b = \frac{N_a d_a}{d_b} \quad (6)$$

Where d_b is the Teeth of the driver sprocket (attached to electric motor), N_a is the Speed of the driver sprocket (speed of electric motor), d_b is the Teeth of the driven sprocket (attached to the machine shaft), N_b stands Speed of the driven sprocket (Speed of machine shaft)

From formula: $N_a d_a = N_a d_b$

$$N_b = \frac{N_a d_a}{d_b} \quad (7)$$

2.4 Materials Selection for Components

The materials selection for gari frying machine components and the reasons for selecting them is as shown below:

2.4.1 Determination of Base Fryer Capacity

The capacity of the base fryer is calculated using the following dimensions: Length of plate = 2440 mm, Diameter of the chamber = 400mm, Breath of the plate = πd = 1,256.8 mm. The length and breathe of the 2mm thickness stainless sheet was then rolled to from a semi-circular trough, which from the base fryer.

$$\text{Volume of Base Fryer} = \frac{volume\ of\ cylinder}{2} \quad (8)$$

$$\text{Volume of cylinder} = \pi r^2 h \quad (9)$$

Radius and height of each paddle are 200 mm and 2,440 mm respectively

$$\text{The approximate volume between each pitch of the paddle} = \frac{Total\ volume}{Number\ of\ paddles} \quad (10)$$

2.4.2 Improvement done on the fryer over the previous design done by Ajayi and Olukunle, 2010

The areas of improvement over Ajayi and Olukunle, 2010 are in the design of the frying trough, the Sweeping paddle, the driving mechanism and on the distribution of heat. The major improvements done on the existing gari fryer were on the mentioned areas. The frying trough was redesigned by solving three major problems, which are, the mild steel material used to build the trough was changed to stainless steel, the efficiency of the sweeping paddles was improved.

2.5 Machine Fabrication and Assembly

The machine was fabricated in the Agricultural Engineering Departmental Workshop of the Federal University of Technology, Akure in Ondo State, Nigeria.

The procedure involved the following steps;

i. Construction of the base/frame

ii. Forming and bending of the trough

iii. Construction of the paddles

iv. Construction of the hopper

v. Construction of the upper chamber

vi. Construction of the discharge outlet.

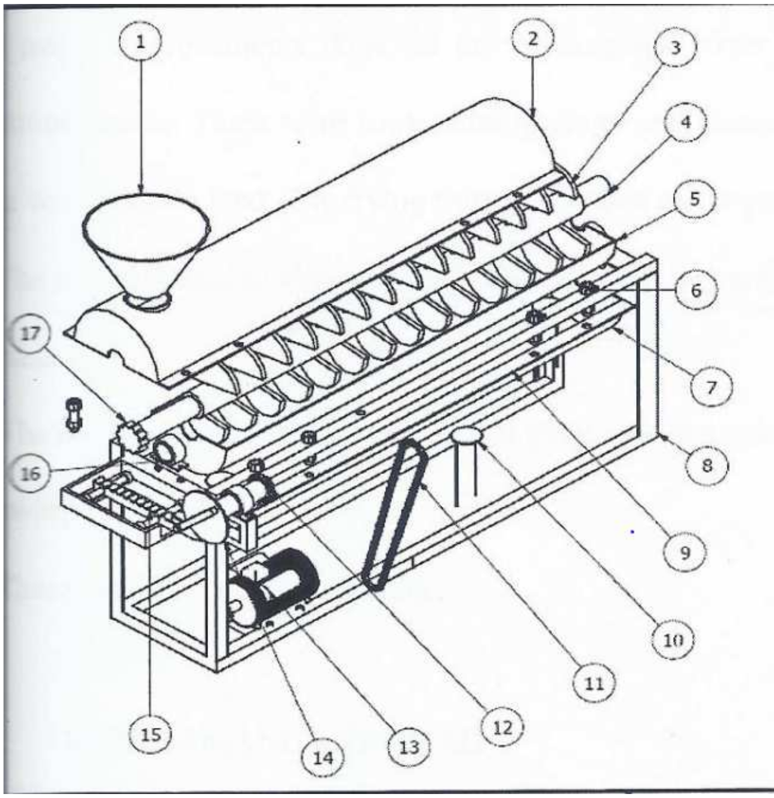
The assembly of the machine started by welding the base fryer framed with angle iron to the main frame (mounting support) of the machine. The wooden paddles mounted with fire bar was attached to the shaft and placed inside the trough. The shaft was then affirmed to the frame of the machine with bearings. The fabricated hopper was welded to the right side of the upper chamber and attached to the base fryer (lower chamber) with hinges. Discharge outlet was welded to the exit created at the lower left side of the base fryer. The trough is double walled with 40 cm lagging material (thermal conductivity k = 0.4 W/mk) which is to insulate and retain heat in the base fryer. The electric motor was mounted on the support attached to the main frame of the machine which transmits power to the shaft through sprocket and chain system to an arrangement of a rack and pinion gear system that converts the rotational motion of the sprocket to a reciprocating motion of the paddles. The electric motor was connected to electricity through the control box. Plate 2 shows the machine during testing.

2.6 Description of the Developed Gari Fryer

The fryer consists of a 400 mm diameter, 2440 mm length of 2 mm stainless steel sheet which houses 14 paddles arranged in two sets on a 2460 mm long shaft. The trough is folded into a semi-circle and mounted at an axial inclination that may be adjusted between 0° and 10° to the horizontal level. The movement of the paddles acts as a conveyor as it reciprocates in movement, this move the gari mash along the trough. The final dried product is collected at the end of the trough. The drive mechanism of the machine consists of 5.0 horsepower three phase electric motor through speed reducer with 1400 rpm, transmitting power to a 17.2 cm sprocket through a chain. A sprocket, 6.5 cm diameter transmits the power to another 17.2 cm sprocket, these two sprockets of diameter 17.2 cm act as speed reducer. Through a crank arrangement and a rack *and* pinion gear system, the power is transmitted to the shaft that carried the paddles. The paddles overlap and are angled relative to the axis of the trough to act as a sort of conveyor. The paddles swing from the side through 180° at 50 revolutions per minutes. As these paddles oscillate, the gari mash moves from one end to the other.

2. 7 Performance Testing

Frying cassava mash from original moisture content to final moisture content was carried out by pouring the cassava mash of 40.2% initial moisture content and mass of 10kg through the hopper into the fryer (Plate 2). The trough was heated using heating element through the help of electricity as a source of energy and the temperature was determined through the use of digital probe thermometer. The cassava mash gelatinizes while being moved over the heated Surface of the metal trough and the gelatinization occur at a temperature between 65° C - 85° C. The paddles are arranged at angle 45° as shown in Figure 1. The paddles convert the rotational motion of the sprocket system to a reciprocating motion sweep, the gelatinizing mash from the trough wall to prevent sticking, burning and also break the lumps that formed during gelatinization. The paddles also move the mash towards the end of the base fryer (exit) with the help of transmission processing and electric circuit to control the temperature of the machine. As the moisture content reduces and most of the small lumps developed have been broken down by constant pressing and agitation, the mash was further cooked and dehydrated as the intensity of peat is increasing. The extent of drying depends on the increase in temperature and the period of frying. Plate 3 shows the electrical component of the fryer. Indeed, all the starch granules gelatinized during the cooking stage before drying commences at slow rate. The product (gari) was then collected at discharge outlet of the trough shown in Plate 4.



PARTS LIST		
ITEM	QTY	PART NAME
1	1	hopper
2	1	upper trough
3	14	paddle
4	1	shaft
5	1	fibre glass
6	10	bolt&nut
7	1	outlet chute
8	1	frame
9	1	lower trough
10	3	heating element
11	1	chain
12	1	sprocket
13	1	electric motor
14	1	cam
15	1	rak
16	1	bearing
17	1	pinion

Figure 1: Exploded View of the Gari Fryer Showing the Component Parts

2.8 Experimental Procedure

2.8.1 Sourcing of Material for Performance Test

The main material used is the fermented sieved cassava mash which was obtained after a series of operations on the cassava tubers. These operations include peeling of the tubers, washing, grating, dewatering, fermentation and sifting. The cassava mash was obtained from a local gari production factory in Shagari village, Akure. A very small quantity of the fermented sieved cassava mash (30g) was poured into the fryer after taking its moisture content which was determined by oven dried method. The final weight was taken when the product was cooled down inside a desiccator, the moisture content was obtained on wet basis as:

$$MC = \frac{W_o - W_f}{W_o} x100\% \qquad 11$$

Where, MC is the moisture content (wet basis) (%), W_o stands for weight of wet mash, (kg), W_f stands weight of the dried mash, kg

2.8.2 Performance Evaluation

Parameters such as moisture content, temperature, machine efficiency and through-put capacity were evaluated. Akinyemi and Akinlua (1999) defined throughput capacity as the ratio of the quantity of gari collected from the machine to the time taken.

$$T_c = \frac{W_s}{T} \qquad 12$$

Where, T_c is the Throughput capacity, kg/hr, W_s is mass of gari collected, (kg), T stands Time taken, (hr)

6. Result and Discussion

Figure 2 shows the plot of the effects of moisture contents on time of frying of cassava mash at different paddle speeds. Figures 3 and 4 show the plots of the effect of moisture content of cassava mash fed into the machine at varying time of frying and effect of quantity of mash fed into the machine on moisture content respectively. Figures 5 and 6 show the plots of the change in trough temperature with time and change in mash temperature with time respectively. Figure 8 shows the plot of the moisture content against mash drying temperature.

3.1 Discussion

At paddle speed of 60 rpm after a period of 4 minutes, the product obtained was not properly cooked and the final moisture content was 16.8 % from the initial moisture content of 40.2 % wb. This moisture was higher than the optimum moisture of gari (10 -15 %). However, the speed of 20 rpm and 40 rpm gave product (gari) of final moisture content of 12.2% and 14.9% respectively at the same period of frying. These moisture contents fall in the range of safe moisture (10 -15%) for storage of gari as reported by Odigboh and Ahmed (1982). The final moisture content at the speed of 10 rpm was 9.2% and the product obtained was burnt. Hence, the operating speed of 20 rpm gave a better result of 12.2% final moisture content from the initial moisture content of 40.2% wb after 24 minutes of frying at a temperature of 118°C using electricity as source of heat energy. The UNN model developed by Odigboh and Ahmed (1982) and that of Egba model designed by Igbeka and Akinbolade (1986) operate at 40 rpm and 15 rpm respectively. Major problems associated with mechanized gari frying have been the formation of lumps and inability to produce products similar in quality to gari obtained during manual frying. This design eliminated these constraints through the incorporation of wooden paddles act as 4 conveyor as it reciprocates in movement. The final moisture content of the cassava mash of 5kg, 7.5kg and 10kg fed into the machine were 11.3%, 11.8% and 12.2% respectively. This is in agreement with Ajayi and Olukunle (2010) final moisture content from the cassava mash of 5kg, 7.5kg, 10kg fed into the machine were 11.5%, 11.8% and 12.6% from the same quantity of cassava mash respectively. It was observed that the moisture content of the mash changed as a result of temperature and time change. As the time of frying increases, the temperature also increases, until a steady state (saturation temperature) is reached. Previous studies suggest that time will increase provided temperatures varies (Ajayi and Olukunle, 2010), which means that change in temperature is directly proportional to time.

4. Conclusions

A machine for frying dewatered and sifted cassava mash was designed, fabricated and evaluated for performance. The machine can be used by the small and medium scale farmers and it can complement emerging mechanized method of cassava processing. Hence, the operating speed of 20 rpm gave a better result of 12.2 % final moisture content from the initial moisture content of 40.2% wb for 24 minutes at 118°C using electricity as source of heat energy. The throughput capacity and functional efficiency obtained from the machine are 17.9 kg/hr and 71.6 % respectively and quality product (gari) was obtained. The gari obtained from the fryer was cooked and dried to safe moisture content for storage.

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PROCESSING OF AGRICULTURAL PRODUCTS AS A WAY OF MINIMIZING FOOD SHORTAGE: AN AGRICULTURAL ENGINEERING PERSPECTIVES

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Abstract

Food is a physiological necessity for the survival of human beings. In combating global food crises, Agricultural product processing and storage plays an important role in food and feed preservation for the continual survival of man. Agricultural Engineering interventions in the form of appropriate tools and technology in maximizing agricultural productivity and profitability on sustainable basis with a minimum drudgery to farm workers. This paper highlights the relevance of appropriate technology to production, processing and preservation of food, advances in biotechnology, renewable energy and waste management for environmental sustainability. Neglect or low level of appreciation for agricultural engineering is partly responsible for food insecurity in Nigeria. The role of agricultural engineers in the development and application of relevant agricultural implements to boost food production and the need for government at all levels to recognize and encourage the profession is emphasized. This will ultimately lead to greater productivity and guarantee food security for the nation.

Keywords: Agricultural Storage, Produce processing, Food security, Mechanization, Indigenous technology.

1. Introduction

Despite various measures taken to alleviate the world hunger problem, food insecurity and under nutrition remain serious problems in many countries (Sibhatu and Qaim, 2017). Although achieving food security is desirable irrespective of the political system and socioeconomic conditions (Jerzak and Smiglak-Krajewska, 2020). It is an extremely high priority in the developing regions of the world, where population growth coupled with the increased intensity of such environmental events as floods, droughts, extreme variability in temperature or rainfall often pose a threat to food security (Ahmed *et al.,* 2017). Furthermore, due to greater food demand and reduced crop productivity, higher food prices along with income inequalities may negatively affect food access and availability for poor households. It should be noted here that poverty, war and conflict, natural disasters and climate change, as well as population growth are considered to be the main causes of hunger and malnutrition

(Prosekov and Ivanova, 2018 ; Smith *et al.,* 2000). According to the most recent Food and Agriculture Organization of the United Nations (FAO) data, around 13% of the population living in developing countries are suffering from undernourishment while Porkka *et al.,* (2013) indicated that feeding the world's population is a challenge that is likely to become even more serious in the future.

Nigeria is blessed with 98 million hectares of arable land and additional 2.5million hectares of Irrigable land, out of which 83 million hectares are suitable for cultivation but with only 30 to 34 million hectares presently under cultivation. The nation has one of the best agro – ecology to grow variety of crops (FMA, 2001; EEPC, 2003, Oriola, 2009). However, it has been reported that the country has not been able to take best advantage of her climatic conditions, the large expanse of land and ever-increasing teaming population to make her sufficient in food production, despite the fact that variety of crops thrive well with maximum yield in different Eco zones of the country. Nigeria is one of the food-deficit countries in sub-Sahara Africa, (Arthur, 2009). A country is food-secure when a majority of its population has access to food of adequate quantity and quality consistent with decent existence at all times (Idachaba, 2004). Oriola (2009) asserted that food security entails producing food that will go round every citizen both in quantity and quality. To achieve this, agricultural production needs to be enhanced with adequate knowledge of the environment, climatic conditions, and appropriate mechanization among others. The Nigerian agriculture is plagued with drudgery, aged and ageing farmers. These small – holding farmers, who depend on manual labour to carry out their various farming operations, cannot produce enough food for the increasing population of this nation.

For Nigeria to overcome the challenge of food inadequacy, she must embrace appropriate agricultural technologies developed by the indigenous agricultural engineers. This will, in the long run, contribute to the improvement of the national economy. This paper examines the prospects of achieving food security in Nigeria and the relevance of agricultural engineering profession in this pursuit.

2. Materials And Methods

The adopted method on this study was the review of literatures and qualitative research findings on food security problems in Nigeria. Related literature from various sources such as internet, newspapers, official documents and publications were reviewed and analyzed to draw conclusions to this work.

Food Security Situation in Nigeria

Recent estimates put the number of hungry people in Nigeria at over 75.6 million, which is about 35 percent of the country's total population of roughly 216 million; and 55 percent live under the poverty line. These are matters of grave concern largely because Nigeria was self-sufficient in food production and was indeed a net exporter of food to other regions of the continent in the 1950s and 1960s. According to Akinyele (2009), food security is currently both a fundamental objective and an expected outcome of development policies in Nigeria, as the country currently faces a challenge in meeting the basic food needs of its population. The majority of Nigerians depend largely on subsistence agriculture, which is hardly sufficient to meet the food needs of the population. However, notwithstanding the many policies, programs, and investments by various local and international agencies operating in the country, food security and the nutrition situation are worsening (Nwajiuba, 2011).

Over 90% of agricultural production is rain-fed. Smallholders, mostly subsistence producers account for 80% of all farm holdings. Both crop and livestock productions remain below potentials. Although the average agricultural growth rate was 7% between 2006 and 2008, this growth lies below the 10% necessary for attaining food securityand poverty reduction (Nwajiuba, 2011). Among other factors, inadequate access to and low uptake of high quality seeds, low fertilizer use and generally inefficient production systems lead to shortfalls. As a result, Nigeria's food import bill has been on the rise. Nigeria's large, growing population has become dependent on imported food staples. This includes commonly consumed staples such as rice, wheat and fish. This was not the case prior to the boom in petroleum exports starting from the early 1970s. It is clearly evident that the present agricultural production cannot meet the food requirement of this country. Appropriate agricultural technology will increase productivity. Oriola, (2009), concluded that if the nation is to escape famine and reduce poverty, crop production must not only be boosted but the political will by government should be there.

Agricultural Engineering Perspectives in Tackling Food Security

Agricultural engineering has important roles to play in solving Nigeria's food insecurity issues. Agricultural Engineering is that field of engineering in which the physical and biological sciences are utilized to find and apply better ways of exploiting natural resources for the production, handling, processing and storing of food and fodder (Makanjuola, 1977). It is also concerned with finding better ways for carrying out such allied activities as rural housing and living. Agricultural Engineering consequently involves the design, development, testing, manufacturing, marketing, operation, maintenance, and repair of all agricultural tools, implements, machines and equipment which are used in mechanizing agricultural operations with the objective of raising the productivity of human labour and land in the face of prevailing economical, human and social realities of the time and place concerned.

According to Babajide (2012), Agricultural engineering in recent times has played very important roles in raising the productivity of Nigerian agriculture, enhancing the overall quality of life, especially in the rural areas, and boosting Nigeria's overall economic development.

Sub-divisions of Agricultural Engineering:

a) Farm Power and Machinery
b) Soil and Water Conservation Engineering
c) Crop Processing and Storage
d) Farm Structures and Environmental Control
e) Instrumentation Engineering.

Each of these sub- divisions has important roles to play in providing an enabling environment where Nigeria as a nation can provide enough food to feed her citizens. There is a lack of Awareness On The Necessity Of Technology In Agriculture Hence The Impact Of Technology Is Little.

Farm Power and Machinery Role in Food Security

Agriculture contributed 41.84% to Nigeria's GDP in 1989 (NIPC, 2010). Nigerian agriculture is still characterized by overwhelmingly small holdings, farm lands are rain fed, fertilizer use, agricultural activities are manually carried out and improved seed variety not adopted (Akinola *et al.*, 2009). This calls for mechanization of agricultural production operations from land clearing, sowing, harvesting, and processing to storage of food. Attempts to minimize drudgery and save time involved in these operations have yielded some results but much is still desired. The objectives of the agricultural mechanization policy of Nigeria presented in the Agricultural Policy for Nigeria (1989) are: reduction of the drudgery of agriculture by providing mechanical power to replace some of the labour required in agricultural business and reduction of the high cost of agricultural production which arises from high labour wage rates and the share of labour cost in the total cost of agricultural production.

Small-scale farmers are estimated to account for the cultivation of about 90% of the total cultivated land area in Nigeria, producing about 90% of the total agricultural output (CTA, 1997). This category of farmers still depends on manual labour to carry out their various farming operations. However, with labour demand at critical crop production stages, high labour cost and food demand for the teaming population of over 216 million with an annual growth rate of 2.5%, the introduction of agricultural labour saving devices to Nigerian agriculture is indispensable. Mrema and Odigboh (1993) reported that about 86% of land preparation operations in Nigeria are carried out with hand tools. The output of a human being is 0.07 kW which is limited by stress at high temperature and humidity conditions in tropical country like Nigeria. Some large scale farmers have been using the mechanized farming system, there is the need to promote mechanized farming amongst small-holder farmers. To achieve an overall inclusive agricultural mechanization, the Nigerian government needs to engage other public and private corporations as well as financing institutions (CEMA 2014).

According to Babajide (2012), application of machines to farm production Nigeria, in a noticeable degree started about 50 years ago but over the recent 20 years has increased remarkably Agricultural equipment innovations are relevant in transforming livelihoods in Nigeria and curtail food insecurity.

Nigerian Agricultural Engineers have developed many machines and equipment for agricultural operations from tillage to processing. Some examples of indigenous machines and equipment produced by Nigerians to enhance agricultural productions are ; Batch process cassava peeling machine (Odigbho 1991), Proda Cassava peeling machine, Proda Garri Frying machine, Reciprocating Triple – sieve multi- grain separator, Passive Solr heated Poultry Chick Brooder, Grain Hammer mill (Anazodo *et al.*, 1989), Rotary Power Weeder (Adekanye, 2010), Maize planter (Akpaleji et al, 1995), Melon Washer (Uzoho *et al.*, 1998) and many other agricultural machines and equipment abandoned in workshops of our institutions. These machines are indigenous, readily available, and cost less than imported ones.

Soil and Water Conservation Role in Food Security

According to Olufayo (2011) this aspect of Agricultural Engineering has direct link with our environment which is unique to us. Soil and Water Conservation Engineering comprises of all aspects of Irrigation and Drainage, Water resources, Soil erosion and Degradation. More than a third of all food production now comes from the one – sixth of the arable land that is irrigated (FAO, 1994).

Musa (2001) asserted that there are a number of reasons why water and not land may become the most important constraint for food production. The first is connected with Nigeria's extreme inter – and intra – annual climate variability. Second, there is strong indication that discharge from West Africa's river systems, including the river Niger, have significantly dropped over the past 25 years. Third, population growth and growing urbanization will probably increase water demand for domestic, industrial and environmental uses, and thus reduce the availability of water for food. Irrigated farms in the dry savanna agro-ecological zones give higher productivity than non-irrigated farms in the same region. This system will be particularly useful in most part of the northern Nigeria (oni, *et al.*, 2009).

FAO projected that Nigeria would be unable to feed itself on rain fed agriculture alone by the year 2000 (FAO, 1994).There is a need for a total reform in irrigation farming if food security must be a reality. One of the strategies of achieving this, according to Musa (2001), is the expansion of irrigated land by 115%. This is practically impossible without the application of Soil and Water Conservation Engineering. Oriola (2009) opined that a reform in Irrigation agricultural system will stimulate growth in food production which can still stimulate wider growth in both farm and non-farm rural economy, and in turn contribute to poverty reduction in the country. Ojediran (1990) reported an enhanced growth in root and shoot length of wheat by proper irrigation scheduling. Kerr and Kolavalli (1999) presented a framework of how irrigation can influence higher productivity, protect the environment and attain food security. Soil and Water Conservation Engineering has definite roles to play in attaining food security.

Application of Biotechnology

Persley (2000) asserted that biotechnology is a technique that uses living organisms or substances from those organisms to make or modify a product, improve plants or animals, or develop microorganisms for specific uses. Biotechnology cuts across a number of fields, agricultural biotechnology however, appears to be the most crucial for African countries and especially for resource-poor farmers whose sole livelihood depends on agriculture. The technique of biotechnology alone cannot solve all the problems associated with agricultural production but it has the potential to address specific problems such as increasing crop productivity, diversifying crops, enhancing nutritional value of food, reducing environmental impacts of agricultural production and promoting market competitiveness (Abah *et al.*, 2010). They further asserted that modern biotechnology could help in enhancing the competitiveness of agricultural products from the developing countries and thereby promoting their integration into the global economy. Biotechnology can be used to slow down the process of fruits spoilage. Enzymes produced by microorganisms provide an alternative to animal rennet – a cheese coagulant – and a cheaper alternative of comparable quality for cheese (Onwualu, 2011). It can reduce dependence on agrochemicals. Oil seeds can be modified to produce fatty acids for detergents, substitute fuels and petrochemicals.

Post Harvest Technology Role in Food Security

Once agricultural products are harvested, deterioration sets in and unless processed into more stable product or stored properly, large part may be lost before reaching the consumers (Onwualu *et al.*, 2006). Agricultural Engineers, over the years, have developed several processing and storage techniques to improve the net economic value of agricultural products. These efforts are still on-going. Agencies like the National Centre for Agricultural Mechanization (NCAM), Nigeria Stored Product Research Institute (NSPRI) where the agricultural engineering profession has been accorded some recognition, have developed and tested simple processing equipment and storage structures. Studies to optimize drying processes and improve drying systems for some tropical crops have been carried out (Ojediran and Raji, 2011); Sorption studies to improve storage methods of various agricultural products are also on-going (Okunola and Igbeka, 2007). No doubt, the agricultural engineering profession is impacting on the lives of the citizenry in Nigeria but more can still be done.

It is observed that despite the many policies, programs, and investments by various local and international agencies operating in Nigeria, food security and the nutrition situations are worsening (Akinyele, 2009).

This made Nigeria to be one of the food deficient nations in sub- Sahara Africa. This largely results from dependence on subsistence farming; the small holding farmers, who depend on manual labour to produce their crops, cannot produce enough for the ever increasing population. Hence, lack of appropriate labour saving agricultural equipment is a major factor affecting food security in Nigeria.

FAO (1994) reported a need for a total reform in irrigation farming in Nigeria if food security must be a reality. Musa (2001) concluded that expansion of irrigated land by 115% is a mean of reforming irrigation farming. Oriola (2009) opined that a reform in Irrigation agricultural system will stimulate growth in food production which can still stimulate wider growth in both farm and non-farm rural economy, and in turn contribute to poverty reduction in the country. Application of Soil and Water Conservation Engineering will no doubt help in combating food challenges in Nigeria. Nigerian farmers must appreciate and adopt appropriate technologies developed by indigenous agricultural engineers.

Agricultural biotechnology is crucial to farmers as it can, among other benefits, reduce environmental impacts of agricultural production and enhance competitiveness of agricultural products. Application of post-harvest technologies developed by indigenous engineers will reduce post-harvest losses and add values to crops.

Conclusion and Recommendations

Agricultural Engineers major function is to mechanized agriculture in order to increase production and ensure food security (Igbeka, 2002). The abundance of land in Nigeria should confer more advantage to the country in terms of food production so as to ensure food security for the entire citizens and nation as a whole.

The following conclusions and recommendations are made;

- Nigeria is blessed with abundant fertile land for agriculture and enormous human resources, still Nigerians are facing food insecurity.
- Larger part of Nigeria's farmers are peasants from rural areas; which operate on small holding, and rely on crude outdated tools for their production
- Application of agricultural engineering can be a great step to ensuring food security in the country.
- Efforts should be intensified on ensuring that there is a change in the conduct of agricultural production from subsistence to commercial.
- Indigenous technologies that have been developed locally should be considered by agricultural engineers and there must be a synergy between modern and indigenous technology so as to ensure

sustainability.

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EVALUATION OF TEMPERATURE OUTPUT ON PASSIVE SOLAR CABINET DRYER FOR COOKING BANANA.

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Abstract

The drying temperature is one of the environmental conditions which must be considered in actualizing the aim of drying as well as the dried products. Here Dryer temperature output was evaluated for passive solar cabinet dryer using unripe *Musa Cardaba* cooking *banana variety* sliced into 15mm thickness were dried with the dryers and open sun as control under the same environmental conditions which shows that the collector section and the drying chamber section of the dryer with regulator raised the temperature to 51% and 44% respectively above the ambient air condition temperature for drying cooking banner while the collector section and the drying chamber section of the dryer without regulator raised the temperature to 50% and 43% respectively above the ambient air condition temperature for drying the same cooking banana. The ANOVA F-statistics indicate a significant difference at p=0.05 which reveals that the collector temperature of the regulated dryer was significantly higher than that of the non-regulated dryer as well as the open sun. The solar cabinet dryers had a considerable advantage over the traditional sun drying method in terms of temperature output and handling convenience thus indicating the prospect of better performance compared with open-air sun drying

Keywords: *Solar cabinet dryer, Passive, Temperature output, cooking banana.*

1.0 Introduction

Energy for human consumption is still very scarce in Nigeria, particularly in the rural areas which have hurt the rate of development of this country. However, millions of naira are lost through spoilage of agricultural commodities due to ignorance about the application of renewable energy, particularly solar energy. Nigeria farmers incur losses of 20% to 60% of their crops every year due to inadequate processing and preservative methods. Drying processes play an important role in the preservation of agricultural products, they are defined as a process of moisture removal due to simultaneous heat and mass transfer (Ertekin and Yaldiz, 2004).

Traditional drying, which is frequently on the ground in the open air, is the most widespread method used in developing countries because it is the simplest and cheapest method of conserving foodstuffs. Some disadvantages of open-air drying are; exposure of the foodstuff to rain and dust, uncontrolled drying, exposure to direct sunlight which is undesirable for some foodstuffs; infestation by insects; attack by animals, etc (Madhlopa, *et al.*, 2002).

Cooking bananas is found to be highly perishable and subjected to fast deterioration as their moisture content and high metabolic activity persist after harvest and It can be produced in a free- flowing powder which is stable for at least one- year packing, the powder is used in baking and confectionery industries and the treatment of intestinal disorders and infants' diets (Adeniji *et al*., 2006). All parts of the banana plant have medicinal applications; the flowers for bronchitis and dysentery and ulcers; cooked flowers are given to diabetics (Morton 1987).

In Nigeria, it has always been an important traditional staple food for both the rural and urban populace. Thus, they serve as a source of revenue for smallholders who produce them both on farms; mixed farms and small-scale banana farms. Cooking Banana can be processed into flour, chips and other secondary productions and may be prepared in a variety of ways such as boiling, roasting, frying, baking or sun drying. The pulp of a ripe banana is essential as sugar-rich easily digested food. The cooking banana is nutritionally similar to the potato it contains about to water solid material, mostly carbohydrate (27%) fats (0.3%) and protein (1.2%) content and is generally low in energy terms each grain provides one calorie. Eleven vitamins have been recorded and the fruit is considered a good source of vitamins A, B, B_2 and C. The difference between a banana and plantain is mainly on their moisture content since hydrolysis where plantain has an average of about 65% and the banana about 83%. (Aurore *et al*., 2009)

From all indications, it is necessary to monitor the drying temperature as this affects the drying rate of every dryer and alleviate the drying problems thus this motivates the choice of this research; evaluation of temperature output of the passive cabinet solar dryer for drying cooking banana based on the environmental conditions.

2.0 MATERIALS AND METHOD

2.1 Description of the Dryers

The dryers used for the test are regulated and non-regulated direct mode passive cabinet solar dryer that utilizes the natural convection principles and the open sun as control as shown in Figure 4. The dryers consist of the solar collector section, the drying chamber and the chimney.

FIGURE 4: Setup for drying test

FIGURE 5: The dried cooking banana

2.2 Instrumentation and Measurement

The parameters monitored for the performance evaluation of the solar dryers are: solar radiation, ambient air temperature, collector section temperatures, drying chamber temperature, and temperature of the products. Here a solar radiator with sensor output measured in W/m^2 which is highly sensitive and available was used to measure the total solar radiation which was placed on the dryer top cover while the air temperature of the environment was monitored and measured with temperature and relative humidity sensor model TT-202 in degree centigrade.

2.3 Drying Test

The temperature output was evaluated using a regulated and non-regulated direct mode passive cabinet solar dryer in the department of Agricultural and Bioresources Engineering, College of Engineering and Engineering Technology, Michael Okpara University of Agriculture Umudike located at latitude 5.29N, longitude 7.33E and Altitude 122m above sea level (Akanno and Ibe, 2005). The Cooking banana was purchased from a nearby market which later was peeled, the endocarp washed and sliced to the same thickness of 15mm and dried with solar dryers while some samples were dried in the open sun as control. The samples were dried in three replicate batches.

3.0 RESULTS AND DISCUSSIONS

3.1 Drying Temperature Output

From figures 2 and 3 of average daily responses of temperature using the corresponding results of the ambient temperatures as a control for cooking banana dried using the regulated dryer and non-regulated dryer respectively and tables 1 and 2 of the absolute values of temperature on cooking banana dried with regulated dryer and that of absolute values of temperature on cooking banana dried with non-regulated dryer, this reveals that the dryers are hottest about mid-day when the sun is usually overhead. The temperatures inside the dryer and the solar collector were much higher than the ambient temperature during most hours of daylight for about two hours immediately after 12.00h (noon) daily thereby allowing continuous drying of cooking bananas. The findings also indicate that the collector section and the drying chamber section of the dryer with regulator raised the temperature to 51% and 44% respectively above the ambient temperature for the drying cooking banana while the collector section and the drying chamber section of the dryer with non-regulator raised the temperature to 50% and 43% respectively above the ambient temperature for drying the same cooking bananas.The indicates the prospect of better performance compared with open-air sun drying.

Table 1: Absolute values of drying temperature on cooking banana dried with regulated dryer

parameters	Ambient Air Condition	Solar Collection Section	Drying Chamber Section
Average drying temp. (^oC)	41	62	59
Average max. Drying temp. (^oC)	41	60	57
Average min. drying temp. (^oC)	29	31	30
Average temp. Of drying product.(^oC)	28	30	30

Table 2: Absolute values of temperature on cooking banana dried with non-regulated dryer

Parameters	Ambient Air Condition	Solar Collection Section	Drying Chamber Section
Average drying temp. (°C)	40	60	57
Average max. Drying temp. (°C)	40	60	57
Average min. drying temp. (°C)	27	29	30
Average temp. Of drying product.(°C)	26	28	30

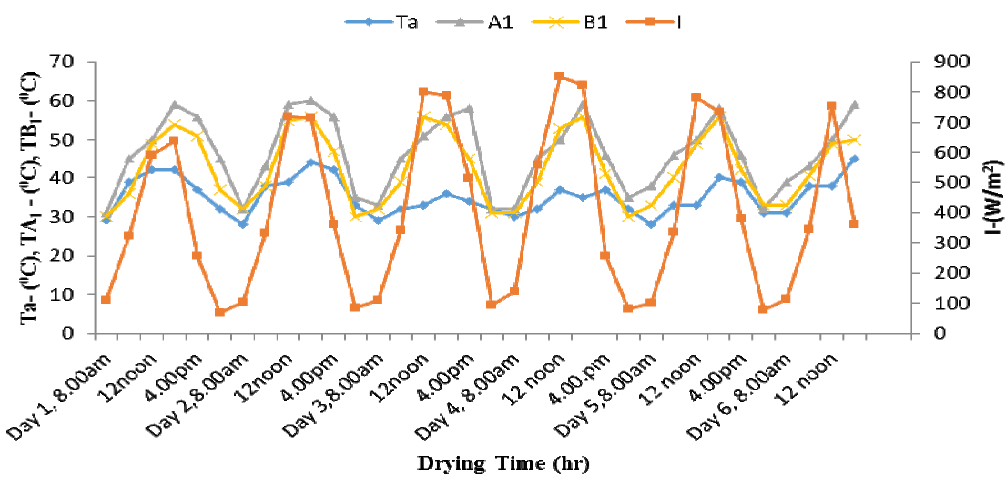

Figure 2: Temperature output of collector temperature (TA1) °C, drying chamber temperature(TB1) °C, ambient temperature (Ta) °C and the corresponding values of solar radiation incidence on the dryer I(w/m2) for cooking banana dried using the regulated dryer

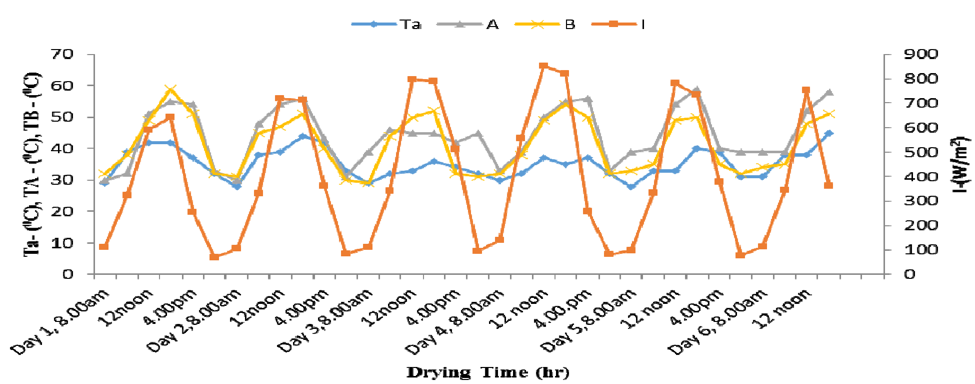

Figure 3: Temperature output of collector temperature (TA) °C, drying chamber temperature(TB) °C, ambient temperature (Ta) °C and the corresponding values of solar radiation incidence on the dryer I(w/m²) for cooking banana dried using the non-regulated dryer.

3.2 Comparing the Drying Temperature Output

Table 3 shows the result of the mean temperature of drying cooking bananas using regulated and non-regulated solar cabinet dryers and open sun serving as control. The result reveals that the mean collector temperature of the regulated solar cabinet dryer fluctuated from 61.67^{0}C on drying day one (1) to 66.15^{0}C on drying day six (6). While the mean collector temperature of the non-regulated solar cabinet dryer used in drying bananas fluctuated. The mean temperature increased from 50.50^{0}C on drying day one to 51.67^{0}C on drying day three (3) and decreased to 51.00^{0}C on drying day six (6). Similarly, the mean open sun temperature serving as control fluctuated within the six day drying period of cooking banana. The mean temperature of the open sun increased from 35.00^{0}C on drying day one (1) to 37.17^{0}C on drying day two (2) and then decreased to 36.70^{0}C on drying day six(6).

The fluctuations in the mean temperature of drying cooking bananas using regulated and non-regulated solar cabinet dryers could be attributed to the unpredictable nature of climate change. The temperature of the regulated and non-regulated solar cabinet dryer decreased as the climate changed as rainfall and relative humidity increased.

The ANOVA F-statistic showed that there was significant difference at ($P=0.01$ and $P = 0.05$) between the collector temperature of the regulated and non-regulated solar cabinet dryer used in drying cooking bananas as well as that of the open sun temperature. Within the drying period, a statistically significant difference was determined by using the Least Square Difference (LSD) mean separation technique. The result showed that the mean collector temperature of the regulated solar cabinet dryer used in drying cooking bananas was significantly higher than the mean collector temperature of the non-regulated solar cabinet dryer as well as that of the open sun serving as the control.

However, the mean collector temperature of the non-regulated solar cabinet dryer used in drying cooking bananas was significantly higher than the open sun temperature serving as the control. This implies that the regulated solar cabinet dryer retains more collector temperature than the non-regulated solar cabinet dryer.

Similarly, the result showed that the mean drying chamber temperature of the controlled vents solar cabinet dryer used in drying cooking bananas fluctuated within the drying period which lasted for six (6) days. The mean drying chamber temperature of the regulated solar cabinet dryer used in drying cooking banana varies from 59.83^{0}C on drying day one (1) to 64.13^{0}C at drying day six (6). Also, the mean drying chamber temperature of the non-regulated solar cabinet dryer used in drying cooking bananas vary from 47.50^{0}C on drying day one (1) to 48.00^{0}C on drying day six (6). The fluctuation in the mean drying chamber temperature was higher in the regulated solar cabinet dryer than observed in the non-regulated solar cabinet dryer. That shows that the regulated solar cabinet dryer retains more temperature than the non-regulated solar cabinet dryer as the collector temperature spreads to the drying chamber of the dryers.

The ANOVA F-Statistic showed that there was a significant difference at ($P = 0.01$ and $P = 0.05$) in the drying chamber temperature between the regulated and non-regulated solar cabinet dryer used in drying tomatoes. Within the drying time measured in hours statistical significant difference was determined by using the Least Square Difference (LSD) mean separation technique. The LSD at 0.05 level of probability result showed that the drying chamber temperature of the regulated solar cabinet dryer for drying cooking bananas was significantly higher than the drying chamber temperature of the non-regulated solar cabinet temperature recorded for both regulated and non-regulated solar cabinet dryer were higher than the dry intensity of the open sun temperature used to dry cooking bananas. The regulated inlet and outlet structure of the solar cabinet dryer with regulator did not allow for much heat loss as the solar temperature at the collector section of the dryer moves to the drying chamber of the dryer than was the case with the non-regulated solar cabinet dryer. This implies that the solar cabinet dryer with regulator would dry cooking bananas faster than the non-regulated solar cabinet dryer as well as the open sun drying. The open sun drying gave the least drying intensity compared to the two dryers, due to the less concentration of the open sun temperature on a product to be dried occasioned by the velocity of wind that often cools the open-air temperature.

The findings further revealed variations in drying product temperature among the regulated and non-regulated solar cabinet dryers used for the study compared to the open sun drying. The mean drying product temperature of the regulated solar cabinet dryer varies from 56.25^{0}C on drying day one (1) to 62.75^{0}C on drying day six (6), while the drying product varies from 45.00^{0}C on drying period one to 45.75^{0}C on drying day six (6). The ANOVA F-Statistic showed that there is a significant difference between the drying product temperature of the regulated solar cabinet dryer and the non-regulated solar cabinet dryer within the drying period measured in hours. This was confirmed by the Least Square Difference (LSD) mean separation technique.

Then the result of the dryers' temperatures compared to open sun temperate revealed that the mean temperature of the regulated solar cabinet dryer varies from 59.25^{0}C on drying day one (1) to 64.34^{0}C on drying day six (6) measured in hours, while the mean temperature of the non-regulated solar cabinet dryer varies from 47.67^{0}C on drying day one (1) to 48.25^{0}C at sixth day drying period measured at six hours intervals. The means temperature of the open sum ranges from 35.00^{0}C on first day drying period to 36.70^{0}C on sixth day drying period measured at six-hour intervals.

The ANOVA F-Statistic was significant and shows that there exists a significant difference between the dryers and the open sum temperature. The statistically significant difference (LSD) means separation technique indicated that the temperature of the regulated solar cabinet dryer used in drying tomatoes was significantly higher than the temperature of the non-regulated solar cabinet dryer and that of the open sun.

4.0 Conclusions and Recommendations

The temperature output of the dryers was evaluated and compared for their performances in drying cooking bananas. From the test carried out, it was observed that the regulated solar cabinet dryer gave the highest temperature among the three methods applied, and as such as the fastest method of drying cooking bananas and the solar dryer can raise the ambient air temperature to a considerable high value of 54% for increasing the drying rate of agricultural crops and the dryer's attained a higher temperature range of 31-58°C. It is also concluded that the regulated solar cabinet dryer exhibited high temperature output of 64.34°C followed by the non-regulated solar cabinet dryer of 48.25°C than could be achieved using the open-air sun method with temperature output of 36.70°C and which indicates the prospect of better performance. Given the results, it's also recommended that the drying temperature should be extensively considered, monitored and evaluated for better performance during drying processes in food drying industry for optimum performances..

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NOTATIONS,

A_1 = Collector temperature for dryer with inlet/outlet regulator

B_1 = Drying chamber temperature for dryer with inlet/outlet regulator

C_1 = Drying product temperature for dryer with inlet/outlet regulator

A = Collector temperature for dryer without inlet/outlet regulator

B = Drying chamber temperature for dryer without regulator

C = Drying product temperature for dryer without regulator

D = Temperature of the open sun dryer

T_a = Ambient temperature (^{0}C)

I = Solar radiation (W/m^2)

Table 3: ANOVA for comparing the mean temperature of drying cooking banana using regulated and non-regulated solar cabinet dryer and open sun serving as the control

Sample Days	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Collector Temperature Compared to Open Sun Temperature						
A_1	61.67±4.06	63.50±5.09	62.83±4.60	64.50±4.04	58.00±3.72	66.15±4.39
A	50.50±4.89	50.67±4.57	51.67±1.09	52.33±4.35	47.17±3.65	51.00±4.78
D	35.00±2.16	37.17±2.33	35.92±2.33	35.00±2.78	33.17±2.36	36.70±4.07
F-statistic	7.70**	7.57**	6.94**	5.07*	4.35*	6.95**
$LSD_{0.05}$	11.68	12.56	9.16	11.40	9.94	14.15
Drying Chamber Temperature Compared to Open Sun Temperature						
B_1	59.83±3.98	59.00±4.633	61.83±4.38	62.67±4.44	56.47±3.70	64.13±3.99
B	47.50±4.55	48.67±3.528	49.67±4.19	50.43±3.96	45.00±3.36	48.00±4.38
D	35.00±2.16	37.17±2.330	35.92±2.33	35.00±2.78	33.17±2.36	36.70±4.07
F-statistic	6.64**	6.66**	7.86**	5.18*	5.05*	4.68*
$LSD_{0.05}$	11.18	10.86	11.28	11.43	9.61	9.28
Drying Product Temperature Compared to Open Sun Temperature						
C_1	56.25±3.31	57.92±2.43	57.12±3.62	58.00±3.59	55.58±3.56	62.75±3.59
C	45.00±3.24	46.33±3.66	46.83±3.60	47.17±3.46	43.83±2.39	45.75±4.59
D	35.00±2.16	37.17±2.33	35.92±2.33	35.00±2.78	33.17±2.36	36.70±4.07
F-statistic	6.28**	8.22**	6.30**	7.24**	3.68*	4.26*
$LSD_{0.05}$	8.89	8.64	9.76	9.93	8.50	8.13
Dryers Temperatures Compared to Open Sun Temperature						
$TA_1B_1C_1$	59.25±10.94	60.14±11.86	60.59±12.02	61.72±11.82	56.68±10.42	64.34±11.77
TABC	47.67±12.47	48.56±11.64	49.39±8.19	49.98±11.67	45.33±9.25	48.25±13.73
D	35.00±2.16	37.17±2.33	35.92±2.33	35.00±2.78	33.17±2.36	36.70±4.073
F-statistic	8.41**	6.64**	5.23*	6.06**	3.09*	5.86*
$LSD_{0.05}$	10.33	10.45	9.35	10.77	9.06	9.66

Notes: Results are means± standard error of the mean of six replicates. A statistically significant difference was determined by using the least square difference (LSD) mean separation technique. ** = Significant at P = 0.01(1%);* = Significant at P = 0.05(5%).

DEVELOPMENT OF A MOTORIZED CASSAVA PELLETER FOR ENHANCED PROCESSING AND EXPORT

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Abstract

An improved cassava pelleter comprising of hopper, barrel, mixer, screw conveyor, electric steam boiler, compression / extrusion plates, cutter, supporting frame and the power transmission unit was designed and developed. The extruding plate has die openings of 4mm to produce the recommended cassava pellet size for export. The average moisture content of the dewatered cassava mash used for the evaluation is 18 %. Also, the steam boiler used for the conditioning produces saturated steam at the temperature of about 103 ^{o}C. The result of the machine performance test indicates that the machine has average throughput capacity and efficiency of 160.05 kg/hr and 96.60 % respectively at operating speed of 250 rpm.

Keywords: Development, Cassava mash, Pelleter, Processing, Export

1. Introduction

Cassava is a major source of carbohydrate in most developing nations of the world (Ugoamadi, 2012). Cassava can be processed into *gari*, *fufu*, *lafun*, chips, pellets, etc. Cassava roots once harvested, undergo rapid physiological changes resulting in quality deterioration if left un-processed within 24 – 48 hours (Ashaye, *et al*., 2005).

Cassava roots are extensively used in the production of livestock and fish feed production in most developed countries of the world (Frame, 2004). Compounding cassava with other ingredients for livestock feed has gained wide practice in Latin America, Asia and the European Union. The substitution of wheat flour partially with cassava flour and production of cassava chips and pellets for animal feed are areas of utilization with some potential significant in Nigeria (Odutan, *et al.*, 2014). The demand for cassava root has been on the increase worldwide, because of its numerous uses. For export purposes cassava roots can be processed into raw cassava chips, but because of environmental concerns, over 90% of cassava that are exported to European Union (EU) enter as pellets. (Hillocks *et al*., 2002). Pelleting is an extrusion process which is simply the operation of shaping dough like material, by forcing it through a restriction or die (Ugoamadi, 2012).

Cassava pellet is a processed dried cassava product obtained by compressing raw cassava mash or chips under appropriate processing conditions resulting in the formation of dried bulky product suitable for the animal feed industry and also for easy transportation and export (Fast and Coldwell, 1990). Pellet samples can be produced through the conventional chipping, drying, milling then pelleting with and without steaming, and modified process of grating, dewatering then pelleting with steaming. Also, the modified process was reported to have greater advantage of reduced processing time and energy with associated quality products than the conventional process (Raji, *et al*., 2008).

Pelleting of cassava is becoming increasingly popular because it decreases volume by about 25 percent. This simplifies transport, handling and storing, and also produces uniform products which are less fragile for overseas shipment than raw cassava chips (Rossen and Miller, 2008). Also, in Nigeria, fish farming is an industry that is growing rapidly, but the major problem facing the local farmers is the high cost of fish feed which is a pelleted product processed from cassava roots and other required components. Series of processing equipment at different levels of sophistication were imported into Nigeria for the pelletization process (Pabis Jayas, 1998). Major problems with such machines include high initial and maintenance costs and requirement for highly skilled maintenance engineers.

Ugoamadi (2012), developed cassava pelleting machine with capacity of 80.46 kg/hr and efficiency of 80.31 % using pre-conditioned cassava mash. Alonge, *et al*. (2012), reported on the development of a cassava pelleting machine with capacity and efficiency of 80 kg/hr and 98.66 % respectively using also pre-conditioned cassava mash. Most of these existing cassava pelleters make use of already pre-conditioned cassava mash as the input product for the production of cassava pellet, but the developed cassava pelleter reported, includes also the conditioning and mixing of the cassava mash.

This paper reported on the development of an improved version of cassava pelleter which includes mixing and conditioning of the cassava mash for pelleting.

2. Materials And Methods

2.1 Description of the Machine

The major components of the developed cassava pelleter (Fig.1) are the hopper, barrel, mixer, electric steam boiler, screw conveyor, compression / extrusion plates, cutter, supporting frame and the power transmission unit which consists of the pulley, bearing, belt and 5hp electric gear motor. The materials for construction used were all stainless. The hopper is welded at an angle of 42^{o}C to a cylindrical based barrel which houses the mixer and the screw conveyor of varying pitch. Directly below the opening where the hopper is mounted is the mixer connected with the steam boiler. The extrusion plate is attached to the end of the barrel by a flange welded in place with four bolts, so that the plate can be changed with other plates having different die sizes for producing different sizes of pellets. There is also a cutter in front of the extrusion plate that cuts the pellets to the required length as they are coming out of the machine. The pictorial views of the developed cassava pelleter are shown in Figure 1.

Figure 1: Pictorial views of the developed cassava pelleter

2.2 Operation of the Machine

The dewatered cassava mash sample was fed into the pelleter which rotates at an optimal speed of 250 rpm. The experiment was repeated with different weights of the dewatered cassava mash from 15 to 35kg. The screw conveyor conveys and compresses the material and force them out through the 4mm die. The cutter attached in front of the extrusion plate cuts the pellets to the required length. The pelletized products then requires drying and proper cooling. The machine was evaluated by estimating the throughput capacity and efficiency using equations 1 and 2 respectively as:

$$\text{Capacity of the machine (kg/hr)} = \frac{\text{Total weight of cassava mash (kg)}}{\text{Pelleting time (hr)}} \quad (1)$$

$$\text{Pelleting Efficiency (\%)} = \frac{\text{Total weight of pellet formed (kg)}}{\text{Total weight of cassava mash (kg)}} \times 100 \quad (2)$$

The weights of dewatered cassava mash used were determined using 50kg weighing balance. Time was measured using a stop watch. Moisture contents of the mash were determined by oven drying the cassava mash samples at a temperature of 75^{o}C for 24 hours. The percentages of moisture content wet basis were calculated as according to (Kajuna *et al*., 2001) and given as equation 3:

$$\text{Mc (wb) \%} = \frac{W_w - W_d}{W_w} X100 \quad (3)$$

Where Mc (wb) % = Moisture content wet basis; W_w is the weight of mash sample (g); W_d is the weight of the dried sample (g).

2.3 Design Considerations- The following were considered for the design of the improved pelleter.

i) The hopper was constructed as to allow easy flow of the product.

ii) The machine is to handle dewatered cassava mash with moisture content of about 18 %.

iii) The extruding plate has die openings of 4mm in order to produce the recommended cassava pellet size for export.

iv) Electric steam boiler that produces saturated steam at the temperature of about 103 ^{o}C was located at the mixing section for easy conditioning of the product.

v) The design is simple and easy to operate.

2.4 Design Calculations

2.4.1 Hopper design

The hopper inclination which is considered an important design factor was determined using the expression by Jayashree and Visvanathan (2011) for calculating the angle of repose.

$$\theta = \cos^{-1}\left(\frac{r}{l}\right) \quad (4)$$

Where, θ is the angle of repose, r is the radius of the heap, cm; l is the slant height of the heap, cm.

2.4.2 Shaft design

The shaft diameter, d is obtained from the ASME code equation for commercial steel shafting (Hall, et al. 1988) as:

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (5)$$

Where, S_s = allowable stress for shaft with key way (Nm^{-2})

M_b = bending moment (Nm)

K_b = combined shock and fatigue factor applied to bending moment

K_t = combined shock and fatigue factor applied to torsional moment

2.4.3 Belt Speed

The speed of the belt used was determined using the expression given by Khurmi and Gupta (2006) as:

$$V = \frac{\pi DN}{60} \quad (6)$$

Where, N = speed of driven pulley (rpm)

D = diameter of the driven pulley (cm)

3. Results and Discussion

The cassava pelleter developed was an improved version over the existing ones since it accommodates major required operations of mixing, conditioning, conveying and pelleting. The machine was found to perform satisfactorily with the operating speed of 250rpm. The steam boiler used also performed effectively and generate saturated steam which produces heat and moisture that ensures proper conditioning of the product for good quality pellet formation. The machine produces high quality cassava pellets of 4mm standard size for both domestic and export market. The data obtained from the evaluation test of the machine is presented in Table 1.

Table 1: Performance Evaluation Results of the Developed Cassava Pelleter

S/N	Speed (rpm)	Weight of cassava mash (kg)	Weight of pellet (kg)	Pelleting Time (min)	Capacity (kg/hr)	Efficiency (%)
1	250	15.00	14.32	7.02	128.21	95.47
2	250	20.00	19.24	8.54	140.85	96.20
3	250	25.00	24.26	9.05	165.56	97.04
4	250	30.00	29.08	10.22	176.45	96.93
5	250	35.00	33.85	11.10	189.19	96.71

3.1 Machine Capacity

The average machine capacity of 160.05 kg/hr was obtained with the average input cassava mash of 25kg and machine speed of 250 rpm. The highest and lowest machine capacities of 189.19 kg/hr and 128.21kg/hr were obtained when it took the machine 11.10 and 7.02 minutes to pelletize 35 and 15 kg respectively of the dewatered cassava mash fed into the machine as shown in Table 1.

It was also observed that the machine capacity increases with weight of cassava mash. The curve of variation of the machine capacity with weight of cassava mash is shown in Figure 2.

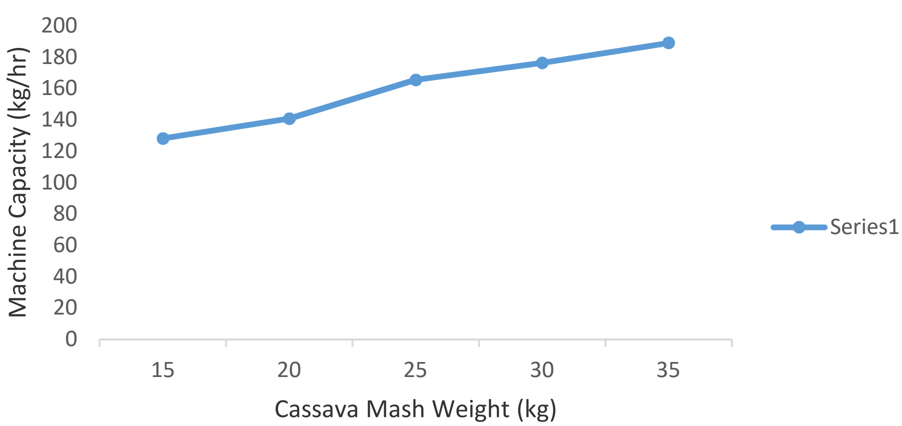

Figure 2: Curve of variation of machine capacity with mash weight

3.2 Pelleting Efficiency

The average efficiency of 96.60 % was obtained at the machine speed of 250 rpm. The highest efficiency of 97.04 % was obtained when it took 24.26 kg out of 25.00 kg of the dewatered cassava mash fed into the machine to be pelletized within 9.05 minutes as shown in Table 1. The lowest efficiency of 95.47 % was also obtained when it took 14.32 kg out of 15.00 kg of the mash to be pelletized within 7.02 minutes. It was observed that beyond the input weight of 25 kg, the efficiency of the machine begins to fall. The curve of variation of the machine efficiency with the cassava mash weight is shown in Figure 3.

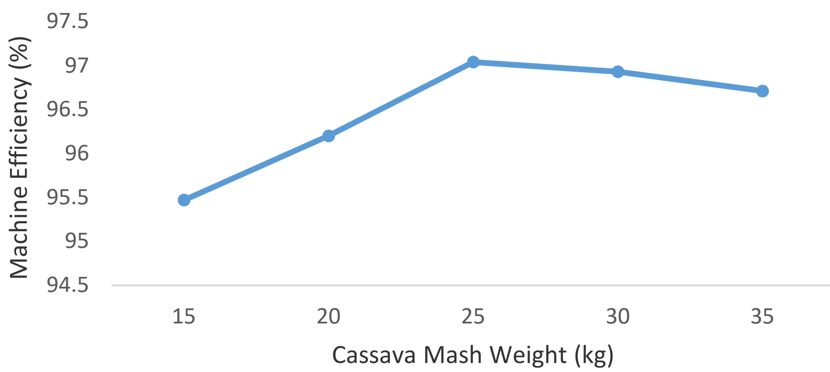

Figure 3: Curve of variation of the machine efficiency with mash weight

4. Conclusion and Recommendations

The cassava pelleter developed is an improved version with steam boiler and mixer that take care of the conditioning / mixing of the mash. The machine also performed satisfactorily and has average throughput capacity and efficiency of 160.05 kg/hr and 96.60 % respectively at operating speed of 250 rpm.

This technology should be adopted for it will enhance export of cassava products, and also help to meet the growing demands of the nation's feed industries. Petrol or diesel powered engines can be used for the operation of the machine where there is inadequate supply of electricity. Funding should be provided by government to encourage massive production of this innovation, so as to make it available to farmers and processors.

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DESIGN AND FABRICATION OF AN IMPROVED CASSAVA GRATING MACHINE

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Abstract

Cassava has become a major staple food providing the basic diet for over half a billion of world population. A major limitation of cassava is its rapid post-harvest physiological deterioration. To reduce this level of losses, it is very necessary that the tubers are processed as early as possible. Grating is a size reduction operation for transformation of cassava tubers into pulp form. Manual grating has been found to be laborious, time consuming and injurious. A number of cassava grating machines have been designed to replace manual grating. However, these machines have been widely regarded as inefficient due to poor quality of the products, and low efficiency of the technologies which is a major constraint to the efficiency of the machines. This study therefore, aimed at designing, fabricating and testing an improved cassava grating machine which would help in producing sufficient quantity and quality of cassava pulp that will meet market demands and standards. The materials and components used in the design of the machine were properly selected considering design requirements and considerations and these were used to justify the detailed design of the machine. The designed machine consists mainly of truncated pyramid hopper, electric motor, shaft, bearing, v-belt, pulley and the grating drum. The volume of hopper, volume of grating drum, shaft diameter, speed of electric motor, speed of machine, belt length, grating force, grating power and torque were obtained as 0.0233 m^3, 0.0172 m^3, 0.025 m, 1440 rpm, 708.0 rpm, 0.99 m, 186.88 N, 2.5 hp and 12.38 Nm respectively. The average grating time, capacity, efficiency and losses were obtained as 59.67 s, 280.63 kg/hr, 93.0 % and 7.0 % respectively. The performance indices of the machine confirmed that it could be used effectively by cassava processors to grate cassava tubers that would meet market demands and standards.

Keyword: Design, Fabrication, Cassava, Grating, machine

1.0 Introduction

Cassava has become a major staple food providing the basic diet for over half a billion of world population (Grubben *et al*., 2014; Onokwai *et al*, 2019). It is a food security crop in Africa and is of much interest that the continent produces more cassava than the rest of the world and Nigeria is the largest producer accounting for 59.5 million tonnes of the crop per year (FAOSTAT, 2018). Cassava is mainly used as food (48 %), feed (34 %) and feedstock (18 %) and for biofuels and as well as biochemical (FAO, 2008). A major limitation of cassava is its rapid post-harvest physiological deterioration, which often begins within twenty-four hours after harvest. To reduce this level of losses, it is very necessary that the tubers are processed as early as possible.

Grating is a size reduction operation for processing cassava root. The transformation of cassava tubers into pulp form is known as grating of cassava (FAO, 2005). The traditional method of cassava grating is made of a perforated metal sheet of aluminum or galvanized sheet and the peeled cassava tuber is rubbed on the rough surface, while the grated product is collected in a container (Jekayinfa *et al*., 2003). The traditional method apart from been laborious, have reported cases of the user having their fingers brushed off on the rough surfaces of the grater.

A number of cassava grating machines have been designed to replace manual grating. These include mechanized grater, motorized grater, hammer mill, disk grater, and hand grater (Odebode, 2008). A patented design of a hand-operated grater is composed of housing with a grater barrel and crank for rotation (Grace *et al*., 2010). Jekayinfa *et al.* (2003) also designed a pedal-operated cassava grater composing of a grating unit, transmission unit, housing, hopper, and discharge chute. Currently, there exist motor powered grater that has been developed by Rural Agricultural Industrial Development Service (RAIDS) and International Institute of Tropical Agriculture (IITA).Despite being mechanized; these machines are still operated by human power which limits grating capacity and efficiency. Other designs have also been proposed like the improvised cassava grater (Adetunji and Quadri, 2011) with a grating capacity of 158 kg/hr and dual-operational mode cassava grating machine (Ndaliman, 2006), which can be powered either electrically or manually. In the Philippines, Doydora *et al.* (2017) developed a cassava grater with juice extractor. However, mechanization may not always be adoptable to the local community because of constraints in getting fuel or power (Jekayinfa *et al*., 2003), high cost of the machine and lack of operating skills (Odebode, 2008), transportation costs (Adebayo *et al*., 2008) and corrosion of machine parts (Adetunji and Quadri, 2011). To prevent these hindrances, the need for the development of modern mechanized grating machines that would conform to indigenous designs and practices and adoptable to cassava processors is inevitable.

This study therefore, aimed at designing, fabricating and testing an improved cassava grating machine which would help in producing sufficient quantity and quality of cassava pulp that will meet market demands and standards.

2.0 Materials and Methods

2.1 Description of Machine Parts

The cassava grating machine consists of hopper, grating drum, transmission shaft, discharge chute, v-belt, pulley, bearing, electric motor and frame. The overall length of the machine is 380 mm, width of 380 mm and height of 850 mm. The truncated pyramid hopper has a large area of 780 × 780 mm, the base area of 380 × 380 mm and the height of 250 mm. The grating drum diameter is 150 mm and a length of 1080 mm. The structural frame was made with 60 × 60 × 5 mm thick angle iron. The machine is operated by an electric motor via belt-pulley transmission system.

The Main Frame: The main frame was constructed with angle iron. The angle iron was welded together to form the frame work. The welding provides very rigid joints. This provides the strength and rigidity for the overall machine.

The Hopper: The hopper is the receptacle through which cassava is admitted into the machine for grating. It is truncated pyramid in shape.

The Grating Unit: This unit consists of the shaft, perforated mesh, rolled sheet, circular discs and rivet pins. The drum was formed by the shaft passing through the rolled cylindrical sheet and it was welded in place by circular discs. This drum is then wrapped with the perforated mesh, they are attached by riveting.

Prime mover and Pulley System: An electric motor was used as prime mover to power the machine. A reduction pulley system was used to transmit power to the grater's drum at reduced speed and increased torque. This enables the drum to exhibit rotary motion thereby grating the cassava.

The Discharge Unit: This is a continuation of the grater's frame connected to the hopper. It directs the flow of the grated cassava to a receptacle.
V-Belt was made to transmit power generated from the prime mover to the rotating drum.
Bearing: It exists as a standard component, it is of various types. For the design, knuckle bearing with sealed ball bearing was opted for to avoid grease contamination on the machine.

2.2 Material Selection

Most of the component parts of the machine were fabricated with local materials as shown in Table 1.

2.3 Design Considerations

Functionality, reliability, durability, materials and labour use, simplicity, portability and space, power supply, usability, maintenance, cost and safety.

2.4 Design Calculations

The details of the design calculations of the hopper, grating unit, type of pulley, appropriate belt design, selection of appropriate bearing support, selection of the prime mover and frame are shown below.

2.4.1 Design of hopper

Volume of hopper (truncated pyramid) V_P is given as:

$$V_p = {}^1/_3\,(a^2 + ab + b^2)h \qquad (1)$$

Where, a = length of longer side
b = length of shorter side
h = height of the hopper

2.4.2 Design of Grating Drum

Centrifugal force (F_c) developed by the electric motor is given as:

$$F_c = M_b \omega^2 r \qquad (2)$$

Where, M_b = mass of belt used for the drive
r = radius of pulley
ω = angular velocity

But, $$M_b = A_b \times \rho_b \times L_b \qquad (3)$$

Where, A_b = cross-sectional area of belt
ρ_b= density of belt
L_b = length of belt

And $$A_b = ½(a + b)h \text{ (for v − belt)} \qquad (4)$$

Angular velocity of rotation (ω) is given as:

$$\omega = \frac{2\pi N}{60} \qquad (5)$$

Where, N = rotational speed of the electric motor

Since the grating drum is cylindrical in shape, its volume (V_c) is given as:

$$V_c = \pi r^2 l \qquad (6)$$

Where, r = radius of the grating drum
l = length of drum

2.4.3 Design for transmission shaft

The solid circular transmission shaft of the cassava grating machine is subjected to combined bending and torsional loads. The diameter (d) of the shaft is obtained from ASME code equation (Hall, *et al*., 1983) as:

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad (7)$$

Where, at the section under consideration

S_s= Allowable combined shear stress for bending and torsion = 40 MPa for steel shaft with keyway.

K_b = Combined shock and fatigue factor applied to bending moment = 1.5 for minor shock.

K_t= Combined shock and fatigue factor applied to torsional moment = 1.0 for minor shock.

M_b = Bending moment (Nm).

M_t = Torsional moment (Nm) = 55.59 Nm.

2.4.4 Determination of Speed of Grating Machine

The machine's speed was determined using the equation for speed ratio as shown in equation 8:

$$D_e N_e = D_m N_m \qquad (8)$$

Where,

D_e = Diameter of engine pulley (m)

N_e = Rotational speed of engine (rpm)

D_m= Diameter of machine pulley (m)

N_m = Rotational speed of machine (rpm)

2.4.5 Belt Selection

The minimum centre distance is determined by equation

$$_d = \frac{D_e + D_m}{2} + D_e \qquad (9)$$

The pitch length of the belt is given by equation 10:

$$L = 2C_d + 1.57\frac{(D_e+D_m)}{2} + \frac{(D_m-D_e)^2}{4C_d} \qquad (10)$$

2.4.6 Angle of contact between the belt and the machine pulley

According to Hall *et al*, 1983, the angle of contact (wrap) between the belt and the machine pulley is given by

$$\propto_1 = 180 + 2\mathrm{Sin}^{-1}\frac{R-r}{C} \qquad (11)$$

Where, r = radius of small pulley

R = radius of big pulley

C = centre distance

$\propto_1$= angle of contact between the belt and the small pulley (rad)

$\propto_2$= angle of contact between the belt and the big pulley (rad)

2.4.7Angle of contact between the belt and the small (engine) pulley

$$\propto_2 = 180 - 2\mathrm{Sin}^{-1}\frac{R-r}{C} \qquad (12)$$

2.4.8 Determination of Linear Velocity of Belt

2.4.9

Linear velocity of belt is given by

$$V = \omega r = \frac{\pi d N}{60} \quad (13)$$

Where,

V = linear velocity of belt (m/s)

ω = angular velocity of belt (rad)

r = radius of small pulley (m)

d = diameter of small pulley (m)

N = number of revolution of small pulley per minute

2.4.9Determination of tension in the tight side

To obtain T_1 and T_2, the following equations are solved simultaneously:

$(T_1 - T_2)V = P_t$ (Khurmi and Gupta, 2004) (14)

and $\frac{T_1 - mv^2}{T_2 - mv^2} = e^{\mu \frac{\alpha}{\sin \theta/2}}$ (15)

Where,

T_1 = tension in the tight side

T_2 = tension in the slack side

$m = bte$

Where,

b = belt width = 17 mm

t = belt thickness = 11 mm

e = belt density = 970 kg/m^3 for leather belt (Khurmi and Gupta, 2004)

θ = 40 deg. (most common angle of groove)

For big pulley,

$$e^{\mu \alpha_1 / \sin \theta/2} \quad (16)$$

For small pulley,

$$e^{\mu \alpha_2 / \sin \theta/2}$$

The pulley with smaller value governs the design. In this case, the smaller pulley governs the design.

Force due to greater (F_g) is obtained as:

$$F_g = M_g \times g \quad (17)$$

Where, M_g = mass of grater (g)

g = acceleration due to gravity

Force due to cassava loaded (F_m)

$$F_m = M_m \times g \quad (18)$$

Where, M_m = mass of loaded cassava (g)

The total force (F_t) due to grater and cassava loaded into the grating machine is obtained as:

$$F_t = F_g + F_m \tag{19}$$

2.4.10 Power required to grate the cassava tubers

$$P = F_t V \tag{20}$$

Where, P = Power required to turn the shaft
V = Speed of rotation of the shaft

But, $$V = \frac{\pi DN}{60} \tag{21}$$

Where, D = Diameter of the shaft
N = Speed in revolution per minute
Therefore,

$$P = \frac{F_t \pi DN}{60} \tag{22}$$

Consider a safety factor of 1.5 for optimum performance, reliability and durability.

2.5 Fabrication and Assembly of the Machine

The main components of the machine are: the hopper, grating unit, delivery chute, the shaft, bearings, pulley, belt, frame and the power transmission unit. The conceptual views of the machine are shown in Figures 1, 2 and 3. Marking out of material was done using rule and scriber. Cutting, drilling, welding and machining operations were also done. Table 2 showed the Bill of Engineering Measurement and Evaluation (BEME) of the machine. The various components were thereafter assembled.

2.6 Testing of the Machine

The fabricated machine was tested for functionality under no load and load conditions by operating with cassava tubers. Under no load testing, the machine was run empty in order to establish that there was no functional defects. Cassava tubers were obtained at the Teaching and Research Farm of Oyo State College of Agriculture and Technology, Igboora. Under load testing, when the prime mover (electric motor) is started, it propels the shaft by transferring power via the belt-pulley transmission system. 5kg of peeled cassava tubers were washed manually and poured into the machine.A piece of wood was used to press the cassava against the drum to prevent scattering of the cassava caused by machine vibration and tubers were grated by the machine and the time taken to grate the tubers and the quantity grated were measured and recorded using a digital weighing balance. The operations were replicated three times and average weights in kilogramme and time taken in seconds were measured and recorded. At the end of the test the following parameters were determined.

2.6.1 Grating Capacity

This determines the quantity of cassava tubers grated per hour. It is obtained from equation 23 as

$$G_c = \frac{W_t}{T} \tag{23}$$

Where, W = weight of cassava tubers (kg)
T = time of grating (s)

2.6.2 Grating Efficiency

This determines how efficiently the cassava tubers are grated by the cassava grating machine. It is obtained from the ratio of weight of grated cassava mash to the total weight of the cassava tubers fed in. It is obtained from equation 25:

$$\eta_g = \frac{W_g}{W_t} \times 100 \quad (24)$$

Where, W_g = weight of grated mash (g)
W_t = weight of cassava tubers fed in (g)

3.0 Results and Discussion

The summary of results obtained from design calculation of the cassava grating machine is shown in Table 3. The machine was fabricated using locally available materials. The pictorial view of the fabricated machine is shown in plate 1. From the performance test, the values of grating capacity from three replicates were obtained as 277.38, 285.52 and 279 kg/hr while the average grating capacity was obtained as 280.63 kg/hr as shown in Table 4. This result is higher than the value of 190.93 kg/hr got by Darlene et al. (2019). In the same vein, the grating efficiency values were obtained as 92.0, 93.0 and 94.0 % with an average value of 93.0 %. This value is a little bit higher than the value of 92.4 % grating efficiency obtained by Ndaliman (2006). Percentage losses obtained from the machine were 6.0, 7.0 and 8.0 % with an average value of 7 %. This value is less than 10 % which is still reasonable. The losses are as a result of some of the grated cassava remained in the housing of the grating assembly because of the high moisture content of the cassava tubers.

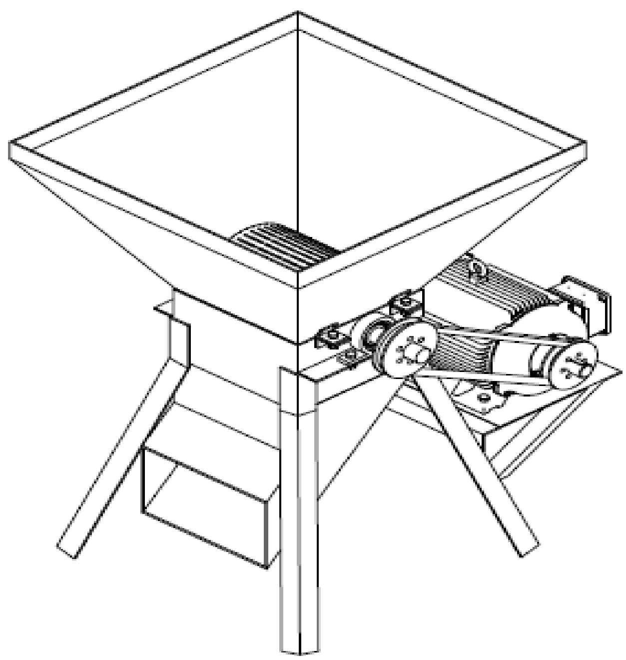

Figure 1 Conceptual view of cassava grating

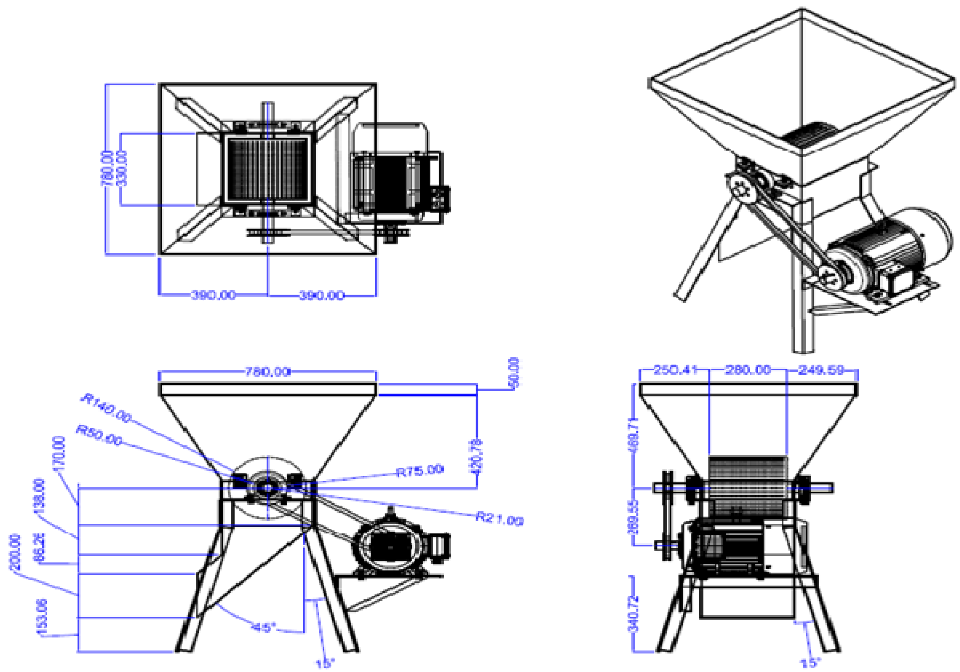

Figure 2 Orthographic view of cassava grating

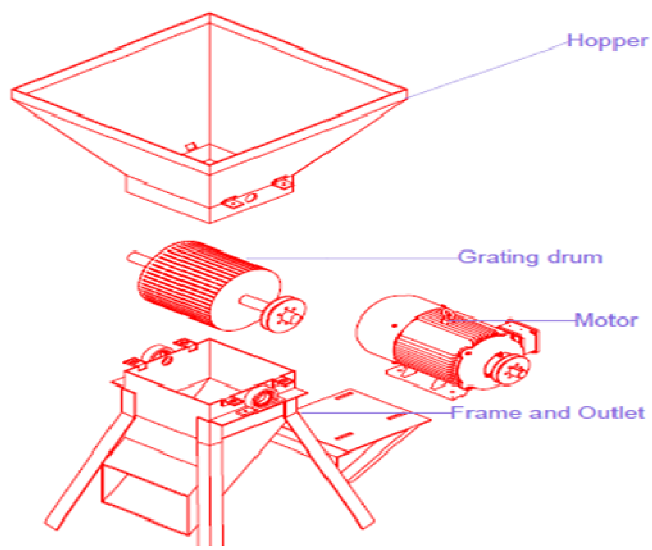

Figure 3 Exploded view of cassava grating machine

Plate 1 Pictorial view of the fabricated cassava grating machine

Table 1 Material Selection for Fabrication of Cassava Grating Machine

S/N	Part	Materials used	Criterion for selection
1	Hopper	Stainless steel	Corrosion resistance
2	Perforated mesh	Stainless steel	Corrosion resistance
3	Transmission Shaft	Stainless steel	Corrosion resistance
4	Drum	Seasoned wood	Availability and cost effectiveness
5	Pulley	Mild steel	Strength and rigidity
6	Discharge chute	Stainless steel	Corrosion resistance
7	V-belt	Rubber	Strength and flexibility
8	Electric motor	Cast iron with windings	Availability and portability
9	Bearing	Cast iron	Accommodate axial loading
10	Frame (angle iron)	Mild steel	Strength and rigidity
11	Fasteners	Cast iron	Strength and rigidity

Table 2 Bill of Engineering Measurement and Evaluation of the Machine

Material	Specification	Quantity	Unit cost (₦)	Total cost (₦)
Sheet metal (Stainless steel)	1.5 mm	1	45,000	45,000
Angle iron (mild steel)	50 ×50 mm	2	2,800	5,600
Belt	Reinforced leather	1	600	600
Pillow Bearing	Ø25 mm	2	3,000	6,000
Pulley (cast iron)	Ø 254 mm		4,000	4,000
Shaft (stainless steel)	Ø 25 mm	1	20,000	20,000
Electrode	Gauge 12 (packet)	1	3,500	3,500

Hacksaw blade		2	700	1,400
Bolt and nut	M 17	10	50	500
Bolt and nut	M 19	6	100	600
Paint (gallon)		1	4,500	4,500
Electric motor	2.5 hp	1	36,000	36,000
Transportation				18,000
Machining				10,000
Total				**155,700**

Table 3 Summary of Results of Design Calculations

S/N	Parameter	Unit	Value
1	Volume of hopper	m^3	0.3349
2	Volume of grating drum	m^3	0.3177
3	Volume of grating chamber	m^3	0.0061
4	Transmission shaft diameter	m	0.022
5	Selected shaft diameter	m	0.025
6	Speed of machine	rpm	708.0
7	Length of belt	m	1.025
8	Linear velocity of belt	ms^{-1}	7.54
9	Torque transmitted by shaft	Nm	12.38
10	Centrifugal force by electric motor	N	315.61
11	Power required to grate cassava tubers	hp	2.15
12	Selected power requirement	hp	2.50
13	Bending moment	Nm	73.26

Table 4 Grating time, grating capacity, grating efficiency and percentage loss of the cassava grating machine

Wt of cassava tubers (kg)	Wt of grated cassava mash (kg)	Grating time (s)	Grating capacity (kg/hr)	Grating efficiency (%)	Percentage loss (%)
5.0	4.70	61.00	277.38	94.0	6.0
5.0	4.60	58.00	285.52	92.0	8.0
5.0	4.65	60.00	279.00	93.0	7.0
Mean	4.65	59.67	280.63	93.0	7.0
SD	0.002	1.556	9.742	0.667	0.667

4.Conclusion

A cassava grating machine was designed, fabricated and tested and found to have a grating capacity of 280.63 kg/hr and sifting efficiency of 93.0 %. The design analysis revealed that the machine was successfully designed and could be fabricated for commercialization. The results obtained from the performance test carried out on the grating machine showed that it could be used efficiently and effectively for grating cassava tubers.

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DETERMINATION OF MASS TRANSFER PARAMETERS DURING DEEP-FAT FRYING OF FRIED MELON CAKE *(ROBO)*

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Abstract

In this investigation, the mechanism of mass (moisture and fat) transfer during deep-fat frying of '*robo*' (fried melon cake) was carried out. The plots of dimensionless concentration ratios against time were used to determine moisture transfer parameters (moisture diffusivity, moisture transfer coefficient, moisture transfer Fourier number, moisture transfer Biot number and activation energy) and fat transfer kinetic parameters (rate constants and activation energy) at different frying temperatures of 140, 155 and 170°C.All moisture parameters increased linearly with frying oil temperatures except moisture transfer Biot number which deceased linearly with increase in temperature with correlation coefficient (R^2) ≥ 0.99. There was also positive linear relationship between fat transfer rate constant and frying temperatures (R^2 ≥ 0.99). An Arrhenius type of relationship was found between temperature and the effective moisture diffusivity and fat transfer rate constant (R^2≥0.99) with activation energies values calculated as 25.66 and 42.18 kJ/mol, respectively. Both moisture loss and fat desorption after initial adsorption of 60 seconds were adequately modeled by the first-order kinetics adopted with high correlation coefficient (R^2) value and were time and temperature dependent as revealed by Arrhenius analysis performed on the experimental data.

Keywords: Activation energy, Arrhenius relationship, Deep-fat frying, 'Robo', Moisture and fat transfer.

1. Introduction

Fried melon cake ('*Robo*') is a local snack in Western Nigeria processed from the cake of wild watermelon (*Colocynthis citrullus* L.) popularly known as egusi among the populace after mechanical expression of its oil (Schipper et al. 2002; Akinoso and Are 2018). It is a nutrient-rich snack that contains protein and some essential amino acids that could complement the cereal or starch-rich meals by supplying the necessarily needed proteins (Jimoh and Adedokun 2014; Adeyeye et al. 2020). The processing involves roasting, sorting, cleaning, milling, kneading/oil expression, molding, frying and packaging (Akinoso and Are 2018).

Immersion frying or deep-fat frying is an important step in the processing of fried melon cake. It is a process that involves desirable improvement in the eating qualities (organoleptic characteristics) such as smooth mouth feel, distinct flavor, color, texture, and palatability of foods (Adedeji et al. 2009; Franklin et al. 2013). According to Franklin et al. (2013), deep-fat frying is a cooking process that involves both simultaneous heat and mass transfer process in which food is immersed in edible oil at a temperature above the boiling point of water contained in that food (Farinu and Baik 2005). By convection, heat is transferred from the hot oil to the food surface and through the body to the centre through conduction. As the product approaches the boiling temperature of water,

moisture vaporizes and exits the product by diffusion, while fat enters or leaves the food product to or from the surrounding medium depending on whether the food is non-fatty or fatty foods (Ateba and Mittal 1994).
Debnath et al. (2009) identified three types of mass transfer in food during deep-fat fring, namely, (1) moisture transfer from the center of food towards the surface, (2) edible oil transfer to and/or from in the fryer environment, and (3) liquefied components transfer in the form of leaching from the food towards the fryer environment.

Presently, '*robo'* is traditionally produced in batches using rudimentary utensils (Akinoso and Are 2018) and thus, the processing needs to be upgraded to standard level that will encourage full commercialization. The fundamental knowledge of mass (moisture and fat) transfer parameters as functions of temperature cannot be overemphasized in designing, modeling and process optimization of deep-fat frying of foods (Mosavian and Karizaki 2012; YildIz et al. 2007). These parameters including effective moisture diffusivity, activation energy, moisture transfer Biot number, moisture transfer coefficient and rate constant are needed in elucidating the dynamics of the process and predicting the rate of mass transfer during deep-fat frying process (Farinu and Baik 2005). In spite of the high spate of use of frying as a technique in food processing, researches about the afore-mentioned engineering aspects have been limited. In addition, tremendous efforts had been made on quantitative determination of mass transfer parameters of fried snack foods such as potatoes chips and French fries, tortilla chips, beef (Ateba and Mittal 1994; Yıldız et al. 2007), pork (Sosa-Morales et al. 2006) and chicken products (Adedeji et al. 2009), cassava chips (Vitrac et al. 2002), tofu (Baik and Mittal 2000), rice cracker (Mosavian and Karizaki 2012), donuts (Vélez-Ruiz and Sosa-Morales 2003), sweet potatoes (Taiwo et al. 2007). However, information about these important engineering parameters of the promising product that can be exploited for food and/or nutrition securities among the populace that consumed it and beyond is practically absent in literatures.
Therefore, the objective of this present study was to determine mass (moisture and fat) transfer parameters such as effective moisture diffusivity (D_m), activation energy (E_a), moisture transfer Biot number (N_{Bi}), moisture transfer coefficient (k_m) and rate constant (k) of DFF of '*robo*' at different frying temperatures.

2. Materials and Methods

Preparation of the melon meal balls

The traditional method as described by Akinoso and Are (2018) was adopted in the preparation of 'robo' (fried melon cake) with some modifications: Shelled melon kernels were dry-cleaned to remove extraneous materials like stone, figs, leaves, immature kernels, etc. and heat-treated (roasted) in a hot pan at 100^oC for 9 minutes. During roasting there was development of flavour (improved eating quality) and coagulation of proteins that made the expression of oil easy in subsequent operations. Thereafter, the roasted kernels were further sorted and cleaned by winnowing to remove majorly any burnt kernels. The roasted melon kernels were milled using an electric plate attrition mill into a paste followed by kneading for 40 minutes in presence of hot wat in which spices and seasonings (dry pepper, onions, and salt) have been previously soaked. After oil expression, 12 g of the resultant cake was molded manually into spherical shape (balls) of average size of 25 mm, the balls were packaged in a low-density polythene bag and stored in a refrigerator until further use.

Frying experiments

Deep-fat frying experiments were performed according to the method described by Franklin et al. (2013) and Torres et al. (2018) with some modifications. A thermostatically-controlled mini fryer of 3-L oil capacity heated by 2-kW electric coils at the bottom of oil tank pre-set at 140, 155 and 170 ± 2 °C with no agitation was used for all frying experiments. Commercial soybean oil obtained from a supermarket in Ogbomoso was added to augment the expressed oil from melon to make up required volume for frying experiments. Twenty pieces of melon meal balls each of melon meal balls were immersed into 3000 ml hot oil at different temperatures to give an average oil-to-melon meal balls ratio of 12.5 to avoid fluctuations in oil temperatures when the melon meal balls were first introduced into the oil and throughout the experimentations. The melon meal balls were submerged with the help of a stainless-steel basket, which was covered with a grid of the same material to ensure total immersion of the samples. The oil temperatures were ascertained to be at each pre-set conditions by inserting a stainless-steel k-type thermocouple probe into the oil. The temperature of the oil was recorded at 10-seconds interval throughout the experiments (10 minutes) through K-type thermocouples connected to a data acquisition system (INTECH Micro 2100-A16 Rev 1.3) and a PID controller (RKC HA 900 Instrument). Oil in the oil bath was replaced after one hour of frying so that the oil properties will not be significantly different throughout the experiments.

Samples for determination of moisture and fat contents of FMCs were removed at 30-s interval for the first 2 minutes, followed by 60-s (8 minutes) and 60 seconds interval. Oil adhering to fried MMCs were allowed to drain out in a stainless-steel wired basket lined with tissue paper immediately after frying.

Determination of moisture and fat contents

Whole fried melon cakes were collected at different time intervals were grounded separately in a mortar with pestle. The moisture and fat contents of the samples at different time intervals were determined using air-convective oven drying method and Soxhlet fat extraction method, respectively (AOAC, 2005).

Model Development

Model Assumptions

The followings were assumed for the development of mathematical models to simplify for analytical solution:

i. The initial moisture and fat contents of fried melon cakes were uniform throughout the sample.
ii. The sample was homogeneous, isotropic, and spherical with constant dimensions throughout frying.
iii. One-dimensional unsteady-state mass transfer was in the radial direction.
iv. No internal heat generation in the product.

Determination of moisture transfer data

The partial differential equation modeling diffusion of water in solids as a function of time and location in a spherical coordinate (Bird et al., 2001; Franklin et al., 2013) was:

$$\frac{\partial m}{\partial t} = D_m\left(\frac{\partial^2 m}{\partial r^2} + \frac{2}{r}\frac{\partial m}{\partial r}\right) \quad (1)$$

where m, D_m and r are moisture content, effective moisture diffusivity (m^2/s) and radial distance from the centre of food sample. The following were the initial and boundary conditions:

$$m = m_i \text{ at } t = 0 \text{ for all } r; \ \frac{\partial m}{\partial r} = 0 \text{ at } r = 0; \ D_m\frac{\partial m}{\partial r} = k_m(m_t - m_0) \text{ at } r = R \text{ for } t \geq 0 \quad (2)$$

where "m_i" was the initial moisture content, "m_t" was the moisture content with respect to time, "m_o" was the moisture content of oil and "k_m" was the moisture transfer coefficient.

$$m(r,t) = \sum_{n=1}^{\infty} m_n \sqrt{\frac{2}{\pi\mu_n}} r^{-1} \sin(r\mu_n) e^{-D_m \mu_n^2 t} \quad (3)$$

where,

$$m_n = \sqrt{\frac{\pi\mu_n}{2}} (m_i - m_\infty) \frac{\left(\frac{\sin(r_0\mu_n}{\mu_n^2} - \frac{r_0 \cos(r_0\mu_n)}{\mu_n}\right)}{\left(\frac{r_0}{2} - \frac{\sin(2r_0\mu_n)}{4\mu_n}\right)} \quad (4)$$

μ_n is the root of the characteristic equation for a spherical solid, given by:

$$1 - r_0\mu_n cot(r_0\mu_n) = \frac{k_m r_0}{D_m} \quad (5)$$

According to Crank (1975), the first term of infinite analytical solution of equation 1 suffices if the moisture transfer Fourier number ($N_{Fo}=\frac{kD_m t}{r_0^2}$)is greater than 0.1 as simply expressed by Eq. (5):

$$\frac{m(r,t) - m_\infty}{m_i - m_\infty} = \frac{\left(\frac{\sin(r_0\mu_1}{\mu_1^2} - \frac{r_0 \cos(r_0\mu_1)}{\mu_1}\right)}{\left(\frac{r_0}{2} - \frac{\sin(2r_0\mu_1)}{4\mu_1}\right)} \times \frac{\sin(r\mu_1)}{r} e^{-D_m \mu_1^2 t} \quad (6)$$

The average moisture content at time t is given by:

$$\overline{m}(t) = \frac{1}{V} \int_0^v m(r,t) dV \quad (7)$$

Where V is the volume of the sphere. By integrating $m(r, t)$ throughout the whole volume, the equation for average moisture content ($m(t)$) in a spherical solid is obtained:

$$MR = \beta e^{-D_m \mu_1^2 t} \quad (8)$$

where,

$$MR = \left(\frac{m_t - m_o}{m_i - m_o}\right) \quad (9)$$

and $$\beta = \frac{6\left(sin(r_0\mu_1) - r_0\mu_1 cos(r_0\mu_1)\right)^2}{(r_0\mu_1)^3 \left(r_0\mu_1 - sin(r_0\mu_1)cos(r_0\mu_1)\right)} \quad (10)$$

Taking the natural logarithm of both sides of Eq. (5) to linearize the equation as follows:

$$LnMR = Ln\beta - D_m \mu_1^2 t \quad (11)$$

or $$Ln\left(\frac{m_t - m_o}{m_i - m_o}\right) = Ln \frac{6\left(sin(r_0\mu_1) - r_0\mu_1 cos(r_0\mu_1)\right)^2}{(r_0\mu_1)^3 \left(r_0\mu_1 - sin(r_0\mu_1)cos(r_0\mu_1)\right)} - D_m \mu_1^2 t \quad (12)$$

Plotting ln MR against time, the intercept and the slope of the graph are equated to Lnβ and $-D_m \mu_1^2$, respectively. Two-step determination of the effective moisture diffusivity was carried out, firstly from the intercept of Ln (MR) versus time plot β from equation 7, the first root of the characteristic equation (μ_1) was calculated. Secondly, from the slope of the same plot, the effective moisture diffusivity was determined. Dimensionless mass transfer Biot number and mass transfer coefficient were calculated from the analytical solution of the first term of equation 1 as:

$$Bi = 1 - r_0\mu_1 cot(r_0\mu_1) = \frac{k_m r_0}{D_m} \quad (13)$$

Determination of fat transfer data

Oil transport was modeled according to the method adopted by Franklin et al. (2013) using the fractional conversion first-order reaction kinetic model with some modifications as expressed below:

$$\frac{f_t - f_e}{f_i - f_e} = k_o exp - kt \tag{14}$$

where, "f_t" was the average fat content at any given time, (gfat/gDM), "f_i" was the average initial fat content, (gfat/gDM), "f_e" was the equilibrium fat content i.e., fat content at the end of frying at 170^{o}C (minimum), "k" was the reaction rate constant (s^{-1}) at a particular temperature, k_o was the frequency factor (/s) and "t" was the frying time (seconds). The first order kinetic model was used because in Fig. 2 the plot of concentration of fat content of fried melon cakes against time is logarithmic in nature which is typical of first order processes. The temperature dependence of rate constant was described using the Arrhenius relationship:

$$lnk = lnk_o - \frac{E_a}{R_g}\left(\frac{1}{T}\right) \tag{15}$$

where, k_o is the frequency factor (/s), E_a is the activation energy, (kJ/mol) and R_g was the universal gas constant (8.314 x 10^{-3} kJ/mol K).

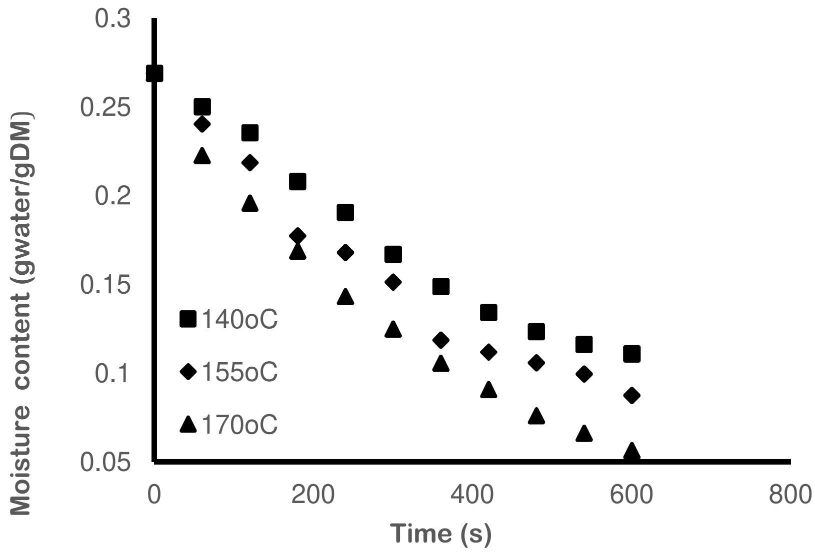

Fig. 1 Average moisture content of '*robo*' during deep-fat frying at different temperatures

3. Results and Discussion

Changes in moisture, fat and weight of robo during frying.

Fig. 1 shows the experimental results of changes in moisture as a function of frying time for *robo* dough fried at different temperatures. When the dough was exposed to frying, the moisture concentration decreased from the initial moisture content of 26.90% (d.b.) to 10.69, 9.58, 8.96% (d.b.) at 140, 155 and 170^{o}C, respectively.

Moreira et al. (1997) and Krokida et al. (2001) also reported the same trend that lower final moisture content was associated with higher frying temperatures. The loss of moisture was

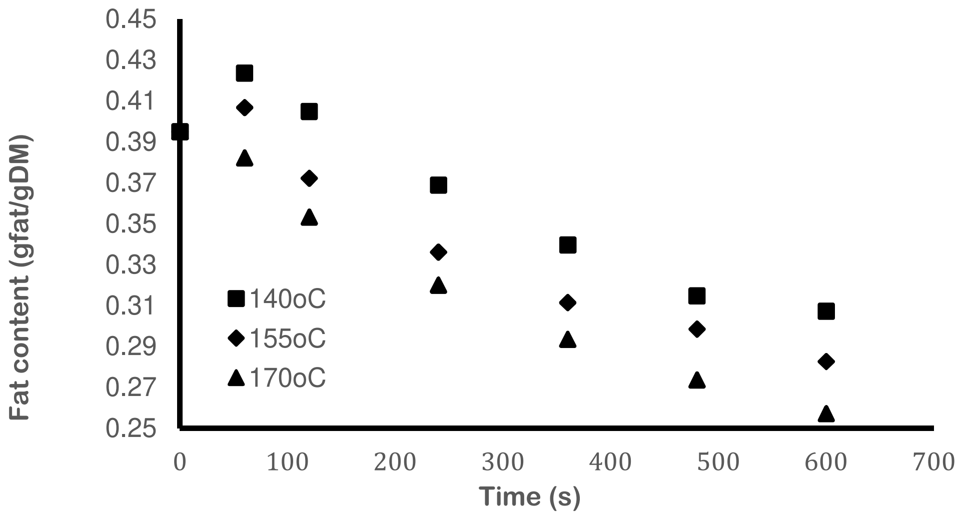

Fig. 2 Average fat content of '*robo*' during deep-fat frying at different temperatures

not as rapid as was observed in other foods especially moisture-ladened foods such as chicken strips (Ve´lez-Ruiz et al. 2002), sweet potato (Taiwo et al. 2007), pork (Sosa-Morales et al. 2006), rice crackers (Mosavian and Karizaki, 2012) with high moisture content (≥70% w.b.). Therefore, the turbulence that is common occurrence at the beginning of frying was not as vigorous as in deep-fat frying process of other foods. However, this does not stop formation of crust layer on the outer surface of *robo* which acts as a barrier to subsequent moisture diffusion once it is formed (Yamsaengsung and Moreira, 2002). This is attributed to the very low moisture content of the melon kernel (Oyolu, 1977b) which is the major ingredient in the formulation of '*robo*'. The little moisture loss can be traced to the water added to convey other ingredients during preparation and pressing.

It is an already established phenomenon that fat/oil is adsorbed in the voids and/or capillaries created by moisture diffusion during cooling after removal of foods from hot oil (Guillaumin, 1988; McDonough et al.1992). This was observed in oil adsorption phase of deep-fat frying of *robo* that lasted for the first 60 seconds during which the fat content rose from 31.12%w.b. (0.395 d.b.) up to 33.98%w.b. (0.425 d.b.), 32.79%w.b. (0.407 d.b.) and 31.26%w.b. (0.383 d.b.) at 140, 155 and 170°C, respectively followed by desorption phase which lasted the remaining period of frying Fig. 2). This is in agreement with the report for meatball (Ateba and Mittal 1994) that frying oil was adsorbed during the first 60 s before commencement of desorption phase, this could be traced to the lag period took by the dough to attain the temperature that favour desorption of the oil (30 – 60°C). Thereafter, the decrease in fat contents at all temperatures was also reported by Ateba and Mittal (1994) for deep-fat frying of meatball which was attributed to partly decrease in viscosity and density of oil in the food at temperatures above 30°C (Bengtsson 1975), denaturation of meat proteins and resultant increase in pressure that favour flow of fat from lower to higher concentrations.

However, the initial fat adsorption did not cause increment in weight of robo dough throughout the period of frying (Figure 3) because moisture was being lost faster than fat at all temperatures which was also experienced by Ateba and Mittal (1994).

Moisture transfer parameters

Table 1 shows the moisture transfer parameters at different frying temperatures. As frying temperature increased, the moisture diffusivity values increased linearly ($R^2 \geq 0.98$) from 1.019×10^{-7} to 1.694×10^{-7} m²/s (Fig. 4), indicating that maximum diffusion of moisture occurred at 170°C. These findings are in accordance with the literature data on frying of various foods (Pandey et al. 2008, Yıldız et al., 2007). The variations of moisture diffusivity with temperature followed Arrhenius relationship as shown in Fig. 5. Activation energy from the Arrhenius plot was found to be 25.66 kJ/mol (R^2 = 0.996), which falls within the range of activation energies reported

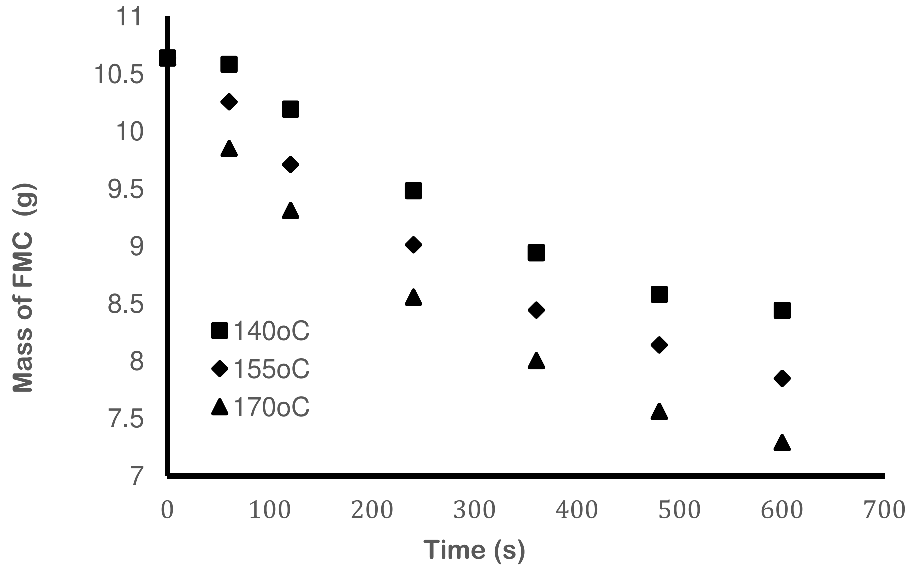

Fig. 3 Average weight of '*robo*' during deep-fat frying at different temperatures

by McMinn and Magee (1996) for drying of potato cylinders and Franklin et al. (2013) for deep-fat frying of *gulab jamun*.

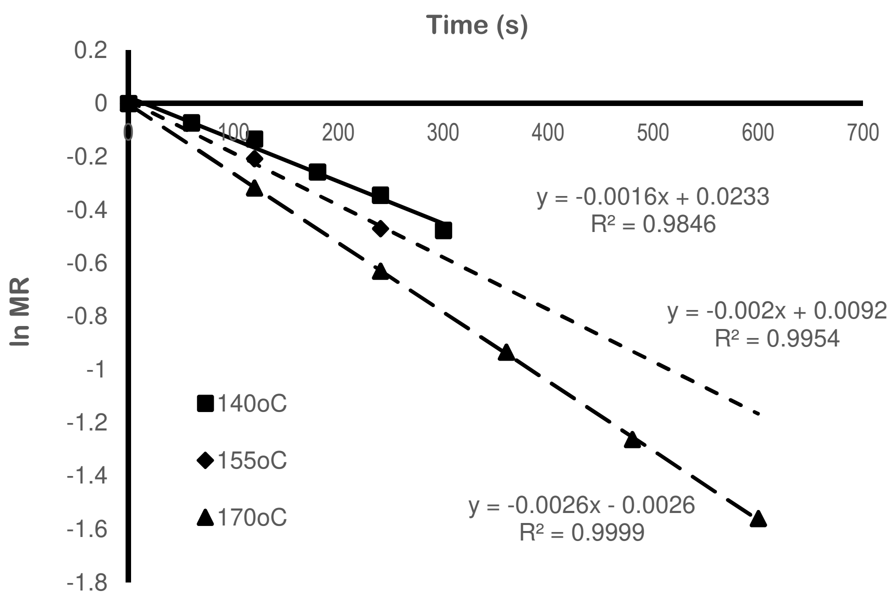

Fig. 4 Dimensionless moisture ratio vs time plots obtained during frying of 'robo'

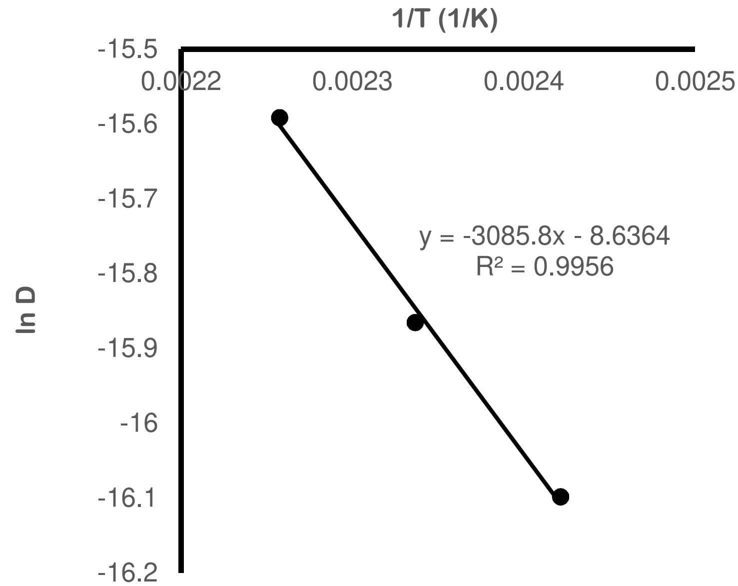

Fig 5 Arrhenius plot of moisture diffusivity of DFF of 'robo'

Calculated moisture transfer coefficient values are shown in Table 1 which ranged from 8.09 to 13.09 x 10^{-6} m/s within the temperature range investigated. These are similar to those reported by Dincer (1996), Franklin et al. (2013) and Mosavian and Karizaki (2012) for DFF of potato (5.98 x 10^{-7} m/s), *gulab jamun* (10.41 – 14.35 x 10^{-6} m/s) and rice crackers (5.51 – 9.31 x 10^{-6} m/s), respectively. Mass transfer coefficient during deep-fat frying of fried melon cake increased with frying temperatures within the domain investigated. The temperature dependency of moisture transfer coefficient was evaluated and there is linear relationship between the variables as it is validated by high correlation coefficient (R^2=0.993) as expressed by Eq. 15:

$$k_m = 1.67 \times 10^{-7}T - 1.54 \times 10^{-5} \qquad (15)$$

Table 1 also shows the outcomes of the determination of moisture transfer Biot number which decreased linearly with increase in temperature range investigated. The values are consistent with those in existing literatures (Franklin et al. 2013; Kashaninejad et al. 2007; Mosavian and Karizaki 2012; YildIz et al. 2007).
The thermal dependency of moisture transfer Biot number is as expressed by Eq. 16:

$$N_{Bi} = 8.48 \times 10^{-4}T - 1.11 \qquad (0.999) \qquad (16)$$

These values fall within the range for finite internal and external restriction to moisture transfer i.e., Biot number of 0.1 and 100 (Singh and Heldman 2009).

Table1 Moisture transfer parameters for deep fat frying of ‘robo’ (FMC)

Temperature (°C)	D_m (x10^{-7} m²/s)	N_{Fo}	N_{Bi}	k_m (x10^{-6} m/s)
140	1.019	0.392	0.992	8.09

155	1.287	0.492	0.980	10.09
170	1.692	0.649	0.967	13.09

Fat transfer parameters

Table 2 Arrhenius model parameters for moisture and fat transfer of deep-fat frying of 'robo'

Temperature (°C)	Moisture transfer			Fat transfer			
	D_o (m²/s)	E_a (kJ/mol)	R^2	k (/s)	k_o (/s)	(E_a) (kJ/mol)	R^2
140				0.0023			
155	-8.64	25.66	0.996	0.0031	6.16	42.18	0.96
170				0.0053			

Fat transfer parameters of *robo* as exuded by chemical kinetics and as affected by frying temperatures are as shown in Table 2 and Fig. 6 and 7. The fat depletion increased throughout the time of frying at all temperatures the initial uptake up to 60 seconds. The decrease was logarithmic in nature and therefore, follows a first-order kinetics (Singh and Heldman 2009). The final fat content was inversely proportional to the frying temperature (Fig. 2), which was consistent with the results for donuts (Vélez-Ruiz and Sosa-Morales 2003), for *gulab jamun* (Franklin et al. 2013). According to Franklin et al. (2013), low frying temperatures and thus weak water outflow led to the formation of surface crust with a structure more favorable to oil absorption. In other words, higher frying temperatures produced harder and tougher crust, promoting an increased resistance and reduced surface diffusivity for fat adsorption (Moyano and Berna 2002). The fat desorption at all temperatures was adequately described by fractional conversion first-order kinetics ($R^2 \geq 0.986$). The activation energy for loss of fat was calculated as 42.12 kJ/mol. The rate constant increased from 2.33×10^{-3} to 5.52×10^{-3} /s as the frying temperature increased from 140 to 170°C (Table 2 and Fig. 7). This trend was contrary to the outcomes of Franklin et al. (2013) that the rate constant decreases as the frying temperature increases. It could be attributed to desorption which happened for larger period of frying rather than the adsorption that was reported by these investigators. However, as expected in both cases, higher temperatures resulted into low final moisture and fat contents which was corroborated by the works of other investigators (Sosa-Morales et al. 2006; Taiwo et al. 2007).

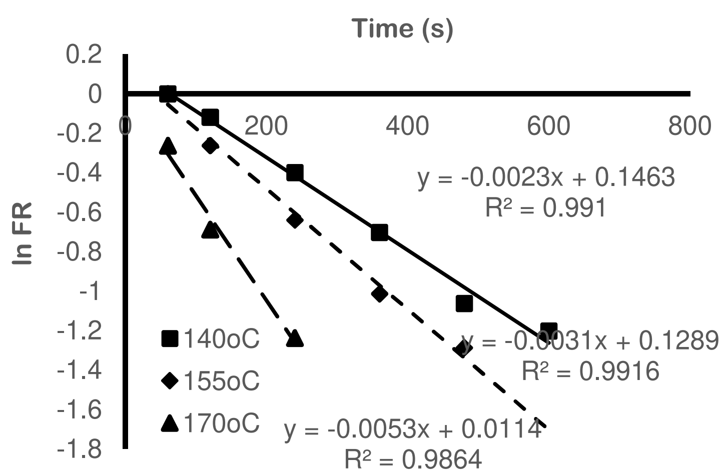

Fig 6. Dimensionless fat ratio vs time plots obtained during DFF of '*robo*'

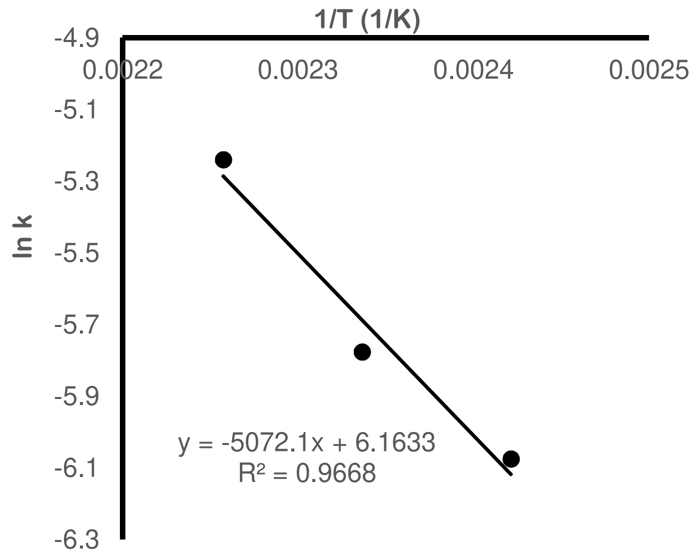

Fig. 7 Arrhenius plot for fat transport of DFF of 'robo'

4. Conclusion

In this work, mass transfer during deep-fat frying of robo was investigated by experimental and analytical methods to determine parameters for process design. The method is based on the measurement of the time-dependent moisture and fat contents of the dough employing Fick's second law equation for 'robo' dough geometry (spherical shape) and fractional conversion first-order kinetics, respectively. The moisture transfer parameters determined increased except Biot number which decreased with increase in temperature and all have linear relationship with temperatures within the domain investigated. The fat desorption after initial adsorption of 60 seconds was adequately modeled by the fractional conversion first-order kinetics adopted with high correlation coefficient (R^2) value and was time and temperature dependent as revealed by Arrhenius analysis performed on the experimental data.

Conflict of Interest

The authors have no conflicting interests, financial or otherwise.

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LEAPFROGGING AFRICA'S AGRICULTURE AND FOOD SYSTEMS FOR SUSTAINABLE DEVELOPMENT: CHALLENGES AND OPPORTUNITIES.

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Abstract

Africa's population is growing fast and is expected to reach about 2.6 billion by 2050. This requires up to a 70% increase in agriculture and food production to meet the population's needs, a serious challenge for agriculture and the food system. These requirements are the intervention of innovations such as new technologies and artificial intelligence to meet the changes needed in the agriculture and food systems sector against the backdrop of resource depletion, climate change, the COVID19 pandemic, and very demanding socio-economic speculation; without which, it will be difficult to achieve without it. The overall goal of the paper is to advance the understanding of the scenario in Africa's agriculture and food systems, identify the challenges and gaps, explore the role of emerging innovative technologies such as artificial intelligence, and proffer solutions to these challenges. Critical sectors that need urgent attention are the preproduction, production, processing and distribution of agriculture and food systems in Africa. Infrasctrural inadequacies, gender imbalance, policy and institutional lapses, and lack of capacity and synergy in science, research, and innovation practices inhibit progress in sustainable food production. A critical pathway to leapfrog Africa's Agriculture and food systems to meet the demand of the growing population and the challenges of climate change is the use of artificial intelligence in agriculture and food production. Hence, Africa's agricultural stakeholders must put up innovative infrastructure financing, ensure gender support and inclusion in all critical sectors, empower youths, and support the development, deployment and scale-up of homegrown artificial intelligence (AI) for agriculture and food systems research. An identified challenge to AI use is the responsibility and capacity that comes with the adoption of new technologies. Hence, an extensive study was recommended on challenges and opportunities in the development, deployment, and scale-up of responsible AI in Africa's agriculture and food systems.

Keywords: Artificial Intelligence, Sustainable Development, Agriculture, Utilization, Access, Stability.

1. Background and Rationale for the Agriculture and Food System Research in Africa

Agricultural and food systems worldwide will face significant challenges in the coming decades. Demand for food continues to grow rapidly due to a variety of factors. The current population estimate for 2050 is between 7.96 billion and 10.46 billion; the average estimate is 9.19 billion (Thornton et al., 2011). Continued population growth could be a significant obstacle to improving food security in some countries, even if the world's population stabilises sometime in the present century. Food demand is also highly dependent on urbanisation.

Now more people live in cities than in rural areas. The next few decades will be marked by unprecedented urban growth, especially in Africa and Asia. Urbanisation has a significant impact on food consumption patterns but is not necessarily associated with a reduction in food insecurity (Thornton & Herrero, 2015). Recent data from South Africa point to both chronic poverty and food insecurity in a survey of 11 cities (Mbow et al., 2014). A third key factor influencing food demand is income growth. Between 1950 and 2000, global per capita income increased at a rate of 2.1% per year (Thornton & Herrero, 2015). As income increases, food consumption patterns change, often consuming more meat, fat and sugar (Tittonell et al., 2020). Prospects for future economic growth vary considerably but are expected to continue. Fourth, the agricultural production sector is increasingly oriented towards a global diet. Supermarket retail growth is growing at an annual rate of 20% in some countries, and this growth will continue for decades to come as urban consumers demand more processed foods and move agricultural production systems from farms to business chains (Gerbens-Leenes et al., 2010).

After decades of lethargy, much of Africa is experiencing rapid economic transformation. Half of the world's ten fastest-growing economies are in sub-Saharan Africa (Shiferaw et al., 2014). Africa's dynamism has spawned efforts to identify the 'megatrends' driving the region's economic growth and anticipate the future opportunities and challenges associated with these trends. Among the most frequently cited trends is the rise of the African middle class, rapid urbanisation and consequent shifts in food demand and downstream modernisation of agriculture and food systems (Tschirley et al., 2015), a rapid shift in the labour force from farming to non-farm jobs, and rising global interest in African farmland (Minde et al., 2015). Agriculture remains the bedrock of sustainability of African economies, where it plays a key part in long-term economic growth and structural transformation, though it may vary by country (Batlle-Bayer et al., 2020). In the past, agricultural activities were limited to food crop production, but in the last few decades, it has evolved to encompass the food systems comprising the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded (Food and Agriculture Organization [FAO], 2018). Agriculture and food systems (AFS) provide the essential source of livelihood, improving Gross Domestic Product (GDP) (Oyakhilomen and Zibah, 2014), being a source of national trade, reducing unemployment, providing raw materials for production in other industries, and overall development of economies (Awokuse, 2009). That notwithstanding, AFS still fails to supply the required food needs of the developing regions, especially in Africa. According to FAO et al. (2020), food security is not improving in Africa. While about 795 million people are undernourished globally, including 90 million children under the age of five (FAO, International Fund for Agricultural Development [IFAD] and World Food Programme [WFP], 2015), the vast majority of them totalling 780 million people, live in the developing regions, notably in Africa and Asia (United Nations Conference on Trade and Development [UNCTAD], 2017). In particular, sub-Saharan Africa (SSA) shows high values, with almost 25% of the population undernourished (FAO et al., 2015).

Even more perplexing, the required increases in food production will have to happen simultaneously as the climate is changing and as climate variability increases. Potential impacts of climate change on agricultural production in SSA have been assessed in several modelling lessons, using approaches grounded in an understanding of both crop and climate science (Gevelt, 2020)

The inability of African countries especially SSA to feed their population pose greater challenges to their development. The agricultural sector in the region is characterised by excessive dependence on primary products, Low fertility soil, minimisation of external agricultural input use, environmental degradation, serious pre-and post-harvest losses, low yields, minimal value addition, and inadequate food storage and safeguard that result in significant commodity price fluctuations. In 2020, the COVID-19 plague, as well as unprecedented desert locust outbreaks in Eastern Africa, have exacerbated financial prospects in ways no one could have expected, and the condition may only deteriorate if unparalleled action is not put in place (FAO et al., 2020). These challenges occur mainly because of poorly developed and non-adoption of good mixes of low to high technologies by small-scale farmers who form the bulk of the farming population in Africa (Ozor and Urama, 2013). With the current geometric rise in Africa's population estimated to reach about 2.6 billion by 2050 and a growth rate of more than 2.5% p.a. (Population of Africa, 2019), it becomes imperative that agriculture and food systems are reviewed to embrace innovative approaches for sustaining and improving the system from production to utilisation. One of the most promising ways for achieving this target is through science, technology and innovation (STI) (Ozor and Urama, 2013; UNCTAD, 2017). STI is recognised as a means for achieving the sustainable development goal (SDG) 2 (End hunger).

The paper aims to advance the understanding of the scenario in Africa's agriculture and food systems, identify the challenges and gaps, explore the role of emerging innovative technologies such as artificial intelligence, and proffer solutions to these challenges.

2.0 Challenges to sustainable agriculture and food systems in Africa

Agricultural and food systems development in SSA countries face significant challenges. Although the world population is projected to reach 9.7 billion by 2050, more than 50% of this increase is expected to occur in Africa, becoming an increasingly important driver of food demand. However, African agriculture's potential to meet growing food demand due to population growth is limited by several factors. Africa is experiencing declining farm size due to growing agricultural populations, traditional land inheritance practices, rapid urbanisation, and arable land conversion to expand urban housing, industry, roads, and other Infrastructure (Jayne et al., 2014). In addition, climate change is a global phenomenon that affects agricultural productivity in all parts of the world by causing altered weather patterns, more extreme weather events, drought, disease and pest change; however, its degree of adversity depends on the adaptability of farmers (Gornall et al., 2010). For example, projections show that in SSA, a 1°C increase in temperature could lead to a significant reduction in income from upland crops ($27/ha) and livestock ($379/farm), but income from crops irrigated crops (US$30/ha) increased again) (Kurukulasuriya et al., 2006). Thus, in response to the increase in temperature, irrigated agriculture has mitigated the loss of income due to the reduced productivity of dryland agriculture. However, irrigation requires a significant capital investment that most African farmers cannot afford.

The increasing demand for agricultural products in the supply chain is a crucial driver of increased productivity, agricultural transformation, and increased household income. Despite the increase in supermarket retailing in several countries in Africa, farmer participation in the market is still constrained by food safety standards, weak Infrastructure, weak institutions and high transaction costs (Shiferaw et al., 2011). Considering that a high portion of the projected increase in world population by 2050 is predicted to return from SSA, the origination of this growth during a limited-resource setting might be considered a risk for development. However, unlike other parts of the planet where the population transition has already occurred, SSA countries are at the first stage of population shift. The demographic configuration is characterised by a high proportion of the population at economically favourable ages. For instance, in 2015, the working-age (25-64 years) group reached 36.2 % of the population and grew sooner than in other parts of the planet (UNECA, 2016). The projected demographic bonus in SSA could reach 11–15% of the GDP growth by 2030 and contribute to 40–60 million fewer poor during an equivalent period (Ahmed et al., 2016). Sub-Saharan African countries are undergoing rapid urbanisation and income growth. Urbanisation and income growth are happening amid changes in dietary patterns. Another example, in Asia in response to income increments, consumption has shifted from rice to wheat and then to livestock (Pingali, 2007). Additionally, urbanisation and income increase produce higher per capita consumption of animal source foods, stimulating growth within the livestock sector (Speedy, 2003; Randolph et al., 2007). People will follow healthier eating styles like increasing their intake of fruits and vegetables.

Furthermore, tendencies and total expenditure for food consumption far away from home will rise (Ma et al., 2006). These circumstances will create demand for the agricultural sector to extend production of an outsized volume of varied food crops and animal source foods, which will again support the expansion of recent supermarkets and the development of restaurants. On the other hand, urbanisation and income growth could shift nutritional habits to a typical "western diet" characterised by increased inclusion of processed foods, meat, more fats, and sugar linked to chronic diseases (Popkin et al., 2011). This dietary transition is happening in developing countries, thus posing everyday challenges of over-nutrition (Abdullah, 2015). the value of overnutrition is not insignificant. Medical and economic costs of obesity in the US in 2014 were estimated to be $1.4 trillion (Waters and De Vol, 2016). Similarly, in developing countries, non-communicable disease contributes to 33% of disability-adjusted life years (DALYs), and this percentage is projected to extend to 45% within the year 2030 (Bygbjerg, 2012).

Many problems face Africa's agriculture and food systems (AFS) sector that require urgent interventions to meet SDG 2 by 2030. The trials facing agriculture and food systems in Africa are classified as agro-based and non-agro-based challenges. Agro-based problems of availability, access, utilisation, and stability affect production, processing, storage, and distribution. Non-agro-based problems are not associated with the four basic agricultural operations but indirectly limit access and increase production potentials. This section discusses the problem areas where there is a need for immediate interventions. Ben-Ayed and Hanana (2021) identified four problem categories in agriculture and food systems: preproduction, production, processing and distribution. In the same vein, the UNCTAD (2017) and FAO (2019) align with the four dimensions of food security: availability, access, use/utilisation, and stability to identify the key problem areas where technical or technological solutions are applied in AFS. For ease of administration and management, the Hub shall adopt the UNCTAD and FAO classification to analyse these problem areas.

2.1 Agro-based challenges

2.1.1 Availability: **Addresses whether or not food is really or potentially substantially present, as well as features of production, food reserves, markets and transportation, and wild foods.**

- ***Low agricultural production and productivity:*** Companies and people in African countries are still utilising rudimentary and obsolete equipment, tools and outdated technologies in their production systems thereby leading to low agricultural productivity, wastage of raw materials and resources, and generation of excessive wastes. Agricultural production and productivity in Africa remained lower than in the rest of the world (Bjornlund et. al, 2020). This is attributed to factors inherent to Africa and its people, such as climate, soil quality, use of crude implements, low-value addition and pests and diseases. Breeding activities by classical methods take years to establish new crop varieties. Farming practices and extension service delivery are still rudimentary. This increases productivity and more efficient power utilisation and reduces wastage in production systems. Productivity in AFS in much of Africa has long been a concern, both because of the low levels of land and labour productivity across much of the continent, and because productivity increases have not been significant. This concern has grown with the renaissance of interest in agricultural growth in Africa seen since the 2003 Maputo Declaration (Wiggins, 2015). Interest in agricultural productivity coincides with debates about overall economic growth across many African countries, where the welcome news of renewed growth has often been tempered by observations that economies are growing, but not transforming. Growth has been largely in primary production with only small changes to economies' structure and similarly weak development of manufacturing and high-value services. The 2014 African Transformation Report (ACET, 2014) sees agriculture as an example of slow productivity growth.

- ***Soil degradation:*** Genetically modified plant varieties could not increase yields unless restrictions such as low soil fertility were overcome. Fertile soil plays a central role in maintaining agricultural productivity and thus food security. Innovation and technological development focus on crops, pests, and disease control, not on sustainable soil management practices (UNCTAD, 2017). However, healthy plants grow in healthy soil that is less susceptible to pests and diseases. Soil degradation resulting from erosion and poor land-use lead to loss of soil fertility and low agriculture productivity. This complex phenomenon also has impacts on the ecosystem services such as pollination.

  In most SSA, soil degradation potentially undermines efforts toward sustainable agricultural production and poses a major threat to the future of agriculture (Sullivan, 2004). Ever since mankind started agriculture, soil erosion has been the single largest threat to productivity (Sunday et al., 2012). Poor soil management and rudimentary farming methods have highly accelerated soil degradation, affecting crops' health and ultimately leading to low yields.

- ***Challenges in insect pest and disease detection:*** Insect pest infestation and diseases are among the most alarming problems in the African agricultural system and have led to heavy economic losses (Ngumbi, 2017). There is increasing pressure from re-emerging and emergent pests and diseases in crop and livestock production across Africa. Such emerging pressures are likely to become more problematic with weather variability and climate change. Over decades, researchers have tried to mitigate these menaces by developing computerised systems that could identify active pests and diseases and thus suggest control measures on time. The use of chemicals has also been prominent over the years although it has been blamed for the rising number of cancers (Rifai, 2017). AI-based tools are used for pests and diseases detection, monitoring and management through image processing, which simultaneously provides big data on pest distribution and incidence at the landscape, country and regional levels. AI algorithms can detect the presence of pests and diseases using satellite images and send alerts to farmers for the timely implementation of mitigation measures. It will be possible to develop a Low Altitude Remote Sensing (LARS) for recognition of early pest infestation.

  According to Bannerjee et. al., (2018), significant expertise and experience are required to detect an ailing plant and to take necessary steps for its recovery. Computer-aided systems are now being used worldwide to achieve these.

- ***Difficulties in livestock management****:* Feed shortage, limited knowledge by farmers in livestock production, the poor genetic potential of indigenous livestock breeds, pests and diseases, vagaries of weather, and land shortage are the main constraints affecting livestock production in Africa; despite the enormous potential that livestock production holds as a source of food, income, foreign exchange, hides and skin, manure, draught power, and risk reduction in times of crop failure. Despite having livestock, many African farmers and their families still suffer from nutritional deficiencies that livestock can easily provide. This is partly due to poor management practices that reduce availability, hence the need to adopt modern livestock management techniques to increase productivity.

2.1.2 Access: Addresses whether or not households have sufficient access to quality, quantity and diversity of nutritious foods.

- ***Supply chain inefficiencies:*** Food supply chains in Africa are vulnerable to many disturbances and disruptions. These include biotic, abiotic and institutional risk factors. The emergence of the COVID-19 pandemic, which has not only interrupted but also tempered food supply chains, has compounded these vulnerabilities. According to FAO (2020), there is not a shortage of agricultural commodities across the world but rather a bottleneck of access and logistics to reach consumers. With over 60% of the African continent's population in rural areas and dependent on smallholder farming, the risk to food supply chains, market access and nutrition especially under the COVID-19 pandemic is high. There has been lockdowns and restriction on the movements of persons and commodities within and among countries. Again, the non-tariff barriers restricting the movement of essential items within Africa demotivates the tenets of the African Continental Free Trade Area (AfCTA). Africa's long supply chains create delays and produce often gets spoiled or loses its value. It is estimated that 30 to 50% of fresh produce is lost through poor handling and limited cold chain facilities (Nieuwoudt, 2019). This leads to increased prices, passed on to consumers in urban centres, who consume 80% of food produced. The many intermediaries and limited technology create poor visibility in the supply chain, and farmers rarely know the price of their products before the sale.

2.1.1 Use/Utilisation: Addresses whether or not households are maximising the consumption of adequate nutrition and energy determined by knowledge and habits as well as the ability of the human body to take food and convert it.

- ***Inadequacies in food processing and safety*:** Food processing is a significant driver of local economies, creating supplier linkages for millions of small-scale processors. Food processing is a major driver of the local economy, helping millions of smallholders connect with suppliers and increase rural income. One of Africa's greatest challenges in AFS development is the inability to process their primary agricultural products to get the full premiums in price, create jobs and sustain their economies. Yet, the few and growing local processors often find it difficult to produce high-quality, inexpensive and nutritious products that meet food safety ethics and regulatory requirements due to a lack of knowledge, investment, and technology. Food demand in interior Africa is expected to grow by 178% by 2050 and African diets are changing with increasing demand for processed foods and meat to complement the various known food types such as crops such as maise, sorghum, cassava and legumes. (Gross, 2020).

- ***Poor nutrition and increased incidences of malnutrition:*** According to the State of food security and nutrition report, 2020, beyond hunger, a growing number of people have had to reduce the quantity and quality of the food they consume (FAO et. al., 2020). Two billion people, or 25.9% of the global population, felt hungry or did not have the regular right to nutritious and sufficient food in 2019. This situation could deteriorate further, especially with the menacing COVID-19 situation if immediate actions are not taken.

  The alarming trends in food and nutrition insecurity increase the risk of child malnourishment, as food insecurity affects diet worth, including the quality of children's and women's diets and people's health in different ways. It is not amazing that the burden of child malnutrition remains a threat worldwide. In 2019, 21.3% (144 million) of children under 5 years of age were estimated to be stunted, 6.9% (47 million) wasted and 5.6% (38.3 million children) are overweight, while at least 340 million children are micronutrient deficient.

The projections for 2030, even without considering the possibility of a global recession, serve as an additional warning that the current level of effort will not be enough to end malnutrition within the decade; unless there is significant transformative change in the AFS, such as the AI technologies.

2.1.4 Stability: Addresses whether or not households are food secure at all times. Stability issues refer to short-term, medium to long-term instabilities that can be caused by climatic, economic, social and political factors.

- ***Poor weather monitoring, forecasting and disaster prediction preparedness:*** Africa is among the most impacted by erratic weather and climate change disasters. The capacity to collect, analyse and use climate data has been a major challenge over the years as governments use obsolete equipment and have low technical capacity for this purpose.

  The challenge of weather forecasting at the temporal and spatial levels in most African countries is severely affecting the predictive capacity of countries leading to their inability to adequately prepare for extreme weather events. There are several critical gaps in the process of climate information generation, processing and dissemination (World Meteorological Organization, 2014). The precise impacts of climate change on AFS vary spatially, but two general predictions are greater variability in agricultural production and possibly a decline in crop productivity (Schlenker and Lobell, 2010).
- ***The unpredictability of crop and livestock yields****:* Many African farmers are unable to predict yields of their crops and livestock accurately and are therefore not in a position to know how products will be apportioned for processing, sale or storage. Yield variations from season to season have led to various associated problems such as price fluctuations, post-harvest losses, gluts, and panic sales. Yield prediction in crops and livestock is very beneficial for marketing strategies and cost estimation.

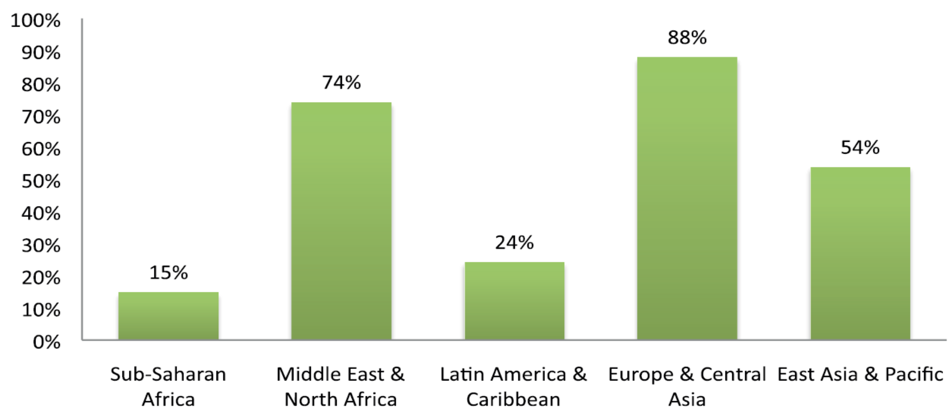
  The amount of food lost each year through post-harvest losses and waste is enough to feed the entire world's undernourished people. SADLY, at SSA alone, where more than 230 million people are chronically undernourished, 30-50% of production is lost at different points in the value chain. (Gevelt, 2020).
- ***Poor use of evidence and data for policy decision-making:*** African governments have rarely used robust data and research evidence in policy decision-making due to inadequate capacity at individual, institutional and systemic levels; poor research infrastructure; lack of political goodwill, and ineffective linkages among research, industry and government among others. African countries have been very proactive in developing policies based on societal needs but the greatest issue is that most of these policies are not based on robust research evidence and data hence implementation usually becomes difficult (Ozor et. al., 2014). Most policies and institutional frameworks focus on top to bottom approach. The power-relation is not famer oriented thus resulting in the overall lack of consideration of the livelihood of the actors (famers).

2.2 Non-agro-based Challenges

2.2.1 Infrastructure

A major determinant of agricultural productivity growth is Infrastructure. In addition to other factors such as credit markets per capita, agricultural extension facilities and technological study, the presence of reliable Infrastructure increases both output per capita and output per land unit. It is, therefore, a major contributor to the productivity, primarily by reducing transaction costs in input and output markets and improving market integration in subregions.

Roads: A well-maintained road network is important when discussing infrastructure issues related to agricultural productivity. Roads connect farmers not only to their input markets but also to their output markets. The lack of efficient transport links and poor roads reduce farmers' profits by increasing input costs and reducing their access to agricultural markets. The present condition of the road linkages in the region is disturbing, and increased investment is needed to address this problem. Only about 30% of rural residents in the region have access to all-weather roads (Gajigo and Lukoma, 2011). As shown in Figure 1, the African region continues to lag behind the rest of the world in terms of the quality of its road network, impacting agriculture and all other sectors of the regional economy. This acts as a constraint on the conduct of trade at all levels, both between African countries and internationally, as the premiums added to transaction costs make African products more expensive and less competitive in the global market.



Source: World Bank, World Development Indicators, 2011

Figure 1 Percentage of paved roads across regions in the world

A recent data collected from the CIA (2021) data collection portal as shown in Table 2 portrays that the number of paved roads is very small when compared to the number of unpaved roads across the regions of the continent. How can agricultural and food systems development occur when 591,887, 135,00, and 147,000 kilometres of roads are still unpaved in South Africa, Nigeria, and Kenya? This scenario shows the huge challenge in the area of roads that Africa is facing. Hence African governments must face this problem and solve them for any meaningful progress to be made in the agricultural and food sector.

Table 1 Percentage of paved and unpaved roads in selected countries of Africa

Country	Total Roads (Km)	Paved Roads (%)	Unpaved Roads (%)
South Africa	750000	21	79
Senegal	16665	37	63%
Mauritius	2428	98	2

Nigeria	195000	31	69
Kenya	177800	8	83
Ghana	109515	13	87
Zambia	67671	22	78
Chad	40000	63	37
Uganda	46000	3	11

Source: American Central Intelligence Agency (CIA), 2021

Another effect of the resulting high cost of transport is that they impede price equalisation of traded produce, leading to shortages in some areas and short-distance surpluses in others. This problem is easily demonstrated in the case of East African rice and corn. Given that both products are tradable and fairly homogeneous, there should be little price difference between certain cities in the region if shipping costs are kept within reasonable limits; however, that is not the case. The geographical price difference is expected to be small, but the magnitude of the difference shown in Table 1 indicates that transaction costs are unusually high. In other words, high transportation costs due to poor road networks hinder market integration between countries and sub-regions. Another complementary infrastructure that is becoming increasingly important in this area is telecommunications, which can enhance the synergies of good road networks. Given the high penetration rate of mobile communications in the African region over the last decade, there is room for innovation to enable both the aggregation of market information and its dissemination to farmers to utilise price information as the road network improves.

Table 1 Cost of Infrastructure as revealed in spatial commodity price dispersion in some selected African countries

Country	Commodity	Price Dispersion (January to June 2011)
Kenya	Rice	32%
	Mazie	39%
Tanzania	Maize	25%
	Rice	37%
Uganda	Rice	14%
	Maize	30%

Source: Regional Agricultural Trade Information Network (RATIN), 2011. The price variance is defined here as the ratio of the monthly price difference of a major city in a country to the monthly average price level of a commodity.

2.2.2 Gender Imbalance

Women play a key role in transforming the food system as researchers, innovators, farmers, food processors, caretakers, cooks, business owners, marketers, and investors. Over 60% of the SSA's female workforce is engaged in agriculture (Vermeulen, 2015). There are about 249 million female herders in Africa(Vermeulen, 2015). Most of them are backyard ranchers, but some have expanded their production into successful commercial businesses. Therefore, women are fundamental in the fight against hunger and malnutrition. Evidence shows that females are as good at food production as men. However, a permanent gender gap in access to key inputs (especially land, finance, and education) means 20-30% less productive than men in SSA (Djurfeldt et al., 2013). To make matters worse, women's contributions to agriculture and the broader food system are not always fully or formally recognised, and in some cases earn half the wages of men. In addition, women's access to inputs and assets is often poor and of poor quality, making it impossible to provide collateral for financial services and reducing resilience to income shocks. Therefore, women throughout SSA are leaving the agricultural sector earlier than men. Between 2011 and 2019, the proportion of women engaged in agriculture in the total workforce of women decreased by 10 per cent. At the same time, the proportion of men engaged in agriculture decreased by only 6 per cent (Sandhu, 2021). The COVID-19 pandemic is likely to exacerbate existing social inequities and make gender gaps even worse, as women tend to suffer disproportionately from job losses and girls are more likely than boys to be pulled out of school(Sandhu, 2021).

If ladies had the equal get right of entry to sources as men, they could gain equal yield levels. Across Africa, giving fair opportunities to women will improve outputs by as much as 19 per cent and many out of poverty. Improving women's rights to input ethical and an imperative to economic growth. Women's empowerment and involvement in meal structures also are useful for family meal security, nutritional quality, and family nutrition. Evidence shows, for example, that wherein women own livestock, families eat meat regularly and extra meals for extra months of the 12 months than do families wherein women do not own livestock (Haddad et al., 2016). It is essential to build a level playing field for both genders in access and opportunities in agriculture and food systems.

2.2.3 Policy and Institutional Lapses

It is a well know fact that policies drive the system. In Africa, there are many policies on Agriculture and food systems that support agricultural production but may not support sustainable ecosystem practices that provide a decent work environment, environmental sustainability, and reduction of biodiversity loss. Policies that are politically driven, such as we have in Africa, cannot cause system change, especially as present institutions and policies support industrial agriculture that does not consider improved livelihoods of farmers and health well-being that benefits the entire ecosystem(Chunga et al., 2022). Policies that ensure social protection do not exist, but such social programs can play an important role by making the process more inclusive; they can mitigate the costs that farmers face in adjusting to changes and enable households to diversify their income-generating activities beyond the farm level. In general, social protection programs target three groups(Chunga et al., 2022): (1) the chronic poor who have limited access to income and instruments to manage risk; for these households, even small reductions in income can have dire consequences; (2) the transient poor whose income is near the poverty line and who may fall into poverty when the household, or the economy, faces a shock; and (3) individuals or households facing special circumstances, whose vulnerability may stem from disability, discrimination, displacement, "social pathologies" of drug or alcohol abuse, domestic violence, or crime. For many poor households, social protection presents a lifeline that helps avoid chronic poverty, malnutrition and disease

Since sustainable agriculture and food production is both Labour and knowledge-intensive, there is a need for an institution with the capacity of transferring the required agro-ecological norms and principles. They cannot affect peer learning among actors (farmers). Agroecology has an impact on power relations and hence can cause or introduce institutional complexities. In summary, existing policies and institutions support industrial agriculture which is not adopted for agroecological practices. There is a need for policy and institutional change or refinement to support the adoption and mainstreaming of Agroecology practices. Institutions set up rules of the game driving them through policies which cover what actors (farmers), may (permitted), most(obliged), or may not (forbidden) to do(Tittonell et al., 2020). Hence the power relations or interactions between drivers and actors are key to agricultural transitions.

2.2.4 Challenges in research, science, and innovation

A robust science, research and technology system that encourages interdisciplinary approaches will be at the heart of addressing the multifaceted challenges facing Africa's food systems such as improving crop and animal productivity and nutrition, tackling pests and diseases, improving storage technologies and methods, raising food safety standards, adapting to and mitigating climate impacts, or developing innovative solutions to deliver humanitarian aid to communities in conflict. Major improvements in science, technology and engineering have indeed already contributed to progress on these issues. However, the outcomes have not always delivered their full transformational potential (Pontieri et al., 2021). While there is evidence of high potential returns on research, actual results have been variable and slow.

Few African countries' agricultural science, research and innovation systems have kept pace with developments in the sector. Over the years, the number and diversity of actors in food systems have grown and their requirements have changed. Yet, the institutional frameworks and funding have remained largely unchanged or have even deteriorated(Haddad et al., 2016). To ensure that Africa's science and research agenda keeps up with its rapidly evolving and complex food systems, governments must consider a more consistent approach to evaluating the quality of education and training across countries and disciplines.

Artificial Intelligence is an innovative system for mitigating the effect of climate on increased agriculture and food production. It is part of emerging and innovative systems to meet sustainable development goals. With the advent of such systems come the capacity and capability to develop, deploy, and scale up homegrown artificial intelligent systems that meet Africa's agriculture and food systems needs. Africa cannot presently develop, deploy, and scale artificial intelligence for agriculture and the food system. This is a pressing issue; if not addressed, Africa would depend on the developed economies. African researchers, entrepreneurs, and governments must identify with the aforementioned need to drive transformational change in agriculture and food systems. Research in this area is either serving the needs of the colonial masters or for fame. Academia must change their curricula to adopt enhanced learning approaches to ensure success. The synergy between private, public, and other relevant organisation are currently missing. Disaggregated data of experts currently dominate the African landscape, and it will be very hard to access a database of the pool of experts in emerging technologies such as artificial intelligence.

3.0 Opportunities for Agriculture and Food Systems in Africa

3.1 AI application in PreProduction, Production, Processing, and Distribution

Africa's population is imagined to reach about 2.6 billion by 2050 (Tschirley et al., 2015). This requires up to a 70% increase in agriculture and food production to meet the needs of the population, which is a serious challenge for agriculture and the food system. Such requirements in the presence of resource depletion, climate change, and the COVID19 pandemic, will require difficult to achieve without the intervention of innovative technologies such as artificial intelligence**.** Leapfrogging the changes needed in agriculture and food systems in Africa, there is a need to set up an artificial intelligence innovation research network for agriculture and food systems; manage the innovation research network; foster collaborations, knowledge exchange, and valorisation among the network and beyond. It is expected that through these interventions, responsible and homegrown artificial intelligence research and innovations will be developed, deployed and scaled to tackle pressing challenges in agriculture and food systems in Africa. Research in AI intelligence is currently gathering momentum in Africa; however, there are new and high-quality skills and capacity, learning opportunities and collaborations, and new policies, and strategies are required. The capacity and capability to develop, and deploy AI is acquired through the interactions of the science-policy-practice community in Africa. This will sustain a continued application of artificial intelligence research and innovations in AFS, thus transforming agriculture and food systems in Africa. With the intervention of artificial intelligence in Africa's agriculture and food systems comes the issue of responsible AI development, deployment, and scale-up. Artificial Intelligence (AI) is the capability of mechanisms to perform cognitive functions related to the human mind such as perception, reasoning, learning, interaction with the environment, problem-solving, and even the exercise of creativity (Manyika et. al., 2017), stands out as one of the emerging technologies with a great potential to transform the AFS and ensure that all aspects of food security including food availability, access, utilisation and stability are achieved even for small-scale farm enterprises in Africa.

Artificial Intelligence (AI) can provide innovative solutions to improve production systems and hence productivity. AI can be applied in precision farming and predictive analytics to increase production and productivity. AI applications and tools have been developed to help farmers reduce inaccuracies and control farm practices by guiding water management, type of crop to be grown, optimum planting, crop monitoring, weeding, pest and disease resistance and control, timely harvesting, nutrition management, and extension service delivery among others (Talaviya et. al., 2020). AI has been used in plant breeding for optimal production and forecasting crop yields under variable and changing climates. Machine failure can lead to wastage of work-in-process inventory and loss of productivity. AI can help analyse historical reasons for failures and combine them with real-time data such as images from the production line to predict upcoming failures of machines.

Nonetheless, AI systems have the potential to mitigate some of these vulnerabilities across supply chains, and thereby improve the state of food security in Africa. The COVID-19 pandemic for example accelerated the application of technologies such as Food apps, drone and robot delivery technologies as new ways to get information and food to the consumer through AI technologies. UberEATS for example is now incorporating AI to make recommendations for restaurants and menu items possibly use of drones for their deliveries. AI allows companies to predict consumer trends and patterns thereby helping them stay competitive within the market by adapting to different popular waves of various trends and making predictions about the market. E-commerce platforms such as Twiga Foods have also been developed and used to market goods and services. They make use of disruptive technologies such as AI, IoT, and Blockchain to automate their distribution and market processes.

AI algorithms using satellite images can determine the quality of soils in a particular area and the kind of crops that can do well in such areas hence leading to optimal productivity. AI can support soil fertility nutrients mapping, and restoration, monitoring using imaging through drones, and generate information to guide food waste management such as recycling. The data captured through imaging by AI-powered devices can support high throughput phenotyping in research.

AI-based tools are used for pests and diseases detection, monitoring and management through image processing which at the same time provide big data on pest distribution and incidence at the landscape, country and regional levels. AI algorithms can detect the presence of pests and diseases using satellite images and send alerts to farmers for the timely implementation of mitigation measures. It will be possible to develop a Low Altitude Remote Sensing (LARS) for recognition of early pest infestation. According to Bannerjee et. al., (2018), significant expertise and experience are required to detect an ailing plant and to take necessary steps for its recovery. Computer-aided systems are now being used worldwide to achieve these.

As the world's population grows and fewer farmers can raise livestock, farmers need to be more productive, even with limited resources. AI and computer vision allow farmers to achieve this. They enable farmers to monitor their animals in real-time and results are forwarded to farmers' mobile phones. They also assume remote control of feeding, milking and cleaning systems on the farm. They alert farmers on abnormal behaviour spotted within their livestock and their herd's overall well-being including sanitising the herd's pens whenever necessary to minimise the risk of infections. Uganda for instance has embraced AI and ML to detect livestock diseases two days before they manifest, connect farmers to veterinary officers remotely and monitor animal movement to avert theft. The innovation, dubbed *Jaguza Luganda*, constitutes a chip with a sensor that is connected to a radio-frequency identification (RFID) reader, and users' mobile phones or computers (Koigi, 2019).

AI impacts directly on food processing and safety in five different ways namely: sorting packages and products, food safety compliance, maintaining cleanliness, developing products, and helping customers with decision making (Sharma, 2019). AI can maximise output and reduce waste through innovative sensor-based sorting machines, detecting and removing any types of foreign materials, reacting to changes in moisture levels, colours, smells, tastes of foods, etc. AI will assist decisions processes about 'cleaning' to improve sanitation and reduce the spread of pathogens and toxins in foods. It helps to reduce energy use and waste by advising against transporting food that may not be used at its destination.

AI can predict the ingredients from photos in a consumer's food journal. It will help to better capture food consumption, determine the nutrients and molecular structure of that food, and predict the health outcomes of those dietary choices. Changing consumer preferences create AI opportunities in food (Taulli, 2021). One example is the increasing demand for plant-based alternatives to meat protein as the world shifts to precision nutrition. Consumer acceptable taste and texture qualities have been achieved through AI.

AI technologies could play a major role in fixing this problem. AI can enhance weather data collection and prediction and hence provide ample time for response. AI can enable farmers to understand the ever-changing weather conditions and be able to precisely plan for farm enterprises along the value chains thereby reducing losses from the vagaries of weather. Forest officials can use ML to identify which crop species are most resistant to natural disasters such as droughts, hurricanes, floods, forest fires etc. and make recommendations for breeding programmes. IoT sensors can be attached to various trees and be used to alert authorities in case of a wildfire. This ensures stability in the AFS.

Machine learning is a vital decision support tool for yield prediction, including supporting decisions on which crops to grow and what optimised crop conditioning practices during the growing season to maximise yield (Sánchez et al., 2020). Farmers use drones for livestock observation for monitoring pregnancies (Ben-Ayed, 2021). Besides aiding in the collection of data, its analyses and use in decision-making, AI can also be used for regulatory purposes. Under the limited rationality model principles, public policymakers have different limitations for the construction of public policies, especially those that require a high level of complexity due to the large number of variables that they present (Shaffer, 2017). For this reason, some research has been carried out using AI tools such as expert systems, case-based reasoning, artificial neural networks, agent-based models, cellular automata, evolutionary algorithms and agrarian public policy variables to improve the decision-making process and to help public policymakers (Sánchez et al., 2020). AI can also be used in understanding the impact of previous policies and predicting the performance of new ones. ML can help analyse previous policy actions automatically and at scale by improving computational text analysis. Such applications will enable governments to effectively leverage AI for the development and stability of the AFS.

3.2 Other opportunities

The countries with robust growth in the agricultural sector are those that have invested in rural Infrastructure. Clearly, investments in roads, storage facilities, telecommunications, and irrigation systems directly impact the efficiency and productive capacity of food systems. Africa Progress 2015 highlights the need to improve access to low-carbon energy to help boost Africa's agricultural sector (Africa Progress Panel, 2015). Investment in rural electrification, including decentralised microgrids or off-grid solutions, is needed to reach the most remote areas and some of the poorest small households (Africa Progress Panel, 2015). African Development Bank, the World Bank, and other international financial institutions have funds to support infrastructure investments, but African governments need to set priorities and encourage public and private domestic investment in these sectors. Digital technology must be at the centre of this massive infrastructure upgrade. Mobile technology is a particularly effective mechanism that enables farmers to purchase agricultural inputs and access financial and extension services and market information (Africa Progress Panel, 2015). Governments and private investors can help promote these services and remove constraints that limit their availability and accessibility. Digital technology must be a central part of this massive infrastructure upgrade. Mobile technologies are a particularly effective mechanism to enable farmers to purchase farm inputs and access extension and financial services and market information. Governments and private investors can help promote these services and remove the constraints that limit their availability and access.

3.3 Financing of agricultural Infrastructure in an innovative way

The delivery of Infrastructure of almost any kind is costly, including that related specifically, to agricultural productivity. This accounts for the secular decline in infrastructural investments across most regions of the world until recently. In theory, agriculture-relevant Infrastructure could be provided either by the private or public sectors. For the private sector, however, several issues make infrastructure provision difficult. User fees required to recover investments, operations, and maintenance costs may become prohibitively high. Moreover, there may be political complications if the particular Infrastructure is sensitive in nature, affecting for example land or settlement rights. This problem in turn can affect the likelihood of securing financing for infrastructure projects. Public financing of agricultural infrastructure projects presents its challenges. The expertise to manage and operate specialist infrastructure may be lacking for most governments in the region. Raising the necessary level of funding from the private capital market may also be difficult where the investment climate is not favourable. On the other hand, many infrastructure projects such as roads have a public goods aspect, implying the need for some government involvement. Other infrastructure projects such as irrigation or storage have less of a public goods characteristic and may present greater opportunities for private sector engagement. Due to these factors, public-private partnerships (PPPs) may represent a good way forward, since they mitigate risk in infrastructure projects through recourse to different sources of financing. Government participation in PPP projects can take the form of subsidies or equity stakes of those components where revenue recovery may be difficult. A project financed through PPP can access sources of capital through both concessionary lending (due to the presence of a government) and the private market (given the presence of a creditworthy private participant).

3.4 Modernisation of rural Infrastructure: prerequisites for agricultural transformation

The fastest-growing countries in the agricultural sector are those investing in rural Infrastructure. Investing in roads, storage facilities, telecommunications, and irrigation systems directly impacts the efficiency and capacity of food systems. Africa Progress Report 2015 highlights the need to improve access to low-carbon energy to boost Africa's agricultural sector. Reaching more remote areas and some of the poorest smallholders requires investment in rural electrification, including decentralised mini-grid or off-the-grid solutions8. The African Development Bank, the World Bank, and other international financial institutions provide funding to support infrastructure investment. However, the African government needs to set priorities and encourage domestic investment-public and private in these sectors.

Digital technology needs to be a key part of this massive infrastructure upgrade. Mobile technology is a particularly effective mechanism for farmers to purchase agricultural inputs and gain access to advisory, financial services and market information. Government and private investors can help promote these services and remove restrictions that limit availability and access to them.

3.5 Establishing the right policies

Agricultural transformation in Africa will only occur if policies that encourage public and private investment in the agricultural and food systems are consistently implemented. These policies must ensure that at least 10% of the national budget is devoted to agriculture to reach the 6% annual agricultural growth target agreed in the Comprehensive African Agricultural Development Program (CAADP). Hmm. Members of the African Union (AU) recently renewed their commitment to CAADP through a declaration adopted at the 23rd African Union Summit or Government Summit held in Malabo, Equatorial Guinea in June 2014. Presently, only a few countries have achieved their budget and agricultural growth goals (Sánchez et al., 2020).

It is also important to expand regional markets and food trade within Africa by breaking trade barriers within the African Regional Economic Communities and between African countries. Tariff and non-tariff barriers, transportation cartels, and various product standards make it difficult for farmers to sell their products or set up commercial businesses in other countries. As part of that, the international community must refrain from harmful agricultural export subsidies and be aware of protectionist tendencies that are detrimental to the poorest. According to a recent study released by the Brookings Institute, OECD countries subsidise the agricultural sector at the expense of poor farmers as they artificially lower crop prices and block food market access from poor countries (Homi et al., 2015). There is a clear urgent need for wealthier countries to adopt effective and equitable market access strategies for food and other agricultural products from developing countries.

3.6 Women and Youth: The driving force for agricultural innovation

Equally important is to create opportunities for young people and women in agriculture and the food system. Females are the dominant face of smallholders and are directly related to the nutrition and health of African families. However, women often have less access to critical resources such as improved utilities and extensions, credit and other financial services, and new technologies than men. As a result, the yields on their farms are 20-30% lower than the plots cultivated by men (FAO, 2011). Bridging the gap can increase agricultural productivity and production and reduce malnutrition in poor families. Africa also has the youngest population in the world (FAO, 2011). To turn this demographic fact into an opportunity for sustainable growth in the agricultural food sector, African countries need to attract the young workforce to innovative agribusiness and entrepreneurship.

Awareness of agriculture must also change in order to attract the younger generation. Agriculture should be seen as a viable and profitable business. Therefore, more investment is needed in agricultural mechanisation and value chain investment and vocational and apprenticeship training for young Africans. Universities and research institutes need to be key partners with government and private sectors in developing the needs and skills of the agricultural sector.

4.0 Conclusions

In conclusion, there are serious challenges identified in the agriculture and food systems in Africa. The identified challenges are:

1. The incoherent policies and institutional gaps.

   Recommendation: Pro-agricultural policies must be put in place to support the establishment of robust institutions that will improve agriculture and food systems in Africa
2. Gender imbalance which must be closed to allow for technology adoption and use, as most technologies displace women who are dominant in the agriculture production sector.

   Recommendation: Gender equality and inclusion principle and practices must be embedded in all intervention to ensure the sustems are responsible. Inculsive programmes and institutions should be set up in line with international best practices. Capacity buiding activities must be put in place to ensure compliance to gender equality and inclusivity.
3. Climate induced risks due to climate change necessitating new approaches to sustainable food production in Africa are outstanding.

   Recommendation: Leaveraging on new and emerging technologies will enhance capabilities in building resilience in adapting to climate change induced risks.
4. Youth empowerment is a force for good in driving agricultural transformations since youths dominate Africa's population.

   Recommendation:
5. The lack of support of the farmers' livelihood drives the urban-rural migration raising questions of just transitions in the agricultural sector.

   Recommendation: Hence it was identified that innovative infrastructure financing focused on improved roads network across African countries will drive the needed change while incorporating new technologies and innovation responsibly.

Therefore from the foregoing, agriculture and food systems in Africa will experience transformational change if and only if innovative actions are taken, utilising emerging technologies such as AI. The introduction of AI for AFS is enabled by other technological advances such as big data, robotics, machine learning (ML), Internet of Things (IoT), availability of affordable sensors and cameras, drone technology, and even broad internet coverage on geographically dispersed fields (Eli-Chukwu, 2019). Despite the growth of movements applying ML, IoT, and AI, among other tools to solve the AFS challenges, it remains necessary to identify how these tools may best benefit Africa under its peculiar circumstances. There is a need to ask; what is the current state of AI development, deployment, and scale-up in Africa to leapfrog agricultural and food systems transformations? What challenges currently face the successful development, deployment, and scale-up of responsible AI in agriculture and food systems in Africa? How can AI be developed, deployed, and scaled up responsibly?

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EFFECT OF TEMPERATURE AND HYSTERESIS ON MONOLAYER MOISTURE CONTENT OF MORINGA SEED GRIT DURING STORAGE

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Abstract

The adsorption and desorption isotherm data of stored moringa (*Moringa oleifera*) seed grit within the water activity and temperature ranges of 0.09–0.92 and 20–40°C respectively were used to determine its monolayer moisture content (M_o) using the Brunauer-Emmett-Teller (BET), Guggenheim-Anderson-DeBoer (GAB) and Caurie equations. Results showed that M_o decreased from 3.03 to 2.064 %db (BET); 4.38 to 2.792 %db (GAB); 4.24 to 2.63 %db (Caurie) and 3.007 to 2.011 %db (BET); 4.346 to 2.621 %db (GAB); 4.215 to 2.545 % (Caurie) in adsorption and desorption processes respectively as temperature increases from 20–40°C at specified relative humidity. The GAB model gave the highest M_o values at various temperatures followed by Caurie equation while the BET model gave the lowest values. The M_o were lower in desorption process than the corresponding adsorption values for the three models, thereby indicating the presence of moisture sorption hysteresis. However, one way analysis of variance (ANOVA) showed that there were no significant differences between adsorption and desorption M_o at ($p \leq 0.05$), thereby indicating that moisture hysteresis has a negligible effect on the monolayer moisture content of moringa seed grit.

Keywords: Moringa grit, temperature, hysteresis, monolayer moisture content, BET, GAB, Caurie equation.

1. Introduction

Moringa (*Moringa oleifera*), also known as drumstick or horseradish (Aviara *et al.,* 2015), is a multi-purpose tree crop that is widely cultivated in Nigeria. The plant produces several seeds with oil content ranging from 27 to 38% in the kernels (Aremu and Akintola, 2014). The seed oil is mostly used as raw material in the cosmetic industry and as lubricating oil for machineries (Adejumo and Abayomi, 2012). The large amount of oil in the seed raises concerns about the grit's consistency when stored for an extended period of time. During storage and processing of agricultural materials, it is essential to have information about the effect of environmental conditions on the behavior of the materials. The knowledge of monolayer moisture content is highly important while determining the physical, chemical and structural stability of these materials such as oxidative rancidity, browning and enzymatic reactions (Bell and Labuza, 2000). Monolayer moisture content (M_o) is of utmost importance because it indicates the exact amount of moisture that is strongly adsorbed to specific pores at the surface of the material. It is generally considered as the least moisture content to which food material can be dried to guarantee storage stability. It has been reported that deterioration reactions occurring below this moisture content differ from those that occur at higher values (Aviara *et. al.,* 2016). At moisture contents below the monolayer, autoxidation is likely to occur and this results in oxidative rancidity which has direct effect on the flavour and odour. This observation negates the generally accepted view that the stability of a material increases as moisture content decreases. For most dry foods, the rate of quality loss due to chemical reactions is negligible at the monolayer value (Sudathip *et al.,* 2009).Several researchers have investigated the monolayer moisture content of various agricultural materials such as Aviara and Ajibola (2002) for melon seed and cassava, Ajibola *et al.,* (2003) for cowpea, Aviara *et al.,* (2004) for soya bean, Oyelade *et al.,* (2008) for maize flour, Moreira *et al.,* (2010) for chestnut and wheat flours, Koc *et al.* (2010) for yoghurt powder, Rodriguez-Bernal *et al.,* (2015) for borojo fruit and gum arabic powder, Aviara *et al.,* (2016) for selected crops and Mohammad *et al.,* (2021) for centella powder. However, there is no information about monolayer moisture content of moringa grit and its behaviour under varying temperature and water activity.

2.Methodology

Matured moringa pods were harvested from OYSCATECH farm in Igboora, Oyo State. The kernels were shelled and the seeds were washed to eliminate the impurities. The clean seeds were then dried in GENLAB oven at 60°C until equilibrium moisture content (7.56±0.05% dry basis) was attained. An electric laboratory burr mill (Gourmia, GCG185) was used to grind the dried seeds in similar methods to Alakali and Satimehin (2007). The grit was then dried for seven days in desiccators over concentrated sulphuric acid (H_2SO_4) to get rid of any remaining moisture and kept in airtight containers until they were analyzed (Ogunsina *et al.,* 2014). Equilibrium moisture content was determined for both adsorption and desorption at five temperature levels (20, 25, 30, 35, 40°C) and nine levels of water activities using concentrated tetraoxosulphate (IV) acid (H_2SO_4) as shown in Table 1 to provide constant water activities at the temperature levels.

Glass desiccators (16cm diameter by 16cm height) containing 350ml of concentrated H_2SO_4 to provide constant relative humidity. The desiccators were placed in a thermostatic water bath at the desired temperature and allowed to reach equilibration. 10g of moringa seed grit was placed in petri dish and was used for each experimentation (both desorption and adsorption). The samples were weighed at intervals of four hours until uniform weight is attained thereby getting the equilibrium moisture content. The experiment was replicated three times and the average was recorded for further analysis.

Table 1: Percentage concentrated H_2SO_4 and their corresponding water activity values at different temperature.

Percent H_2SO_4	Temperature (°C)				
	20	25	30	35	40
15	0.9237	0.9241	0.9245	0.9253	0.9261
25	0.8218	0.8218	0.8252	0.8285	0.8317
35	0.6607	0.6651	0.6693	0.6773	0.6846
40	0.5599	0.5656	0.5711	0.5816	0.5914
45	0.4524	0.4589	0.4653	0.4775	0.4891
50	0.3442	0.3509	0.3574	0.3702	0.3827
55	0.2440	0.2505	0.2563	0.2685	0.2807
60	0.1573	0.1625	0.1677	0.1781	0.1887
65	0.0895	0.0933	0.0972	0.1052	0.1135

Bell and Labuza (2000) as reported by Aviara (2020).

Monolayer moisture content

The monolayer moisture content (M_o) of moringa seed grit was evaluated at 20°C, 25°C, 30°C, 35°C, 40°C temperature for the adsorption and desorption arms of their isotherms by applying the two-parameter BET (Brunaeur-Emmett-Teller) and Caurie's equations and three-parameter GAB (Guggenheim-Anderson-De Boer) equation to the isotherm data.

Brunauer-Emmett-Teller (BET) Equation

The BET isotherm equation (Brunauer *et al.*, 1938) is a widely used moisture sorption isotherm model and it gives a good fit to data over the region a_w<0.45 (Chirife and Iglesias, 1978). The BET equation in terms of EMC as a function of a_w is stated in Equation 1.

$$M = \frac{M_O C a_W}{(1-a_W)[1+(C-1)a_W]} \quad (1)$$

where: M is equilibrium moisture content (% db), M_o is monolayer moisture content (%, db), a_w is water activity in the range 0.01-0.45 and C is energy constant related to net heat of sorption. The algebraic manipulation of Equation 1 yields the linear form as shown in Equation 2.

$$\frac{a_W}{(1-a_W)M} = \frac{1}{M_O C} + \frac{a_W(C-1)}{M_O C} \quad (2)$$

A plot of $\frac{a_W}{(1-a_W)M}$ against a_w at each temperature within the water activity range of 0.01-0.45 gives the slope as $\frac{(C-1)}{M_O C}$ and intercept as $\frac{1}{M_O C}$. From the slopes of the plots from Equation 2 at different temperatures, the BET monolayer moisture content, M_o and energy constant, C, of the products in adsorption and desorption processes, were obtained. The values of BET adsorption and desorption M_o were plotted against temperature to obtain the sorption isotherms.

Guggenheim-Anderson-De Boer (GAB) Equation

The three-parameter GAB equation was derived independently by Guggenheim, Anderson and de Boer as stated by Van den Berg and Bruin (1981) and Bizot (1983). In terms of EMC as a function of a_w, the GAB model is as expressed in Equation 3.

$$M = \frac{M_O C k a_W}{(a-k a_W)[1-k a_W+C k a_W]} \quad (3)$$

where: M is equilibrium moisture content (% db), M_o is monolayer moisture content (%, db), C and k are sorption constants of the GAB model and a_w is the water activity of the entire range.

Equation 3 was transformed into a polynomial of the second order as shown in Equation 4 and used to determine the constants and monolayer moisture content.

$$\frac{a_W}{M} = \propto a_W{}^2 + \beta a_W + \gamma \quad (4)$$

where:

$\propto = \frac{K}{M_o}\left(\frac{1}{C} - 1\right)$

$\beta = \frac{1}{M_o}\left(1 - \frac{2}{C}\right)$

$\gamma = \frac{1}{M_o Ck}$

Equation 4 was solved by plotting a_w/M versus a_w at each temperature and fitting the plot with a second order Polynomial using Microsoft Excel (2007) in order to determine the values of the coefficient of the quadratic term, ∝, the linear term coefficient, β, and the constant, γ. The values of GAB adsorption and desorption M_o obtained were then plotted against temperature.

Caurie's Equation

Caurie's monolayer moisture content was computed for the entire range of water activity using Equation 5.

$$ln\left(\frac{1}{M}\right) = -ln(M_o C) + \left(\frac{2C}{M_o}\right) ln\frac{(1-a_w)}{a_w} \quad (5)$$

where: M is equilibrium moisture content (% db), M_o is monolayer moisture content (%, db), a_w is the water activity of the entire range and C is Caurie's constant. Rearranging Equation 5 results in Equation 6.

$$ln\left(\frac{(1-a_w)}{a_w}\right) = ln\left(\frac{1}{M}\right)\left(\frac{M_o}{2C}\right) + ln(M_o C)\left(\frac{M_o}{2C}\right) \quad (6)$$

A graph of $ln\frac{(1-a_w)}{a_w}$ was plotted against $ln\left(\frac{1}{M}\right)$ to obtain a straight line with slope $\left(\frac{M_o}{2C}\right)$ and intercept $ln(M_o C)\left(\frac{M_o}{2C}\right)$. The monolayer moisture content, M_o, was then obtained through regression analysis.

3.Results and Discussion

Monolayer moisture contents of moringa seed grit determined using BET, GAB and Caurie models at different temperature levels are presented in Table 2. 3.03 to 2.064 %db (BET); 4.38 to 2.792 %db (GAB); 4.24 to 2.63 %db (Caurie) and 3.007 to 2.011 %db (BET); 4.346 to 2.621 %db (GAB); 4.215 to 2.545 % (Caurie) in adsorption and desorption processes respectively as temperature increases from 20–40^{o}C.

Table 2: Monolayer moisture content of moringa seed grit determined using BET, GAB and Caurie models at different temperatures.

	Adsorption			Desorption		
T (°C)	BET M_o	GAB M_o	Caurie M_o	BET M_o	GAB M_o	Caurie M_o
20	3.030	4.380	4.240	3.007	4.346	4.215
25	2.823	4.145	4.086	2.776	4.120	4.054
30	2.441	3.432	3.606	2.405	3.393	3.424
35	2.200	2.977	2.851	2.168	2.899	2.833
40	2.064	2.792	2.630	2.011	2.621	2.545

It has been reported that the decrease in the monolayer moisture content with increase in temperature is due to reduction in the number of active sites as a result of chemical and physical changes induced by temperature (McMinn and Magee, 2003). Similar reports were given by Oyelade *et al.* (2008) for maize flour, Moreira *et al.,* (2010) for chestnut and wheat flours, Koc *et al.* (2010) for yoghurt powder, Rodriguez-Bernal *et al.,* (2015) for borojo fruit and gum Arabic powder and Mohammad *et al.* (2021) for centella powder. GAB and Caurie monolayer values were close and higher than the corresponding BET values. Timmermann *et al*., (2001) also reported a similar observation. This occurrence may be as a result of BET model being associated more with moisture sorption at the immediate layer, thereby making it more suitable to predict the monolayer moisture content of dry materials, while GAB and Caurie models are with moisture sorption at the multilayer region, making them more suitable for predicting the monolayer moisture content of intermediate to high moisture foods (Maleki-Majd *et al*., 2014).

Variations in monolayer moisture content of moringa seed grit with temperatures during adsorption and desorption are presented in Figures 1a and 1b respectively. It was observed that adsorption monolayer moisture values were higher than the corresponding desorption values at the same temperatures and relative humidity. The ANOVA results showing the effects of hysteresis on the monolayer moisture content during adsorption and desorption for BET, GAB and Caurie models are shown in Tables 3a, 3b and 3c respectively. One way analysis of variance showed that there were no significant differences between adsorption and desorption monolayer moisture content at $p \leq 0.05$. This means that hysteresis had not occurred before monolayer moisture content was attained. The monolayer moisture content (Mo) calculated using the three models varied linearly with temperature for both adsorption and desorption processes. Suitable regression models that could be reliably used to predict the Mo of moringa seed grits at different temperature levels are presented in Table 4.

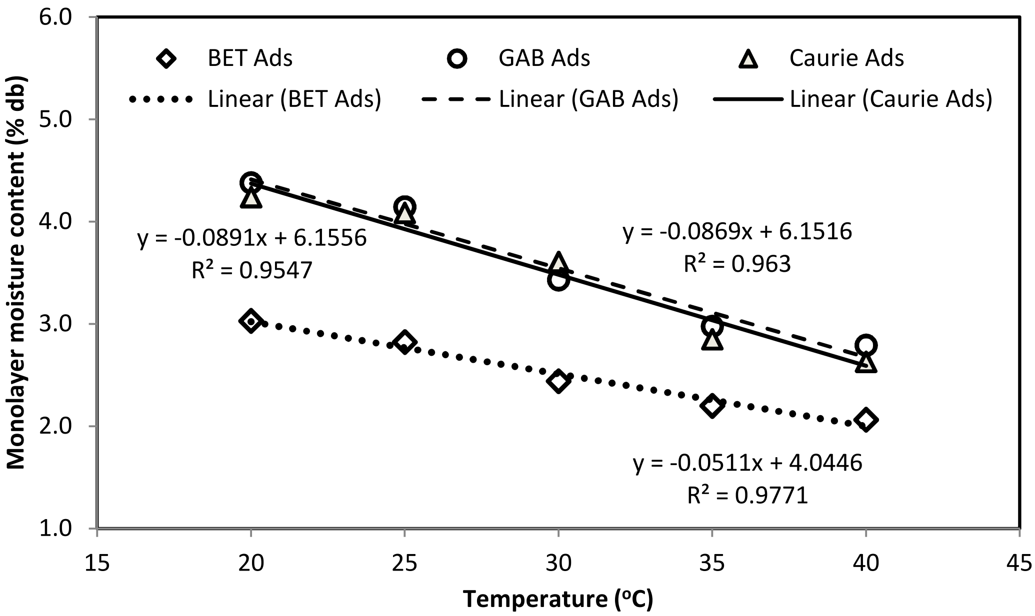

Figure 1a. Variations of adsorption M_o of moringa seed grit with temperatures.

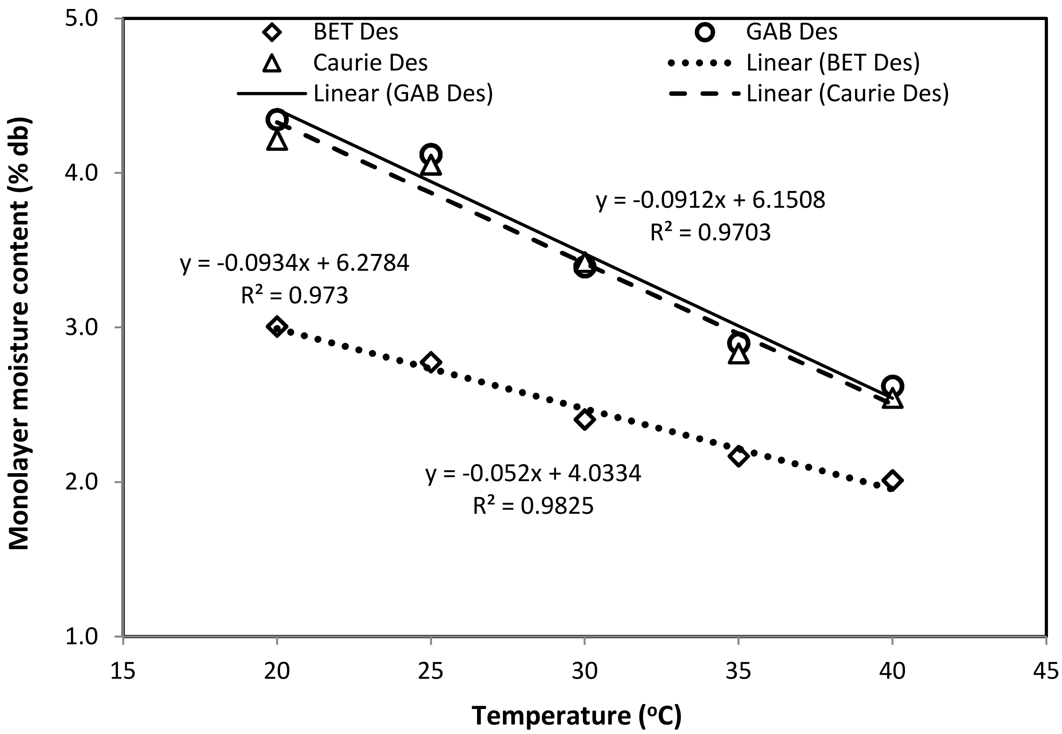

Figure 1b: Variations of desorption M_o of moringa seed grit with temperatures.

Table 3a: One-way Analysis of Variance for BET Monolayer Moisture Content

Source	SS	df	MS	F	Prob > F
Between groups	.014516067	1	.014516067	0.03	0.8717
Within groups	4.17385402	8	.521731753		
Total	4.18837009	9	.465374455		

Bartlett's test for equal variances: chi-square (1) = 0.0003; Prob>chi^2 = 0.985

Table 3b: One-way Analysis of Variance for GAB Monolayer Moisture Content

Source	SS	df	MS	F	Prob > F
Between groups	0.003648099	1	0.003648099	0.02	0.8870
Within groups	1.35619048	8	0.16952381		
Total	1.35983858	9	0.151093176		

Bartlett's test for equal variances: chi-square (1) = 0.0008; Prob>chi^2 = 0.978

Table 3c: One-way Analysis of Variance for Caurie's Monolayer Moisture Content

Source	SS	df	MS	F	Prob > F
Between groups	0.012040908	1	0.012040908	0.02	0.8834
Within groups	4.20210591	8	0.525263238		
Total	4.21414682	9	0.468238535		

Bartlett's test for equal variances: chi-square (1) = 0.0161; Prob>chi^2 = 0.899

Table 4: Relationship between BET, GAB and Caurie models monolayer moisture content and temperature

Models	Adsorption	Desorption
BET	$M_o = -0.0511T + 4.0446$	$M_o = -0.052T + 4.0334$
	$R^2 = 0.9771$	$R^2 = 0.9825$
GAB	$M_o = -0.0869T + 6.1516$	$M_o = -0.0934T + 6.2784$
	$R^2 = 0.963$	$R^2 = 0.973$
Caurie	$M_o = -0.0891T + 6.1556$	$M_o = -0.0912T + 6.1508$
	$R^2 = 0.9547$	$R^2 = 0.9703$

Conclusions

The adsorption and desorption monolayer moisture content of moringa seed grit was determined at various temperatures using BET, GAB and Caurie moisture sorption isotherm equations. It was deduced that monolayer moisture content decreased with increase in temperature in both adsorption and desorption for the three models which shows that temperature affects monolayer moisture content significantly. GAB and Caurie monolayer moisture contents were greater than those of the corresponding BET monolayer moisture content for both adsorption and desorption. Temperature had significant effect on the monolayer moisture content while moisture sorption hysteresis did not significantly affect the monolayer moisture content of moringa seed grit.

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THE ROLE OF DIGITAL AGRICULTURAL PRACTICES TOWARDS FOOD SECURITY IN NIGERIA

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Abstract

The digitalization of Agricultural production systems which typically involves both collection and analysis of data to improve both on-farm and off farm decision, is the newest shift in Agricultural production system which utilizes recent technologies and innovation such as Artificial intelligence (AI), Internet of Things (IoT), Machine learning, Digital communication Technology like mobile phones, Digital platforms such as e-commerce, cloud computing, big data analysis, to improve agricultural production system, mainly towards food production, in order to meet up with the worlds forecasted exploding population, and to ensure maximum food security among the growing populace, which will grant them possible access at all times to sufficient, safe and nutritious food that meets their dietary needs for an active and healthy life. This will go a long way to ensure socio-economic development of the country.

Keywords: *Digital Agriculture, Food security, Food insecurity,*

1.0 Introduction

Agricultural activities (food production) are different from other commodities because everybody needs it for their survival, and it is an indispensable factor in the nations quest for economic growth and development. Unfortunately, most of the food needed in Nigeria is produced by peasant farmers who lacks capital, skills, energy and newest Technological innovation and other viable ingredients to produce in large and timely, inorder to meet the requirement of the country's growing population Otaha (2013). Agriculture has the potentials to be the biggest contributor to Nigeria Gross Domestic Product (GDP) if properly harnessed through investment and technologies Femi (2021). Today at the beginning of the 3rd millennium, Agriculture is confronted with a wide range of complex challenges in Nigeria. The task is to meet the growing demand for food, feed, fiber fuel, industrial products and products based on functional plants and improved agricultural production systems. According to a recent report by BCG titled "the Digital Agriculture Revolution", agricultural practices will need more than innovation in order to meet the growing world population. Already, greater crop yield is required to feed Nigeria's exploding population. The population of Nigeria has been forecasted to reach over 400 million people by 2050. Estimation published in 2019 shows that by the time the consumption rate of farm produce such as eggs, milk, beef, cassava, maize, wheat and others will increase by almost 300 percent, and if not properly addressed, the scenario might lead to a full-blown food insecurity Tolu (2021). Within this context, the possibility offered by the implementation of digital technologies in Agriculture will improve the prospects of being able to use our limited resources to the best.

The appropriate use and timely development of these new technologies will enable agricultural production systems. By pressing the IGREEN (R) evolution (innovation in Green Revolution – digital revolution of the 4th Agriculture) forward in Agriculture through implementation of digital systems such as the use of Smartphones, apps, Global Positioning System (GPS), Sensors, Robotics drones, Unmanned Ariel Vehicle (UAVs) and others in agricultural practices, the changing world will be able to address the nation's growing population in terms of food demands, which are milestones on a road map for tackling the challenges of the 21st Century. Kern, M. (2014).

2.0 Digital Agriculture

Digital Agriculture as the name implies can be referred to as "e – agriculture" or "smart farming". It can be seen as those tools that digitally collects, store, analyze and share electronic data and/or information along the agricultural value chain (Digital Agriculture. feeding the future). Digital agriculture can also be referred to as the use of digital technology to integrate agricultural production from the paddock to the consumers FAO (2019). Digital agriculture is seen as the newest shift in agriculture which could help ensure agriculture meets the need of the global population in the future FAO (2019). It usually impacts the entire agri-food value chain before during and after on farm production (Wolfert *et al*, 2017). Digital agriculture also includes precision agriculture but it is not limited to it, as it encompasses most farm technologies like yield mapping, GPS, guidance systems, and variable rate application system.

Digital agriculture which makes use of digital technology, has the potential to change farming practices beyond recognition. Its technology usually affects all part of the agricultural value chain including off farm segments. The technology also has the potentials to provide farmers with the information and ability to meet challenges and sizes opportunity for growth. They also have multiple applications along the agricultural value chain, and will improve efficiency throughout the value chain (Zang *et al,* 2012).

Some of the technologies used in digital agriculture includes but are not limited to the following * Cloud computing/big data analysis tool
* Artificial Intelligence (AI)
* Machine learning *
The Internet of Things (IoT) *
Digital communication technologies, like mobile phones

* Digital platforms, such as e-commerce.

3.0 Food Security And Food Insecurity

The concept "Food Security", is a situation that arises when all people at all times, have physical social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preference for an active and healthy life FAO (2005). Food security also involves access and availability of food stuffs, stability of food supplies and the quality of diet (Honfoga *et al. 2003).* According to Ifejimalu (2018), issues on food security was brought to lime light in 1974 during the world food conference in which nations all over the world needs to strategize on how best to improve agricultural production so as to match the per capita income needs of the growing population. In a simple term, food security is access by all people at all times to enough food for active and healthy living (Agwu *et al*. 2011). The core determinant of food security in every nation are usually availability, accessibility, utilization and stability (FAO, 2015). These determinant in the agricultural production processes can only be actualized in a country like Nigeria with a rapid growing population, only if the newest shift in agricultural activities (Digital Agriculture) is embraced, which will go a long way to ensure the meet of the needs of the growing population in the future FAO (2019). Food insecurity on the reverse, is the absence of food security; that is, the lack of access to enough food that can be either temporary or chronic. It signifies the consequences of inadequate consumption of food, bearing in mind that the physiological use of food within the domain of nutrition and health (FAO, 2010). Some aspects/or consequences of food insecurity are: malnutrition leading to poor health or death, famine and hunger. Most key factors responsible of food insecurity in Africa nay Nigeria as identified by Haile and Alemu (2005) are low agricultural productivity, lack of agricultural policies, poor infrastructures and high transportation cost, extreme weather conditions, high disease burden, ethnic and religious conflict.

4.0 Impact of Digital Agricultural Practices on Production and Accessibility to Food

Food security as a major path to socio-economic growth and development of Nigeria, can only

be achieved by embracing/adopting the newest shift (change in Agricultural system i.e digitalization of Agriculture), as a digital agricultural revolution, which will help ensure that agriculture meets the need of the country's growing population. This can be done by taking into consideration the agriculture 4.0 (digital agricultural revolution) which is expected that over the next 10years, there will be dramatic changes in the agri-food system driven by the digital technology and innovation, (block chain, Internet of Things (IoT), Artificial intelligence (AI), immersed reality etc.) FAO (2015). It is generally agreed that the adoption of this newest shift (digital agriculture) will deliver a step change in Agricultural efficiency, productivity and sustainability at the farm level and across the value chain (Aubert et al., 2012; Wolfert et al., 2017). The sensing systems and associated analytics used in the digitalization, will provide farmers with better information to make decision with more predictable outcomes while automating task using technologies and machine learning will increase reliability. Rapid development in the Internet of Things (IoT), cloud computing, robotics and Artificial Intelligence (AI) will accelerate the transition to smart farming and promotion of big data and precision agriculture which in turn improves agri-food sustainability. This digital application and platform will have the potentials to dramatically change the way knowledge is processed, communicated, accessed and utilized. For farmers, digital application will provide decision-making capabilities that were previously not possible, which will potentially lead to radical changes in farm management (Sonka, 2014; Wolfert et al., 2017). In the agricultural production systems, the spread of mobile technologies, remote-sensing services and distributed computing services, will improve small holders' access to information, inputs and markets, increase production and productivity, streamlining supply chains and reducing operational cost FAO (2022).

5.0 Constrains Of Digital Agriculture In Nigeria. The digitalization of agriculture in Nigeria is expected to be faced with certain challenges which needs to be overcome for its impact to be felt in food production, sustainability as well as economic growth. Among these challenges includes: * Cyber security and data protection

* Labour replacement and re-education

* Individuals with differing abilities to adopt new technologies

* Insecurity

* Ethnic/communal clash

* Illiteracy

* Religious/traditional believe.

Despite these challenges, there is no doubt that Digital Agriculture will do better in Nigeria as the FAO is committed to assisting the government and partners in bridging such multidisciplinary digital divides in order to ensure that everyone benefits from the emerging digital society.

6.0 Conclusion

This newest shift in agriculture (Digital Agriculture), if properly embraced/adopted, will be committed in assisting the government and partners in bridging the projected global food challenges due to projected population growth and migration, by increasing productivity and timely delivery in the agri-food value chain. This will help to see that the UN sustainable development goal of 'a world with zero hunger' by 2030 will be achievable.

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MATHEMATICAL MODEL FOR PREDICTING WHOLE KERNEL RECOVERY OF A PALM NUT CRACKING MACHINE USING MIXED VARIETY OF PALM NUT

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Abstract

This research work aimed at developing a mathematical model for predicting whole kernel recovery as a performance parameter for a palm nut cracking machine, using mixed variety of palm nuts. The drying temperature of 105°C; five levels of cracking speed (1200, 1400, 1600, 1800 and 2000rpm); six levels of moisture content (12.4, 14.0, 16.2, 18.1, 20.0 and 27.8% w.b) and five levels of feed rate (360, 400, 450, 514.29, 600kg/h) were selected for the study. Full factorial design was used in the design of the experiment with three independent variables; cracking speed (rpm), moisture content (%) and feed rate (kg/hr), set at five, six, five level factorial respectively. Four hundred and fifty (450) samples of 1000g each of fresh palm nuts were used for the experiment. 150 samples were selected for each experimental run. The samples after drying to specified levels of moisture content, were cracked at 5 different speeds with 5 levels of feed rate. Mean values for each variety was computed and used for statistical analysis. Models to predict whole kernel recovery were developed using the concept of Buckingham Pi theorem. The developed models were verified and validated by fitting them into experimental data. Method of regression analysis as computed using Microsoft Excel programme of Microsoft package was used to describe the relationships, plot the graphs and compute the coefficients of determination (R^2) between the predicted and experimental values.

Keywords: Model, Whole Kernel Recovery, Palm Nut, Cracking, Machine, Mixed Variety

1.0 Introduction

The oil palm fruit (*Eleasis guineesis*) as one of the predominant agricultural products over the years, has gained much attention in the world due to its wide application as a major raw material in industries. It is one of the most essential cash crops grown in the tropics. Nigeria is one of the leading producers of palm oil obtained from the oil palm fruit. The oil palm is a unique crop with two distinct types of oil namely; palm oil and palm kernel oil. Palm oil is extracted from the mesocarp of the fruits and palm kernel oil from the kernels of the palm nuts. The palm kernel is an edible seed and its oil can be fractionated into a liquid (olein), solid (stearin), and intermediate as shortening. Palm kernel oil can be used for making glycerin, candle, margarine, pomade, medicine, polish, oil paint and cheaper raw material for biodiesel when produced in abundant quantity (Adebayo, 2004; Emeka and Olomu, 2007).

Palm nut shell has become an essential commodity in the oil palm industry. Many applications have been developed. Due to high calorific value of palm nut shell, this commodity has been considered one of the key biomass materials which may possibly replace fossil fuel for steam engines (Mohammad, 2005).

Basically, there are three distinct varieties of the oil palm fruit. These are the *Dura, Tenera* and *Pisifera*. *Dura* variety has a thin mesocarp, thick endocarp (shell) and the kernel tends to be large, comprising 7 - 20% of the fruit weight. The *Tenera* variety has a large mesocarp, thin endocarp (shell) and large to medium kernel. The *Pisifera* variety possesses thick mesocarp, small or no endocarp (shell) with small kernel where applicable. The endocarp (shell) of palm nut generally contains one or more kernels (Okokon *et al*., 2007). The nuts are not useable until the kernels are sorted out from the shell (Hartmann *et al.,* 1993). The nut recovery is a unit operation that encompasses nut drying after separation from the pulps. This is followed by cracking, kernel separation from cracked nut mixture, kernel storage and kernel oil extraction. Therefore, cracking and sorting are two major operations that need serious development for drastic improvement in quantity and quality of palm kernel oil produced.

There are heaps of palm nuts in virtually all processing mills and in local markets as a result of cracking problems. Considering the economic importance of palm kernels, this is a great loss to farmers and industrialist. There is need to establish the moisture content that will increase the cracking efficiency, whole kernel recovery, reduce the percentage or possibly eliminate the broken kernels during cracking of fresh palm nuts. Drying temperature and drying time to get the expected moisture content must be ascertained.

Sorting out different varieties of palm nut also constitutes another major challenge in palm nut cracking. In most plantations, mixed varieties (Dura, Tenera and even Pisifera) of oil palm are planted, harvested and processed together in large quantities. To overcome the rigorous task of sorting and damages, the existing cracking machines need to be improved for effective cracking of mixed varieties of palm nuts simultaneously.

The various factors affecting the performance of cracking machine as presented by Ndukwu (1998) and Shahbazi (2012) include: the cracking time, nuts moisture content, feed rate, bulk density, throughput capacity, cracking speed and power. These factors if not properly controlled could reduce cracking machine performance. Therefore, modelling the performance parameters or contributing factors for cracking process of palm nut would provide better understanding of the fundamental relationship of these variables in order to identify the contribution of each variable. Also, optimization of the model will help to identify the best contribution of the variables that can be used to establish optimum conditions for palm nut cracking.

2.0 MATERIALS AND METHODS

The materials/equipment used for the study are: Mixed varieties of fresh oil palm nuts; Impeller Palm nut cracker; Friction Absorption Dynamometer; Digital Tachometer – Photo type; Model: DT-2234B; Digital Stop watch; Vernier Calliper; Electronic Weighing Balance (Model: EK5350; Max.: 5kg/11lb with 0.01g accuracy); Desiccators and Air Oven – Model: MINO/50; Serial No.: 13C280

2.1 Sample Acquisition and Preparation

Mixed varieties of fresh oil palm nuts were purchased from VIKA Farm, Uyo and NIFOR, Abak Station palm fruits processing mill. Cleaning of nuts was carried out manually to remove immature nuts and other unwanted materials from the bulk sample. The nuts were sorted out and graded into large, medium and small nuts as shown in Figure 1.

Figure 1: (a) Large nuts (b) Medium nuts (c) Small nuts

2.2 Description of the Experimental Machine

Palm nuts were cracked in a cracker (Figure 2) developed by Etuk Tech. Engineering Company based on the design consideration and analysis by Ismail *et al.* (2015) and Stephen and Lukman (2015). The machine was coupled together with a Friction Absorption Dynamometer, for determining torque during each run of cracking**.** It consists of five major units: the in-feed unit, the cracking unit, the discharge outlet, the driven unit and the dynamometer.

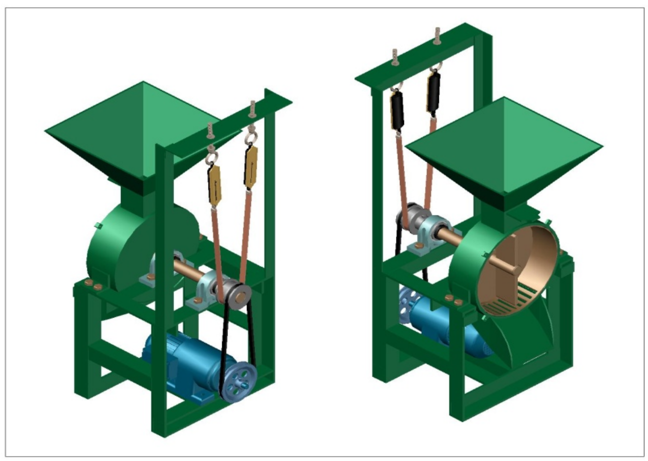

Figure 2: Isometric view of the palm nut cracker (Source: Sam, 2017)

2.3 Working Principles of the Machine

The machine was put into operation by starting the electric motor, which provides the required power to drive the pulley of the cracking machine thereby causing the impeller blades to rotate. The cracking speed was adjusted by adjusting the power supplied to the electric motor. The cracked mixture falls by gravity through discharge outlet situated directly below the cracking chamber.

2.4 Model Development

Model to predict the percentage of whole kernel recovery of a palm nut cracking machine was developed using the concept of Buckingham Pi theorem.
The variables influencing the percentage of whole kernel recovery WKR are:

- Volume of the nut before cracking - - - - V_n
- Moisture content of nuts - - - - - α_{mc}
- Diameter of cracking drum (mm) - - - - D_{cd}

- Feed rate (g/s) - - - - - - - F_r
- Peripheral velocity of impeller (m/s) - - - - P_v
- Nut dimension (mm) - - - - - - d_n
- Nut density (kg/m³) - - - - - - δ_n
- Cracking speed (rpm) - - - - - - S_c
- Speed of the nut (m/s) - - - - - - $\cap_s$
- Throughput (kg/h) - - - - - - T_p

The whole kernel recovery from the cracker is expressed in Equation (1) as:

$$WKR = f(V_n\ ; \alpha_{mc}\ ;\ D_{cd}\ ;\ F_r\ ;\ P_v\ ;\ d_n\ ;\ \delta_n\ ;\ S_c\ ; \cap_s\ ;\ T_p) \quad (1)$$

Adopting the $M\ L\ T$ system of dimension, the dimension of variables and the dimensional matrix are presented in Tables 1 and 2 respectively.

Table 1: Dimension of variables influencing whole kernel recovery of a palm nut cracking machine

S/N	Variables	Symbol	Unit	Dimension
1	Whole kernel recovery	WKR	%	$M^0\ L^0\ T^0$
2	Volume of the nut before cracking	V_n	m^3	$M^0\ L^3\ T^0$
3	Moisture content of nuts	α_{mc}	%w.b	$M^0\ L^0\ T^0$
4	Diameter of cracking drum	D_{cd}	mm	$M^0\ L^1\ T^0$
5	Feed rate	F_r	g/s	$M^1\ L^0\ T^{-1}$
6	Peripheral velocity of impeller	P_v	m/s	$M^0\ L^1\ T^{-1}$
7	Nut dimension	d_n	mm	$M^0\ L^1\ T^0$
8	Nut density	δ_n	kg/m^3	$M^1\ L^{-3}\ T^0$
9	Cracking speed	S_c	Kgm^2/s	$M^1\ L^2\ T^{-1}$
10	Speed of the nut	$\cap_s$	m/s	$M^0\ L^1\ T^{-1}$
11	Throughput capacity	T_p	kg/h	$M^1\ L^0\ T^{-1}$

Table 2: Dimensional matrix of the variables influencing the whole kernel recovery of a palm nut cracking machine

S/N	Variables	Symbol	Dimension		
			M	L	T
1	Whole kernel recovery	WKR	0	0	0
2	Volume of the nut before cracking	V_n	0	3	0
3	Moisture content of nuts	α_{mc}	0	0	0
4	Diameter of cracking drum	D_{cd}	0	1	0
5	Feed rate	F_r	1	0	-1
6	Peripheral velocity of impeller	P_v	0	1	-1
7	Nut dimension	d_n	0	1	0
8	Nut density	δ_n	1	-3	0
9	Cracking speed	S_c	1	2	-1
10	Speed of the nut	$\cap_s$	0	1	-1
11	Throughput capacity	T_p	1	0	-1

Applying the Buckingham pi theorem to identify the dimensionless group to be formed, the following assertions were made:
The dependent variable = WKR
The repeating variables = V_n ; α_{mc} ; D_{cd} ; F_r ; P_v ; d_n ; δ_n ; S_c ; $\cap_s$; T_p
Total number of variables = 11
Number of fundamental dimension = 3
Number of dimensionless groups to be formed = 11-3 = 8
So the required terms is expressed in Equation (2) as:

$$\pi_1 = f(\pi_2, \pi_3, \pi_4, \pi_5, \pi_6, \pi_7) \quad (2)$$

The pi terms can be determined by considering the corresponding dimensional expression in Equation (3) as:

$$WKR ; V_n ; \alpha_{mc} ; D_{cd} ; F_r ; P_v ; d_n ; \delta_n ; S_c ; \cap_s ; T_p = 0 \quad (3)$$

From Table 2, α_{mc} is dimensionless and is therefore excluded from the dimensionless terms determination as shown in Equation (4); and is added when other dimensionless terms are determined (Simonyan *et al*., 2019).

$$WKR = f(V_n ; D_{cd} ; F_r ; P_v ; d_n ; \delta_n ; S_c ; \cap_s ; T_p) \quad (4)$$

The dimensionless equation is given in Equation (5) as:

$$f(V_n ; D_{cd} ; F_r ; P_v ; d_n ; \delta_n ; S_c ; \cap_s ; T_p) = 0 \quad (5)$$

Nut dimension (d_n), speed of nut ($\cap_s$) and throughput (T_p) were selected as recurring set of variables since their combination does not form a dimensionless group.

With d_n, $\cap_s$ and T_p selected, the exponent a, b and c attached to each recurring set respectively as $d_n{}^a \cap_s{}^b T_p{}^c$

The component of the exponential recurring set is divided by the remaining variables: V_n ; D_{cd} ; F_r ; P_v ; δ_n ; S_c . So the dimensionless group π_1, π_2, π_3, π_4, π_5, and π_6 were obtained as given in Equation (6) to (11) according to Ndirika (2005); Ndukwu and Asoegwu (2010). These expressions form the basis of the Buckingham Pi theorem of dimensionless groups.

$$\pi_1 = \frac{V_n}{d_n{}^a \cap_s{}^b T_p{}^c} \quad (6)$$

$$\pi_2 = \frac{D_{cd}}{d_n{}^a \cap_s{}^b T_p{}^c} \quad (7)$$

$$\pi_3 = \frac{F_r}{d_n{}^a \cap_s{}^b T_p{}^c} \quad (8)$$

$$\pi_4 = \frac{P_v}{d_n{}^a \cap_s{}^b T_p{}^c} \quad (9)$$

$$\pi_5 = \frac{\delta_n}{d_n{}^a \cap_s{}^b T_p{}^c} \quad (10)$$

$$\pi_6 = \frac{S_c}{d_n{}^a \cap_s{}^b T_p{}^c} \quad (11)$$

In order to obtain values for the exponents a, b and c, the principle of dimensional homogeneity is used to equate the dimension on each side of the equations of the π groups (Sam *et al*., 2022).

So, Equation (6) becomes; $M^0L^0T^0 = \frac{M^0L^3T^0}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (12)

From Equation (7); $M^0L^0T^0 = \frac{M^0L^1T^0}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (13)

From Equation (8); $M^0L^0T^0 = \frac{M^1L^0T^{-1}}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (14)

From Equation (9); $M^0L^0T^0 = \frac{M^0L^1T^{-1}}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (15)

From Equation (10); $M^0L^0T^0 = \frac{M^1L^{-3}T^0}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (16)

From Equation (11); $M^0L^0T^0 = \frac{M^1L^2T^{-1}}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (17)

Employing dimensional homogeneity for M, L and T, the exponents a, b and c were evaluated. Substituting the values of the components a, b and c into Equations respectively;

$\pi_1 = \frac{V_n}{{d_n}^3{\cap_s}^0{T_p}^0} = \frac{V_n}{{d_n}^3}$ (18)

$\pi_2 = \frac{D_{cd}}{{d_n}^1{\cap_s}^0{T_p}^0} = \frac{D_{cd}}{d_n}$ (19)

$\pi_3 = \frac{F_r}{{d_n}^0{\cap_s}^0{T_p}^1} = \frac{F_r}{T_p}$ (20)

$\pi_4 = \frac{P_v}{{d_n}^0{\cap_s}^1{T_p}^0} = \frac{P_v}{\cap_s}$ (21)

$\pi_5 = \frac{\delta_n}{{d_n}^{-2}{\cap_s}^{-1}{T_p}^1} = \frac{\delta_n\, {d_n}^2\cap_s}{T_p}$ (22)

$\pi_6 = \frac{S_c}{{d_n}^2{\cap_s}^0{T_p}^1} = \frac{S_c}{{d_n}^2T_p}$ (23)

And $\pi_7 = \alpha_{mc}$ (24)

Combining the expressions for π_1, π_2, π_3, π_4, π_5, π_6 and π_7, Equation (2) is expressed in Equation (25) as:

$\frac{V_n}{{d_n}^3} = f\left\{\frac{D_{cd}}{d_n}, \frac{F_r}{T_p}, \frac{P_v}{\cap_s}, \frac{\delta_n\, {d_n}^2\cap_s}{T_p}, \frac{S_c}{{d_n}^2T_p}, \alpha_{mc}\right\}$ (25)

Combining the dimensionless terms to reduce the Equation to a manageable level. The dimensionless terms is expressed in Equation (26) to (29) as:

$\pi_{12} = \frac{\pi_1}{\pi_2} = \frac{V_n}{{d_n}^3} \times \frac{d_n}{D_{cd}}$

$\pi_{12} = \frac{V_n}{{d_n}^2D_{cd}}$ (26)

$\pi_{34} = \frac{\pi_3}{\pi_4} = \frac{F_r}{T_p} \times \frac{\cap_s}{P_v}$

$\pi_{34} = \frac{F_r\cap_s}{T_pP_v}$ (27)

$\pi_{56} = \frac{\pi_5}{\pi_6} = \frac{\delta_n\, {d_n}^2\cap_s}{T_p} \times \frac{{d_n}^2T_p}{S_c}$

$\pi_{56} = \frac{\delta_n{d_n}^4\cap_s}{S_c}$ (28)

$\pi_7 = \alpha_{mc}$ (29)

The new dimensionless functional equation is expressed in Equation (30) as:

$WKR = f(\pi_{12}; \pi_{34}; \pi_{56}; \pi_7)$ (30)

$WKR = f\left\{\frac{V_n}{{d_n}^2D_{cd}}; \frac{F_r\cap_s}{T_pP_v}; \frac{\delta_n{d_n}^4\cap_s}{S_c}; \alpha_{mc}\right\}$ (31)

$WKR = f(A; B; C; D)$ (32)

Equation (31) gives the whole kernel recovery, WKR with all variables in Equation (1) as a function of four efficiency components which are presented as A, B, C and D respectively in Equation (32).

2.5 Model Input Parameters for Whole Kernel Recovery

The average experimental results, machine input, crop and design parameters for mixed varieties of palm nut are presented in Tables 3

Table 3: Experimental results of the effects of different crop and cracking machine parameters on whole kernel recovery for Mixed variety of palm nut.

S/N	V_{nc}	$\propto_{mc}$	D_{cd}	F_r	P_v	d_n	δ_n	S_c	$\cap_s$	T_p	WKR_e
1	0.0016	12.4	0.385	360.00	20.73	0.0165	710.55	1200	7.54	277.78	58.37
2	0.0016	14.0	0.385	400.00	24.19	0.0165	710.55	1400	8.79	187.92	62.29
3	0.0016	16.2	0.385	450.00	27.65	0.0165	710.55	1600	10.05	177.84	86.00
4	0.0016	18.1	0.385	514.29	31.10	0.0165	710.55	1800	11.31	156.63	80.71
5	0.0016	20.0	0.385	600.00	34.56	0.0165	710.55	2000	12.57	141.36	70.61

2.6 Development of the Prediction Equation

The prediction equation was established by allowing one π-term to vary at a time while keeping the other constant and observing the resulting changes in the function (Sam *et al*., 2022). This was achieved by plotting the values of experimental whole kernel recovery against dimensionless constants shown in Tables 4. The values of experimental whole kernel recovery were plotted against dimensionless constant π_{12}, while keeping π_{34}, π_{56} and π_7 constant; π_{34}, while keeping π_{12}, π_{56} and π_7 constant; π_{56}, while keeping π_{12}, π_{34} and π_7 constant; and π_7, while keeping π_{12}, π_{34} and π_{56} constant as illustrated in Figures 3 to 6.

Table 4: Experimental whole kernel recovery values (WKR_e) and calculated values (π_{12}, π_{34}, π_{56}, π_7) of whole kernel recovery for Mixed variety of palm nut in an impeller-type nut cracker

S/N	WKR_e	$\pi_{12} = \frac{V_{nc}}{{d_n}^2 D_{cd}}$	$\pi_{34} = \frac{F_r \cap_s}{T_p P_v}$	$\pi_{56} = \frac{\delta_n {d_n}^4 \cap_s}{S_c}$	$\pi_7 = \propto_{mc}$
1	58.37	15.26	0.4714	0.03309	12.4
2	62.29	15.27	0.7735	0.03313	14.0
3	86.00	15.32	0.9197	0.03327	16.2
4	80.71	15.33	1.1941	0.03329	18.1
5	70.61	15.34	1.5438	0.03330	20.0

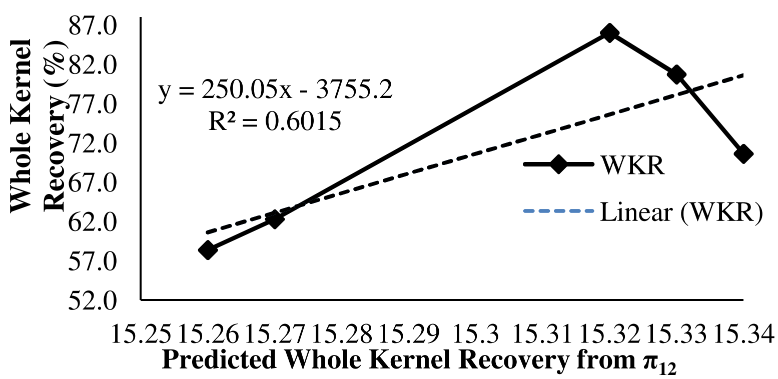

Figure 3: Variation of experimental whole kernel recovery against π_{12}, keeping π_{34}, π_{56} and π_7 constant

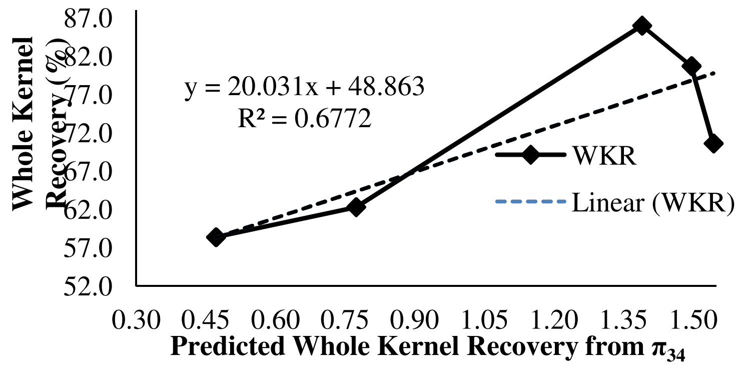

Figure 4: Variation of experimental whole kernel recovery against π_{34}, keeping π_{12}, π_{56} and π_7 constant

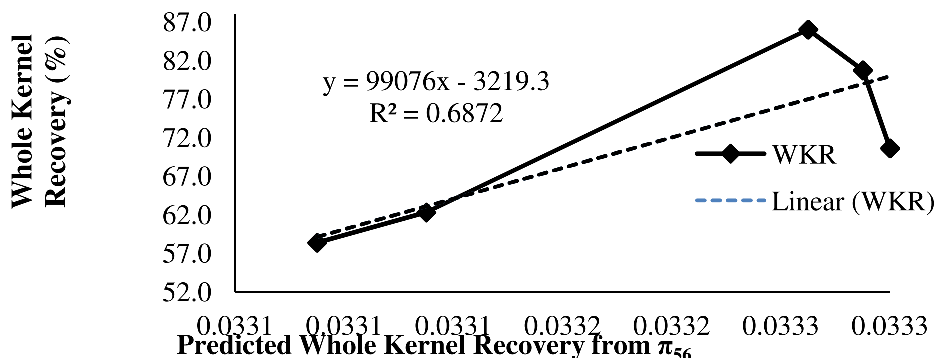

Figure 5: Variation of experimental whole kernel recovery against π_{56}, keeping π_{12}, π_{34} and π_7 constant

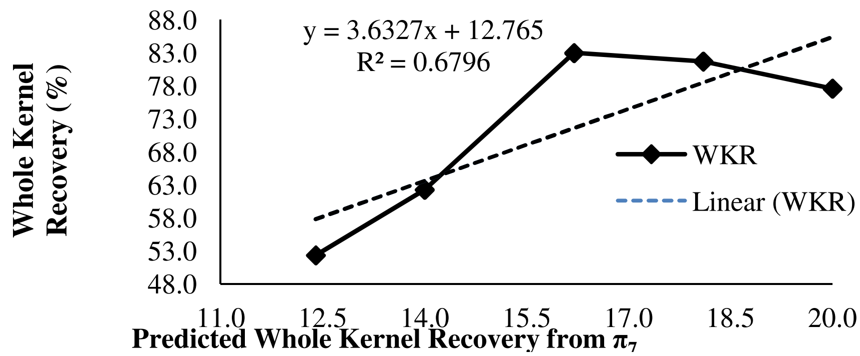

Figure 6: Variation of experimental whole kernel recovery against π_7 keeping π_{12}, π_{34} and π_{56} constant

The model equations obtained from the linear functions and R² values for mixed variety of palm nut are expressed in Equations 33 to 36 as:

$$WKR_{e/\pi_{12}-MIXED} = 250.05\pi_{12} - 3755.2 \qquad R^2 = 0.6015 \qquad (33)$$
$$WKR_{e/\pi_{34}-MIXED} = 20.031\pi_{34} + 48.86 \qquad R^2 = 0.6772 \qquad (34)$$
$$WKR_{e/\pi_{56}-MIXED} = 99076\pi_{56} - 3219.3 \qquad R^2 = 0.6872 \qquad (35)$$
$$WKR_{e/\pi_{7}-MIXED} = 3.633\pi_{7} + 12.77 \qquad R^2 = 0.6796 \qquad (36)$$

The plot of the π terms (Figures 3 – 6) forms a plane surface in linear space, and according to Mohammed (2002), Ndukwu and Asoegwu (2011) and Musa (2012), it implies that their combination favours summation or subtraction. Therefore, the component equation was combined by summation. The component equation was formed by the combination of the values of Equations 33 – 36 and expressed in Equation (37) as:

$$WKR_p = f_1(\pi_{12};\pi_{34};\pi_{56};\pi_7) + f_2(\pi_{12};\pi_{34};\pi_{56};\pi_7) + f_3(\pi_{12};\pi_{34};\pi_{56};\pi_7) + f_4(\pi_{12};\pi_{34};\pi_{56};\pi_7) + K \quad (37)$$

Substituting Equations (33) to (36) into Equation (37), WKR_p for mixed varieties were obtained in Equation (38) as:

$$WKR_{p-MIXED} = 250.05\pi_{12} + 20.03\pi_{34} + 99076\pi_{56} + 3.633\pi_7 - 6912.87 \quad (38)$$

A further manipulation as permitted under the rules of the Burkingham pi theorem is manipulating with a constant factor. Therefore, Equation (38) was divided with a constant factor of 3.65, which yields the predicted model Equation expressed in Equation (39) with values close to the actual ones.

$$WKR_{p-MIXED} = 68.51\pi_{12} + 5.488\pi_{34} + 27144.11\pi_{56} + 0.995\pi_7 - 1893.94 \quad (39)$$

Substituting the values of dimensionless π terms $(\pi_{12};\pi_{34};\pi_{56};\pi_7)$ into Equation (39), the predicted equation for whole kernel recovery was obtained as expressed in Equation (40) as:

$$WKR_{p-MIXED} = 68.51\left(\frac{V_{nc}}{{d_n}^2 D_{cd}}\right) + 5.488\left(\frac{F_r \cap_s}{T_p P_v}\right) + 27144.11\left(\frac{\delta_n {d_n}^4 \cap_s}{S_c}\right) + 0.995(\propto_{mc}) - 1893.94 \quad (40)$$

2.7 Model Validation

The mathematical model was validated using the data generated from the impeller-type palm nut cracker. The model validation was carried out at five levels of cracking speed (1200, 1400, 1600, 1800 and 2000 rpm), nut moisture content (12.4, 14.0, 16.2, 18.1 and 20.0 % w,b) and feed rate (360.00, 400.00, 450.00, 514.29 and 600.00 kg/h). The method of regression analysis as computed using Microsoft Excel programme of Microsoft package was used to describe the relationships, plot the graphs and compute the coefficients of determination (R^2) between the predicted and experimental values. Experimental values of parameters were substituted into Equation 40 to yield the predicted whole kernel recovery as presented in Table 5.

Table 5: Experimental (WKR_e) and calculated (WKR_p) values of whole kernel recovery for Mixed varieties of palm nut in an impeller-type nut cracker

S/N	Cracking Parameters			Whole Kernel Recovery	
	S_c	$\propto_{mc}$	F_r	$WKR_{e-Mixed}$	$WKR_{p-Mixed}$
1	1200	12.4	360.00	58.37	64.61
2	1400	14.0	400.00	62.29	68.03
3	1600	16.2	450.00	86.00	76.06
4	1800	18.1	514.29	80.71	78.80
5	2000	20.0	600.00	70.61	81.67

The predicted and experimental whole kernel recovery values were evaluated on a regression curve in order to obtain the coefficients of determination (R^2) and the Root Mean Square Error (RMSE). Figure 7 present the regression curves between the predicted and experimental whole kernel recovery, with their linear Equations and R^2 values.

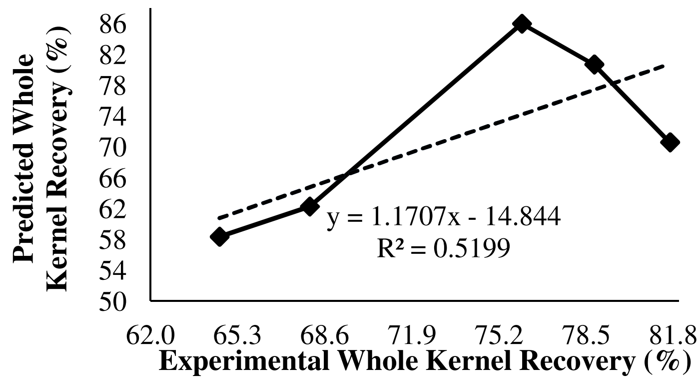

Figure 7: Graph of predicted (WKR_p) against experimental (WKR_e) whole kernel recovery for mixed variety of palm nut

From figures 7, it was observed that the predicted and experimental values have a very high correlation with R^2 values of 51.99% with a standard deviation of 11.76 and 13.77 as presented in Table 6.

The linear equations relating the predicted and experimental values of the whole kernel recovery is given in Equation (41) as:

$$WKR_{p-MIXED} = 1.17076WKR_{e-MIXED} - 14.844 \quad (41)$$

Equations 41 express the relationship between the predicted and experimental whole kernel recovery with R^2 values of 51.99%, with RMSE of 3.18 (Table 6) between the experimented and predicted whole kernel recovery values which is less than 5% of the average value of the experimental whole kernel recovery of palm nut using the impeller-type palm nut cracker. The validity of the models was examined by testing to know if the intercept and the slope were significantly different at 5% significance level.

Table 6: Experimental (WKR_e) and predicted (WKR_p) values of whole kernel recovery for mixed varieties of palm nut

S/N	Cracking Parameters			Whole Kernel Recovery	
	S_c	$\propto_{mc}$	F_r	$WKR_{e-Mixed}$	$WKR_{p-Mixed}$
1	1200	12.4	360.00	58.37	53.49
2	1400	14.0	400.00	62.29	58.08
3	1600	16.2	450.00	86.00	85.84
4	1800	18.1	514.29	80.71	79.64
5	2000	20.0	600.00	70.61	67.82
Standard deviation				11.76	13.77
RMSE				3.18	

3.0 Conclusion

Models to predict whole kernel recovery for mixed varieties of palm nut cracking machine were developed using the concept of Buckingham Pi theorem. The developed models were verified and validated by fitting them into experimental data. The method of regression analysis as computed using Microsoft Excel programme of Microsoft package was used to describe the relationships, plot the graphs and compute the coefficients of determination (R^2) between the predicted and experimental values. The simulated and experimental results during the cracking process and the best combination for optimum whole kernel recovery for mixed varieties was obtained

The developed model satisfactorily predicted the whole kernel recovery as performance parameters of the cracking machine during the cracking process with < 5% relative error.

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EFFECTS OF COCOPEAT AND RICE HUSK WASTES ON GROWTH AND YIELD OF CUCUMBER IN SOILLESS GREENHOUSE CULTURE

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Abstract

This study was carried out to determine the growth and yield performance of cucumber planted using agricultural wastes that served as a planting media (soilless farming) against traditional soil planting. The research was carried out in a greenhouse of 10.64 m² area. The experiment was randomized in a complete block design which comprised two treatments and three replications with a control experiment (soil farming). The treatments were: T_1 and T_2 irrigated manually at intervals of once per day. The physicochemical parameters of the culture media were determined, also the agronomic parameters (growth indices) of the plants were determined and the results were subjected to statistical analysis. The result showed that T_2 (100% rice husk) had the highest plant height of 151.0 cm on average, and a pedicel length of 12. 8cm.T_2 (100% rice husk) produced the highest cucumber fruit yield of 0.53 kg/m² with an average length and size of 23.77cm and 542.73 cm, respectively while T_1 (100% cocopeat) produced the lowest yield of cucumber for harvest. The control experiment (soil), with the highest average stem diameter of 2.57 cm had an average fruit length and size of 23.77 cm and 429.5 cm, respectively. The difference between the culture media was significant ($P < 0.01$) as yield and some other growth indices were higher in rice husk growing media. Results showed that crop growing indices for cucumber plants were sufficient when cultured in rice husk substrate, showing the capacity of this agricultural waste to anchor plant growth while providing alternative waste disposal and utilization method for this waste. Prospects for further work are suggested.

Keywords: Greenhouse, soil, crop waste, porosity, soil.

1. Introduction

The misuse of resources-land (soil), unplanned industrialization and the release of domestic and industrial wastes into the water sources pollute the soil and water resource which is most important for food production. The increasing need for food and raw materials for food industries in an increasingly rising population region like Nigeria necessitates the effective use of water resources. This increasing challenge has led to the adoption of alternative food-crop production techniques, for immediate consumption and as raw material for industries. (Senol *et al.*, 2018). For many millennia, farming has been dependent on soil because it is seen as the most available growing medium for plants. It harbours air, and water, among others for plant growth. However, soil degradation, climate change; population increase has been identified as major global challenges facing land use for food production. (Ajibade and Oyeniyi, 2018). These challenges have led to the adoption of many organic and inorganic materials as a growing medium for crops across the world. Soilless culture as one of the adopted methods can be defined as any method of growing plants without the use of soil as a rooting medium, in which the nutrients absorbed by the roots are supplied via irrigation water. The nutrients to be supplied to the crop are dissolved in appropriate concentration in the irrigation water and such solution is referred to as "nutrient solution" (Ajibade and Oyeniyi, 2018). When choosing a growing media, the media must be subjected to meet some criteria fit for use as a growing media. The most important functions of the growing media are to serve as a reservoir for plant nutrients, hold water for the plants, gas exchange, and provide anchorage for the plant (Haytham *et al.,* 2014). Rice husk and coco peat are organic substrates that have been used by some researchers to amend the soil for planting while some have used them in combination with other organic substrates to culture and cultivate to provide anchorage for crops.

According to Mohammadi (2013) investigations reviewed how Hasandokht *et al.* (2009) addition of rice husk to the soil in the rice farm caused the rice farm to increase in yield for a long time. He also stressed that the results of the use of zeolite, vermiculite and some organic materials as media for hydroponic tomato production showed that the lowest yield was obtained from the rice husk and a mixture of rice husk with other materials. The highest yield, shoot dry weight and number of clusters per pot were obtained from coco peat and perlite + mica media (Saberi *et al.,* 2006). Borji *et al.* (2010) investigated the effect of some media including date-palm peat, perlite, cocopeat and a mix of these materials on growing indices of tomato. Their results showed that fruit yield, fruit number, stem length, titratable acidity and ascorbic acid (in fruit) in different media had no significant differences. The effect of some culture media such as date-palm peat, cocopeat and perlite on some tomato growing indexes was studied by Mohammadi *et al.* (2011a). The treatments were perlite, date-palm peat and different ratios of coco peat and perlite and date-palm peat and perlite. Results showed a higher amount of total soluble solids (TSS) was related to coco peat and perlite treatment that had no significant difference with date palm peat and perlite, perlite and date-palm peat treatments. These researches were all centred on locating alternative materials for planting crops inside and outside the greenhouse. Most of the materials were used for soil amendment purposes due to the unavailability of these materials and cost-related challenges too.

However, in a clime like Nigeria where there is an abundance of rice husk lying waste at rice mills, another agro-waste also is cocopeat, a by-product of the coconut dehusking process that could serve as a substrate on its own (that is, providing an anchorage for plants). Coconut fibre is also known as palm peat, cocopeat, cocos, kokos and coir. Coir is coconut pith, the fibrous part just under the heavy husk. Coir is biodegradable and a good media, for plant propagation through the flowering and fruit growth stages (George *et al.,* 2013). Rice husk on the other hand is a by-product of the rice milling industry. It accounts for about 20% of the whole rice grains. The annual yield of rice husks in Egypt is about 960,000 tons (one ton of rice paddy produces 200 kg of the husk) (Esa *et al*., 2013).

Currently, appropriate disposal methods have not been put in place to efficiently dispose of or utilize this waste. Inhabitants of the environments where this waste is produced tend to dispose of only by burning the waste material and this has also posed health challenging issues therefore this present study aimed to compare the effects of rice husk, cocopeat, and soil (control) as a growing media, on the growth and performance of cucumber crop (*Cucumis sativus L.*) in the greenhouse. The objective of this research was to carry out some physicochemical characteristics of these culture media used in the cultivation of cucumber. It also covered the assessment of some selected growth indices of the cucumber crop during the growing and harvesting period. Analysis of variance (ANOVA) using SPSS statistical software was used to verify the effects and significance of the different treatment levels in cucumber production done in the greenhouse.

2. Methods

This research was carried out in a greenhouse located in the Department of Agricultural and Bioresources Engineering of the Federal University of Technology, Owerri. The experiment was designed using the randomized complete block design (RCBD) technique with two complete treatments and three replications. The treatments were: 100% coconut coir, or cocopeat, 100% rice husk, and pure loamy sand soil. *Cucumis Sativus L*. cultivar was used as the seed under study.

Cucumber seeds were sown one seed per square hole in a cocopeat medium inside a seedling tray and young plants at three true leaf stages were transplanted into the plastic grow bags filled with the different growing media. One cucumber plant per bag was planted in grow bags of dimensions 63.5cm wide and 40.6cm high from ground level and the distance between bags was 27cm row-wise and 22cm column-wise. Plants were grown between June and August. The cucumber plants were fertigated with a nutrient solution (A formulation of BIC Farms Concept, Abeokuta), mixed at 10 g per 100 L of water for mix B and 12 g per 100 L of water for only mix A, a week after transplanting till before fruiting. The pH of the nutrient solution was kept between 5.5-6. Irrigation was performed by hand twice daily based on the water holding capacity of the media (which varied from 8.33 to 186.23%). The average temperature day and night was kept at 30^{o}C and 18˚C, respectively.

Some of the physicochemical characteristics of the culture media including; Bulk density, organic carbon, total porosity, water holding capacity, cation exchange capacity, and moisture content was measured. Electrical conductivity (EC) and pH of the culture media were also measured using the Microorganism population in the culture media was determined using the five-fold serial dilution method. The plants were grown for three months and the selected growing indices included; Plant height (cm), stem diameter (cm), fruit weight (kg), fruit length (cm), fruit size (cm^2), the total number of fruits harvested throughout the growing period, and pedicel length (cm), were measured during and after the growing period. Experimental data normality was verified, and then the data were submitted for analysis of variance, using SPSS Statistical software. Means were compared using Duncan multiple tests ($P < 0.05$).

3. Results and Discussion

Physicochemical properties of media

The results of some selected physicochemical characteristics of the culture media are listed in Table 1. The lowest bulk density (0.90) and highest porosity (30.45) were related to 100% rice husk. This is an indication that the media portrayed sufficient root aeration than the other media. By implication, root media sufficiency indicates a better supply of oxygen, water and nutrients to the cultivated plants. The EC value (0.15μs/cm) was higher in 100% rice husks and lowest in the soil medium (0.02μs/cm).

Table 1. Some physicochemical characteristics of the culture media.

Substrate	Bulk density, g/cm³	WHC, ml	OC, g	MC, %	Porosity, %	MP	pH	EC, (µs/cm)	CEC, (meq/100g)
100% cocopeat	0.99	26.00	2.00	186.3	0.45	1.23×10^7	6.62	0.15	3.29
100% rice husk	0.90	2.00	2.34	73.5	0.53	33.8×10^6	5.82	0.39	2.62
Loamy sand soil	1.58	4.00	0.91	8.33	0.59	2.45×10^7	6.22	0.02	2.36

The 100% cocopeat CEC (3.29meq/100g) and MP (1.23×10^7) showed an ability to conduct and supply more nutrient compounds to the crop, however, this was limited by the capacity of this media to hold water longer than the other media WHC (26%) and this is followed by 100% rice husk, CEC (2.62meq/100g) and MP (33.8×10^6). The 100% rice husk had the lowest pH (5.82), this is a similar result when compared to Mohammadi's (2013) research. However, 100% rice husks had the lowest water holding capacity, WHC (2%) which resulted in the media requiring higher irrigation water quantity or demand.

Growing indices

The results of the selected growing indices of the cucumber crop are presented in Table 2. Plants in 100%rice husk medium recorded the highest fruit yield when compared to the other media at a 5% level significant difference. The rice husk medium also recorded the highest pedicel length. The level of porosity, cation exchange capacity, bulk density and water holding capacity of rice husk media was sufficient enough to support plant root health, this, in turn, supported water and nutrient elements availability for plant growth and better fruit yield. The higher porosity and lower bulk density of the medium provided for less resistance to root motion in this medium.

Table 2. Effect of the culture media on the growth and yield of cucumber.

Culture media	Stem Diameter, cm	Plant height, cm	Fruit number	Fruit weight, kg	Fruit length, cm	Pedicel length, cm	Fruit diameter, cm	Fruit size, cm²
100% cocopeat	2.10	106.00	12	0.30	3.73	11.5	0.25	0.93
100% rice husk	2.37	151.00	21	0.43	28.10	12.8	9.66	271.31
Loamy sand soil	2.57	123.30	15	0.36	23.77	8.00	9.04	214.88

A good growing media would provide sufficient anchorage to the plant, serve as a reservoir for nutrients and water, allow oxygen diffusion to the roots and permit gaseous exchange between the roots and atmosphere outside the root substrate (Mohammadi, 2013). The fruit length and diameter in 100%cocopeat were the lowest and it had a significant difference from the other culture media at a 5% level. This was a result of its high-water holding capacity and higher bulk density even with a lower porosity value than the rice husk medium. These medium plant roots suffered suffocation and salinity issues due to their ability to retain fluid (both water and nutrient mix) longer than the other media. This led to a delay in its maturity and fruiting duration extending effects to the fruit size.

Most researchers incorporate these organic wastes into the soil as soil amendments to improve its productivity or growth yield (Mohammadi, 2013). However, for this research, these organic (agricultural) wastes were used by themselves as an anchorage for plant growth and development and this was carried out in comparison to traditional soil growing medium. Mohammadi (2013) recorded an improvement in the physicochemical properties of soil when mixed with organic wastes, however, he noted that there was an increase in the microorganism population due to the decomposition process which battled with the crop for nutrients and as a result led to the lower yield he had. This research, however, focused on using these organic wastes on their own (soilless farming) as a medium for plant growth and development in greenhouse agriculture. The organic matter or waste that was used for this research was 100% fresh and had not passed through fermentation or earlier use period.

The result obtained from this study clearly showed that rice husk waste with a bulk density of 0.90g/cm3, water holding capacity of 2 ml porosity of 53% and cation exchange capacity of 3.29 meq/100g can be comfortably adopted as a medium for plant growth and development. It gave the best physical and chemical conditions required of a plant growth media and produced the highest yield (21 fruits) within the required fruiting period. Therefore, there is no need for composting, charring or using the material as a soil amendment to achieve the desired output. Adopting organic waste as a culture media in itself alone will not only improve crop yield but will reduce its mass deposit and illegal disposal techniques adopted by the producers of these agricultural waste materials. This is one of the objectives of this research, to not only create an alternative waste disposal technique for rice husk and cocopeat wastes but to also achieve a zero-waste goal of SDG 2030 by providing an alternative waste utilization method which is in this research as a culture media.

Waste to wealth conversion is a keenly pursued subject in Nigeria by policymakers and industry stakeholders, driven by international and domestic needs concerning the mission statement in the Nigeria Agenda. It has been observed therefore that using this method for recycling agricultural waste, not only utilized the agricultural wastes but provided food and employment to the populace.

However, improvements on the work by the installation of solar-powered, sensor-timed drip irrigation that could irrigate the crop under study or any other crop based on their crop water needs are recommended for further studies.

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SUITABLE DRYING MODEL FOR BLOODMEAL PRODUCTION FROM A FRESH RED BOROROBULL'S BLOOD USING A CONVECTIVE OVEN.

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Abstract

This research was aimed at identifying a suitable drying model for bloodmeal production from a fresh blood sample of a male Red Bororo cattle. Convective oven dryer was used to effect the drying process, EDTA tubes was used to collect the samples to prevent it from coagulating, Design expert version 8 was used for the experimental design and to study the interaction effects of the drying process variables. Drying experiments was carried out at air temperatures of 40° C, 50° C, 60° C and 70° C and drying air velocities of 2.5 m/s, 3.0 m/s, 3.5 m/s and 4.0 m/s. A preliminary laboratory experiment showed the best dosage of the sample to be 3g. It was observed from the drying kinetics of the bloodmeal that the most suitable model for describing the thin layer drying of 3g of fresh Bull's blood at the optimized drying conditions is the two-term model amongst the studied models. It had R^2 = 0.99563 and lowest sum of squared estimate of errors (SSE) value of 0.00333 for 51.981° C drying temperature and 2.864 m/s air speed in 33.944 minutes.

Key words: Cattle blood, Bloodmeal, Thin layer drying, Drying Models, Convective Oven drying.

1.1 Introduction

Drying is an old preservation technique of farm products and is a complex thermo-physical and biochemical process involving heat and mass between the material surface and the environment. Nwajinka *et al.* (2015) maintained that, "movement of moisture within a bio-material during drying follows various complex mechanisms and kinetics that will continue to attract attention".

Numerous studies have been conducted on drying and product quality of dried food samples, leading to the deployment of several drying models. According to Dhanugh Kodi *et al.* (2017), drying in the food industry may be classified into three groups of goals; economic considerations, environmental concerns and product quality.

For an integrated zero waste system, blood (effluents) from abattoirs should no longer be treated as a waste. Damba, (2017) reported that blood can be used in the following areas: fertilizer, leather finishing, animal feed, in plaster, sugar refining, buttons, therapeutic iron preparations etc. In Nigeria, blood effluents from abattoirs are currently notable sources of environmental pollution and if left unchecked, could trigger off a very serious epidemic.Because of the nutritive value of bloodmeal and accessibility of blood compared to other protein materials of animal origin (Winter 1929). Bloodmeal should find greater use as an animal feed (Aladetohun and Sogbesan, 2013).

Bloodmeal relieves the enormous pressure of sourcing animal feed from the same food materials available to man. It will improve environmental sanity as well as food security for man's benefit. The thin layer drying studies provide the basis for understanding the peculiar drying characteristics of a particular food material. In the determination of the effects of drying conditions on the characteristics of bloodmeal; the bone-dry weight was determined. The fresh bull blood sample was weighed and the sample exposed to a stream of drying air in a convective oven dryer. The drying characteristics was determined by monitoring air velocity and temperature over a period of time. A number of existing mathematical models were used to simulate moisture movement and mass transfer during the sample drying. Understanding the kinetics of blood drying will enhance bloodmeal processing. This study is therefore aimed at fitting known drying models to the drying of fresh cattle bull's blood.

2.0 Materials and Methods

2.1 Sample Collection and Preparation

Fresh whole blood was collected from an abattoir at Ochanja market, Onitsha, Anambra State, Nigeria of latitude 6.1329^o N and longitude 6.7924^o E, immediately after the slaughtering of a Red Bororo Fulani cattle breed, Care was taken so that only clean blood was collected; there was no contamination with undigested food. To prevent the blood from coagulating, EDTA tube of 250ml was used to store the collected blood before taking it to the Department of Chemical Engineering Laboratory at the Nnamdi Azikiwe University, Awka, Anambra State, Nigeria for drying. The Convective oven dryer was used in this experiment.

2.2 Study Approach

The central composite design (CCD) was used for the experimental design and to study the interaction effects of the drying process variables. Variables on the drying efficiency, Temperature (A,X_1), Air speed (B,X_2) and drying time (C,X_3) were the identified set of independent process variable. A dosage of 3g per batch was from preliminary experiment as the best, was used for this experiment. The influence of these variables on the output variables (Moisture content (%), weight loss (g) and dried mass (g)) were investigated. A simple plot of Moisture ratio (MR) of the material being dried against drying time easily reveals the drying rate. The MR is obtained as

$$MR= \frac{m_t}{m_i} \qquad (1)$$

where MR is the moisture ratio, m_t is the moisture content at a given time and m_i is the initial moisture content. Design expert version 8.0 software was used for the design of the experiment. For a design of three independent variables (n=3), each with two different levels, the total number of twenty experiments (N=20) was worked out. The numerical values of the variables were transformed into their respectively coded values as shown in Eq. 1:

$$X_i = \frac{2x-(x_{max}-x_{min})}{x_{max}-x_{min}} \qquad (2)$$

Where X_i is the required coded value of a variable; X, X_{min} and X_{max} are the low and high values of X respectively. The output variables (responses) were used to develop an empirical model that depicts its (responses, Y_i) with the selected independent variable using second-order Polynomial equation given by Eq. 2 (Abonyi *et al*., 2020);

$$Y_i= \beta_0 + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \beta_{ii} x_i^2 + \sum_{i=1}^{n} \sum_{j=1}^{n-1} \beta_{ij} x_i x_j \qquad (3)$$

Where Y is the predicted response, β_0 is the constant coefficient, β_I is the linear coefficient, β_{ij} is the interaction coefficient, β_{ii} is the quadratic coefficient, and X_i, are the coded values for the factors.

2.3 Developing Suitable Drying Models for Bull's Blood Drying

The models' error functions were evaluated as in Eqs 4 – 12. The goodness of fit of each model was determined based on the coefficient of determination (R^2) value. The R^2 value measures how much of the variability in the observed response value could be explained by the experimental variables and their interactions. The R^2 value is always between 0 to 1. The closer the R^2 value is to 1, the stronger the model and the better its prediction of the response (Chandana *et al*., 2011).

Table 1: The error function and mechanistic models

Error model	Mathematical expression	Eq. no.
Correlation coefficient (R)	$R = \frac{\sum_{i=1}^{N}(y_{pred.(i)} - y_{pred.ave.}).(y_{exp.(i)} - y_{exp.ave.})}{\sqrt{\left[\sum_{i=1}^{N}(y_{pred.(i)} - y_{pred.ave.})^2\right]\left[\sum_{i=1}^{N}(y_{exp.(i)} - y_{exp.ave.})^2\right]}}$	4
Coefficient of determination (R^2)	$R^2 = 1 - \frac{\sum_{i=1}^{N}(y_{exp..(i)} - y_{pred.(i)})^2}{\sum_{i=1}^{N}(y_{pred.(i)} - y_{exp.ave.})^2}$	5
Adjusted R^2	$Adjusted\ R^2 = 1 - \left[(R^2) \text{ x } \frac{N-1}{N-P-1}\right]$	6
Absolute average relative error	$AARE = \frac{1}{N}\sum_{i=1}^{N}\left(\left|\frac{y_{exp.(i)} - y_{pred.(i)}}{y_{exp.(i)}}\right|\right)$	7
Marquardt's percent standard deviation	$MPSED, \% = \sqrt{\frac{\sum_{i=1}^{N}\left[\frac{y_{exp.(i)} - y_{pred.(i)}}{y_{exp.(i)}}\right]^2}{N-P}} \text{ x } 100$	8
Root mean square error	$RMSE = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(y_{pred.(i)} - y_{exp.(i)})^2}$	9
Standard deviation	$SD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(\left|\frac{y_{exp.(i)} - y_{pred.(i)}}{y_{exp.(i)}}\right| - AARE\right)^2}$	10
Sum of squares error	$SSE = \sum_{i=1}^{N}(y_{exp.(i)} - y_{pred.(i)})^2$	11
Hybrid fractional error function	$HYBRID, \% = \frac{1}{N-P}\sum_{i=1}^{N}\left[\frac{(y_{exp.(i)} - y_{pred.(i)})^2}{y_{exp.(i)}}\right] \text{ x } 100$	12

3.0 Results and Discussions

The plot of Moisture ratio versus drying time for the processing of bloodmeal are presented in Fig. 1. From the plots, it was noticed that the drying occurred predominately during the falling rate period; hence it may be deduced that the dominant physical mechanism governing the moisture movement in Bloodmeal was diffusion along the moisture concentration gradient as obtained for most agricultural products (Aregbesola *et al*., 2015).

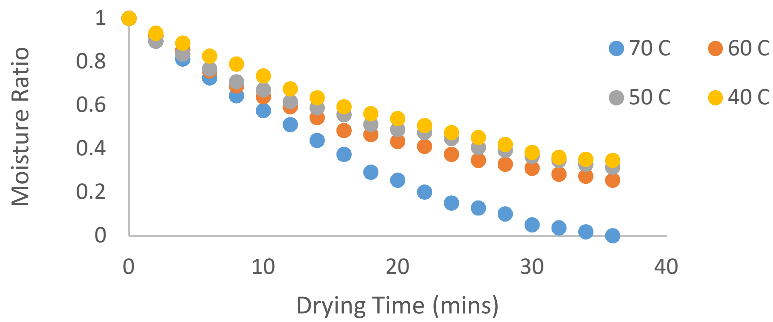

Fig 1 Moisture Ratio against drying time (mins) for different temperatures.

Table 2 shows the different moisture content values for the fresh cow blood sample for the different drying times at different oven air velocities. At two minutes, across the different air speed, highest bloodmeal weight of 2.01g, 1.95 and 1.93 was obtained for air speeds of 3.0m/s, 2.5m/s and 4.0m/s respectively.

Table 2 Effects of Drying Time on Sample Weight for Different Air Speeds

Sample weight (g)

Time (min)	4.0m/s	3.5m/s	3.0m/s	2.5m/s
0	3	3	3	3
2	1.93	1.8	2.01	1.95
4	1.79	1.61	1.87	1.79
6	1.58	1.49	1.66	1.63
8	1.41	1.33	1.51	1.52
10	1.19	1.23	1.4	1.45
12	0.99	1.08	1.3	1.35
14	0.85	0.98	1.19	1.26
16	0.68	0.86	1.06	1.15
18	0.57	0.78	1.02	1.09
20	0.46	0.7	0.95	1
22	0.35	0.6	0.9	0.98
24	0.26	0.53	0.82	0.88
26	0.22	0.48	0.76	0.84
28	0.15	0.38	0.72	0.81
30	0.11	0.31	0.68	0.74
32	0.08	0.24	0.62	0.7

The moisture loss was least at two minutes drying time, while at thirty-two minutes, the smallest weight of the sample was determined to be 0.08g at 4.0 m/s oven air speed. It may be concluded that temperature has a more profound influence on drying the fresh cow blood than the air velocity of the oven. At thirty-two minutes, the moisture content of the sample at different air speeds of 4.0 m/s, 3.5 m/s, 3.0 m/s and 2.5 m/s were 0.08 %db, 0.24 %db, 0.62 %db, 0.7 %db respectively. This also implies that more time and increased air velocity is required to remove the moisture content of the fresh cow blood sample. The airspeed can be varied in the dryer. The effect of air velocity on bloodmeal processing almost replicated the pattern of the effects of temperature on the processing of bloodmeal. At thirty-two minutes, the new weight of the fresh cow blood sample at different air speed of 4.0 m/s, 3.5 m/s, 3.0 m/s and 2.5 m/s were 0.89g, 1.05g, 1.43g and 1.51g respectively. At two minutes drying time, the weight loss was minimal across the different air speed. This implies that more time and increased oven air velocity is required to dry the fresh cow blood to bloodmeal.

The plot of Moisture ratio versus drying time for the processing of bloodmeal in terms of air velocity are presented in Fig. 2. From the plots,

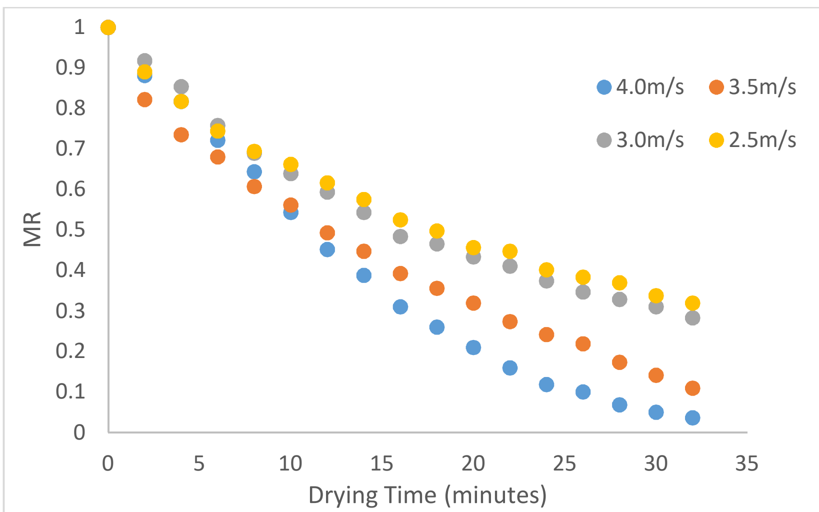

Fig. 2: Moisture ratio versus drying time for different Air speeds

It was noticed that the drying occurred predominately during the falling rate period; hence it can be inferred that the dominant physical mechanism governing the moisture movement in Bloodmeal was diffusion along the moisture concentration gradient as obtained for most agricultural products (Aregbesola *et al.*, 2015 and Karathanos and Belessiotis, 1999).

3.1 Drying Kinetic Models

Fig. 3 present the result of non-linear analysis of the fitting of nine semi-theoretical models to the drying data of bloodmeal at 40°C and the plots of the moisture ratio against the

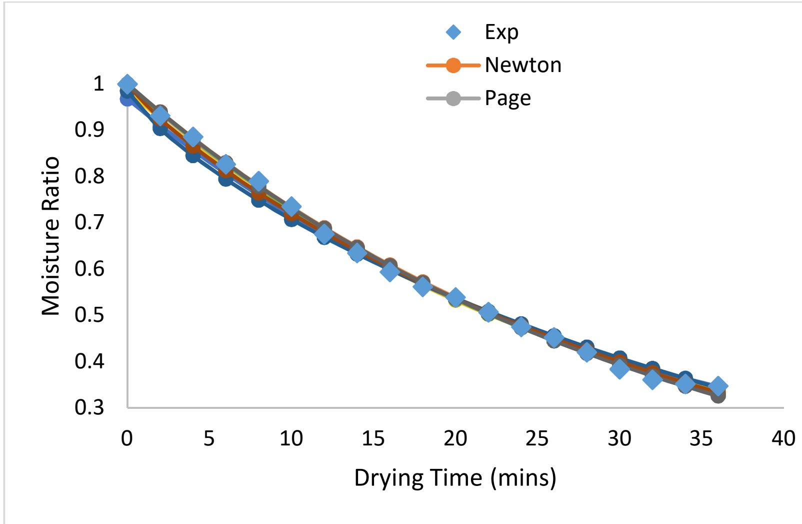

Fig. 3: Moisture Ratio Vs Drying time for different drying models at 40°C.

Drying time for the nine semi-theoretical drying models. All the models tend to follow the same curve pattern in the plot. Across the Table, the values of the moisture ratio for most theoretical models did not show a remarkable difference for different drying times. It can be deduced in Table 3 that model parameters other than the constant (k) did not show a definite trend. The constant (k) decreased mathematically with increase in temperature for most of the models.

Table 3: Thin layer drying models for the study

Name	Model	Reference
Newton	MR = exp(-kt)	Ayensu (1997)
Page	MR = exp(-kt^n)	Diamante and Munro (1993)
Modified page	MR = exp((-kt))^n	White et al., (1981)
Henderson and Pabis	MR = a exp(-kt)	Akpinar et al., (2003)
Logarithmic	MR = exp a(-kt) + C	Yagcioglu et al., (1999)
Two term	MR = a exp(-k$_0$t) + b exp(-k$_1$t)	Togrul and Pehlivan (2004)
Diffusion	MR = a exp(-kt) + (1-a) exp(-kbt)	Yaldiz and Erdekin (2001)
Midilli	MR = a exp(-k$_1$t^n) + bt	Midilli and Kucuk (2003)
Hii	MR = a exp(-k$_1$t^n) + b exp(-k$_2$t^n)	Hii et al., (2009)
App. Diff.	MR =a exp(-kt)(1-a) exp(-kbt)	Erbay and Icier (2009).

Table 4: Kinetic Parameters of Different Drying Models at Different Temperatures

		40°C	50°C	60°C	70°C
Model	Parameters		Values		
Newton	k	-0.03100	-0.03517	-0.04080	-0.09300
Page	k	-0.03310	-0.03980	-0.04500	-0.09900
	n	0.98000	0.96000	0.96800	0.98100
Logarithmic	a	0.90000	0.88000	0.85000	0.98000
	k	-0.03510	-0.03900	-0.04430	-0.10100
	C	0.08660	0.08840	0.08850	0.01351
Two Term	a	0.07800	0.10000	0.08000	0.10000
	k_0	0.00001	0.00005	0.00005	0.00001
	b	0.89000	0.87000	0.85000	0.90000
	k_1	-0.03340	-0.04000	-0.04290	-0.13000
App. Diff.	a	0.85000	0.89000	0.93000	0.98000
	k	-0.03420	-0.03760	-0.04260	-0.09400
	1-a	0.15000	0.11000	0.07000	0.02000
	b	0.50600	0.52000	0.52100	0.66300
Midilli	a	0.98500	0.95300	0.95100	0.98000
	k	-0.04610	-0.04700	-0.05400	-0.12000
	n	0.81800	0.82000	0.82800	0.81190
	b	-0.00200	-0.00250	-0.00247	-0.00247
Hii Model	a	1.50000	1.44200	1.50000	1.50000
	k_1	-0.03210	-0.03210	-0.03900	-0.06000
	n	0.88900	0.88900	0.88900	0.88020
	b	-0.50100	-0.50100	-0.50100	-0.50090
	k_2	-0.01398	-0.01398	-0.01398	-0.01398
Henderson & Pabis	a	1.00000	0.98000	0.98300	0.98300
	K	-0.03115	-0.03400	-0.03980	-0.09221

Fig. 4 shows the result of non-linear analysis of the fitting of nine semi-theoretical models to the drying data of bloodmeal at 50°C and the plots of the

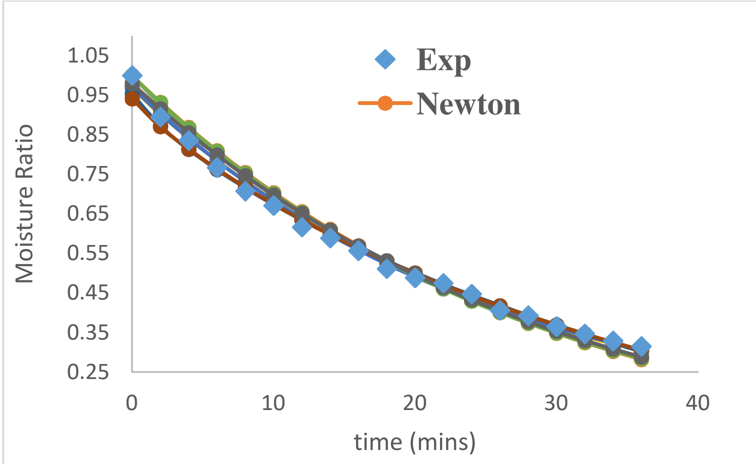

Fig. 4: Moisture Ratio against drying time for different drying models at 50°C.

moisture ratio against the drying time for the nine semi-theoretical models respectively. All the models tend to follow the same curve pattern in the plot. Across the table, the values of the moisture ratio for most theoretical models did not show a remarkable difference for different drying times. Down the Table, Moisture ratio decreases with increase in drying time.

Fig. 5 shows the result of non-linear analysis of the fitting of nine semi-theoretical models to the drying data of bloodmeal at 60°C and the plots of the moisture ratio against the drying time for the nine semi-theoretical models respectively. All the models tend to follow the same curve pattern in the plot.

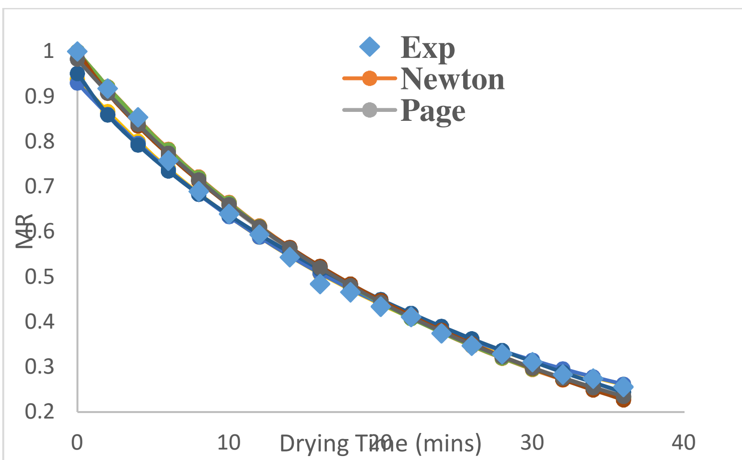

Fig. 5: Moisture Ratio against drying time for different drying models at 60°C.

Fig. 6 shows the result of non-linear analysis (exponential function) of the fitting of nine semi-theoretical models to the drying data of blood sample at 70°C. It depicts the plots of the moisture ratio against the drying time for the semi-theoretical models respectively

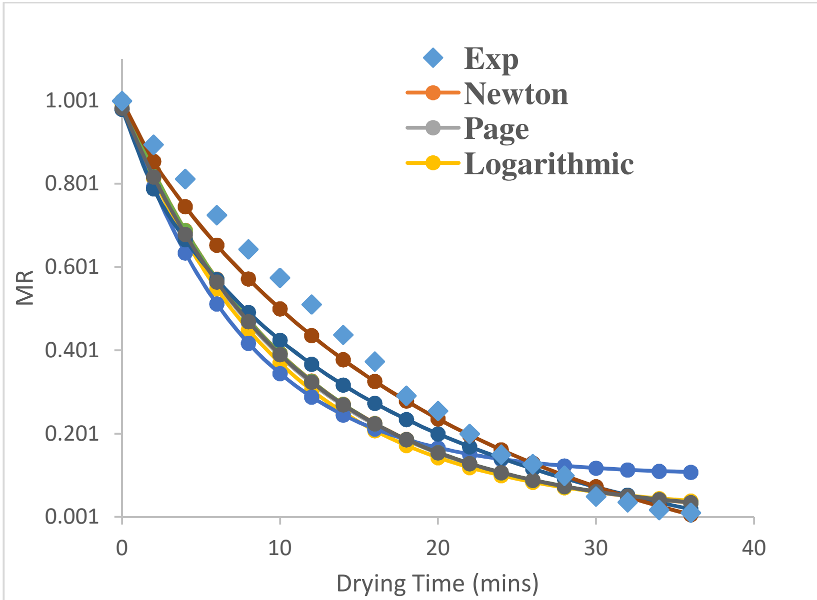

Fig. 6: Moisture ratio vs drying time for different drying models at 70°C.

This could be as a result of higher energy of the high drying temperature. All the plots tend to follow the same curve pattern in the plot. Across the table, the values of the moisture ratio for most theoretical models did not show a remarkable difference for different drying times. Table 4 presents the error analysis of the different semi-theoretical models at 40°C. From the evaluation criteria (R^2 and SSE) of 0.99828 and 0.00133 respectively. The page model gave a good description of the thin layer drying characteristics of Bloodmeal with $R^2 > 0.97$.

However, based on the highest R^2 values and lowest SSE values, the suitable models for describing thin layer drying characteristics of Bloodmeal at 40°C are the Newton, App. Diff., page and Henderson & Pabis respectively.

With the aid of Excel solver (software), the Goodness-of-fit from error analysis for the different temperatures was generated with the aid of the formulae in the Table 1.

Table 5: Values of Goodness-of-fit parameters from Error Analysis for 40^0

		R – Sqrd	Adj R - Sqrd	AARE	HYBRID	ARE	MPSE	SSE
Newton	0.97252	0.99805	0.99781	0.01345	0.02101	1.34459	0.02176	0.00154
Page	0.97572	0.99828	0.99807	0.01287	0.01821	1.28736	0.02034	0.00133
Logarithmic	0.96264	0.99684	0.99645	0.01578	0.02651	1.57772	0.02315	0.00229
Two Term	0.92233	0.99215	0.99117	0.02070	0.05346	2.07009	0.03094	0.00532
App. Diff.	0.97635	0.99835	0.99815	0.01333	0.01792	1.33327	0.02029	0.00129
Midilli	0.89009	0.98848	0.98704	0.02543	0.07678	2.54340	0.03647	0.00770
Hii Model	0.96260	0.99681	0.99641	0.01552	0.02702	1.55202	0.02320	0.00235
Henderson & Pabis	0.97314	0.99814	0.99791	0.01397	0.02063	1.39732	0.02185	0.00147

All models gave a good description of the thin layer drying characteristics of Bloodmeal with R-sqrd > 0.97. The Diffusion Approximation model with R-Squared of 0.99835 and SSE value of 0.00129 gave the best description of the thin layer drying characteristics of Bloodmeal with R-sqrd > 0.97 at 40^o C.

Table 6 presents the error analysis of the different moisture ratio fitted into various semi-theoretical models at 50^o C. From the evaluation criteria (R^2 and SSE),

	R	R – Sqrd (R^2)	Adj R – Sqrd	AARE	HYBRID	ARE	MPSE	SSE
Newton	0.83824	0.98498	0.98311	0.04493	0.16191	4.49313	0.05746	0.01364
Page	0.88744	0.99001	0.98876	0.03563	0.10258	3.56323	0.04557	0.00867
Logarithmic	0.95022	0.99523	0.99464	0.02005	0.03768	2.00491	0.02562	0.00365
Two Term	0.95469	0.99563	0.99509	0.01866	0.03410	1.86586	0.02415	0.00333
App. Diff.	0.85105	0.98623	0.98451	0.04255	0.14574	4.25544	0.05426	0.01238
Midilli	0.93787	0.99316	0.99230	0.01862	0.04249	1.86210	0.02590	0.00469
Hii Model	0.92778	0.99123	0.99014	0.01829	0.04906	1.82932	0.02621	0.00591
Henderson & Pabis	0.88201	0.98956	0.98825	0.03650	0.10455	3.64975	0.04609	0.00877

all models gave a good description of the thin layer drying characteristics of Bloodmeal with R- Table 6: Values of Goodness-of-fit parameters from Error Analysis of 50^oC

sqrd > 0.97. The two-term model with R-Squared of 0.99563 and SSE value of 0.00333 gave the best description of the thin layer drying characteristics of Bloodmeal with R-sqrd > 0.97.

However, based on the highest R^2 values and lowest SSE values, the best models for describing thin layer drying characteristics of Bloodmeal at 50^0C are the page, Logarithmic, Two term, Midilli and Henderson & Pabis respectively. While the two term model is the most suitable at this temperature which is close to the optimal temperature of 51.98^o C.

Table 7 presents the error analysis of the different semi-theoretical models at 60^o C. From the evaluation criteria (R-sqrd and SSE). All models gave a good description of the thin layer drying characteristics of Bloodmeal with R-sqrd > 0.97.

.Table 7: Values of Goodness-of-fit parameters from Error Analysis (60 ^{o}C)

	R	R - Sqrd	Adj R - Sqrd	AARE	HYBRID	ARE	MPSE	SSE
Newton	0.90829	0.99365	0.99285	0.03438	0.09726	3.43761	0.05023	0.00654
Page	0.93748	0.99574	0.99521	0.02757	0.06234	2.75662	0.03986	0.00424
Logarithmic	0.89597	0.98673	0.98507	0.02397	0.08631	2.39713	0.03459	0.01063
Two Term	0.87039	0.98301	0.98089	0.02715	0.10774	2.71460	0.03868	0.01329
App. Diff.	0.91741	0.99429	0.99358	0.03227	0.08621	3.22750	0.04706	0.00584
Midilli	0.86582	0.98432	0.98236	0.03221	0.11631	3.22075	0.04328	0.01274
Hii Model	0.90401	0.99367	0.99288	0.03568	0.09827	3.56769	0.05169	0.00626
Henderson & Pabis	0.92395	0.99449	0.99380	0.03114	0.07507	3.11436	0.04303	0.00535

However, based on the highest R-sqrd values and lowest SSE values, the most suitable models for describing thin layer drying characteristics of Bloodmeal at 60^oC are the Newton, page and App. Diff., Hii and Henderson & Pabis respectively

Table 8 presents the error analysis of the different moisture ratio fitted into the semi-theoretical models at 70^0 C. From the evaluation criteria (R-sqrd and SSE). Only the Hii model gave a good description of the thin layer drying characteristics of Bloodmeal with R-squared > 0.97.

Table 8 Values of goodness-of-fit parameters from error analysis for 70 °C

	R	R – Sqrd	Adj R – Sqrd	AARE	HYBRID	ARE	MPSE	SSE
Newton	0.25874	0.88027	0.86530	0.43225	3.80437	43.22515	0.72867	0.21940
Page	0.24347	0.86136	0.84403	0.44399	4.04517	44.39910	0.74797	0.23679
Logarithmic	0.20387	0.83545	0.81488	0.49050	4.90337	49.05003	0.83887	0.28424
Two Term	0.03045	0.77192	0.74341	1.11949	14.67342	111.94877	2.71036	0.35475
App. Diff.	0.25622	0.87062	0.85445	0.43490	3.84581	43.48984	0.73404	0.22181
Midilli	0.36976	0.89706	0.88419	0.27688	2.12110	27.68792	0.40627	0.15618
Hii Model	0.73104	0.97885	0.97620	0.14819	0.54514	14.81858	0.23911	0.03476
Henderson & Pabis	0.24521	0.86672	0.85006	0.44024	3.94249	44.02361	0.74026	0.23120

However, based on the highest R-squared values and lowest SSE values, the most suitable model for describing thin layer drying characteristics of Bloodmeal at 70°C is the Hii model with R-sqrd value at 0.97885 and the SSE value of 0.03476.

4.0 Conclusion

The results and observations of the drying process indicate that temperature and time are the two most crucial factors in the production of bloodmeal. The study also revealed that bloodmeal contains a lot of proteins and that fresh cow blood can be dried within the temperature of 40°C and 70°C to avoid protein denaturation. This drying process could be said to be predominantly driven by diffusion by increasing the energy of the fresh cow blood molecules. This followed the trend of drying of most agricultural materials. The two-term model (with R^2 value of 0.99563 and SSE value of 0.00333) best fitted the experimental data.

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DRYING KINETICS, ENERGY REQUIREMENT, BIOACTIVE COMPOSITION AND MATHEMATICAL MODELING OF ALLIUM CEPA SLICES

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Abstract

The drying kinetics, specific energy consumed (SEC), effective moisture diffusivity (EMD), flavonoid, phenolic and vit. C contents of onion slices dried under convective oven drying (COD) were compared with microwave drying (MD). Drying was performed with onion slice thicknesses of 2, 4, 6 and 8 mm; air drying temperatures of 60, 80, and 100°C for COD and microwave power of 450 W for MD. A decrease in slice thickness and increase in drying air temperature led to a drop in the drying time. As thickness increased from 2 – 8 mm, EMD rose from 1.1 – 4.35 $\times 10^{-8}$ at 60°C, 1.1 – 5.6 $\times 10^{-8}$ at 80°C and 1.25 – 6.12 $\times 10^{-8}$ at 100°C with MD treatments yielding the highest mean value (6.65$\times 10^{-8}$ m^2 s^{-1}) at 8 mm. Maximum SEC for onion slices in COD was 238.27 kWh/kg H_2O (2 mm thickness) and the minimum was 39.4 kWh/kg H_2O (8 mm thickness) whereas maximum during MD was 25.33 kWh/kg H_2O (8 mm thickness) and minimum, 18.7 kWh/kg H_2O (2 mm thickness). MD treatment gave a significant ($p \leq 0.05$) increase in the flavonoid (39.42 – 64.4%), phenolic (38.0 – 46.84%) and vit. C (3.7 – 4.23 mg 100 g^{-1}) contents while COD treatment at 60°C and 100°C had positive effects on only vit. C and phenolic contents respectively. In comparison, the Weibull model gave the overall best fit (highest R^2=0.999; lowest SSE=0.0002, RSME=0.0123 and χ^2= 0.0004) when drying 2 mm onion slices at 100°C.

Keywords: Allium cepa, drying kinetics, specific energy consumption, flavonoid, vitamin C, microwave oven drying.

1. Introduction

Allium cepa L (onion) is one very profound perishable and largely consumed biennial horticultural crops that are grown across the entire globe (Sagar et al., 2020), which is used for it nutritional and health values. Drying process has long been regarded as an efficient means to increase the shelf-life of crops and createvalue-added added products as well as the reduction in the cost of postharvest handling (Sagar et al., 2020). Drying brings about moisture removal from agricultural products to a certain extent, under controlled conditions, leading to a drop in weight and volume, which is a very vital parameter for storage and transportation (Sakare et al. 2020). Drying also reduces enzymatic activities, diminishes the rate of microbial growth and undesirable chemical changes and enhances the concentration of nutrients and phytochemicals.

All through the decades, convective oven drying (COD) has been generally regarded as one of the most inexpensive, dominant and long-utilized drying methods in the culinary and food industries. This involves concurrent mass exchange prompting the expulsion of moisture from the intercellular spaces of the agricultural products to the ambient environment by means of evapo-diffusion (Castro et al. 2018).

Microwave drying (MD) has attracted a lot of global attention in recent times. During MD short frequency electromagnetic waves are released. As the waves penetrate the cells of the biomaterial, polar molecules, like salts and water, vibrate and cause the transportation of ions, thereby leading to the quick conversion of microwave energy to heat within the sample. Improved product quality, reduced drying time, improved energy consumption, enhanced volumetric heating and lower operating cost are some of the advantages of MD.

Dried onions as powder, granules and flakes are used as culinary ingredient in most processed foods e.g snacks sauces, onion flavored meat, soups products, and salad dressings (Süfer et al., 2018), as a substitute to the fresh form, because of the concentrated nutrients, flavor, aroma and phytochemicals as well as increased storage capacity.

Simulation and modeling of drying processes under varying process conditions is very vital in gaining efficient control over drying processes and an overall best enhancement of the quality of the resultant end product. Models are usually employed to investigate the process parameters needed to predict drying kinetics of biomaterials and to optimize such operating variables (Kaveh et al. (2021). Drying process involving food and vegetable materials ordinarily happen in the falling rate time frame (Agbede et al. (2020). In predicting mass exchange during drying under the falling rate period, a few numerical models are required.

From the industrial perspective, the need for the drying kinetics of onion slices is extremely important and has gained traction in recent times so as to be able to save energy and optimize drying conditions. Therefore, this study aims to explore the drying of onion slices (2 – 8 mm thickness) by contrasting the drying behaviour of the samples utilizing two diverse drying systems like COD (60 – 100°C) and MD (450 W). In addition, the drying parameters of the equations, EMD, activation energy, and specific energy consumption were equally estimated. Some qualitative properties of the sample such as phenolic, flavonoid and vitamin C contents were also investigated.

2. Materials and method

2.1 Sample preparation of onion

Matured and ripe onion (*Allium cepa*) was procured from a known onion farmer in Ogige Main Market, Nsukka City, Enugu State, Nigeria. Uniform onion sizes were selected and stored in a refrigerator (6°C). Using a digital weight balance (A-200DS Digital Analytical Balance, Denver Instruments, Germany), 120 kg of onion was measured and the average initial moisture content (MC) of the samples was estimated at 89.35 ± 0.5% (wet basis) by dehydration at 72 ± 1°C for 24 hr according to oven drying method (AOAC, 1990). The onion was neatly cut into slices of various thicknesses (2, 4, 6 and 8 mm) using a stainless-steel knife.

2.2 Drying experiments

2.2.1 COD

A laboratory oven (CD21, Gallekamp) was used for the drying. An anemometer (Lutron AM-4202; Electronic Enterprise Co., Taipei, Taiwan) was used to measure the inside air velocity of the oven as 1.0 ms^{-1}.

2.2.2 MD

The drying experiment was performed with a Haier thermocool laboratory microwave oven (HTMO-Trendy slv D90D25EL-QF) with maximum output power of 900 W.

2.3 Analysis of drying characteristics

Equations (1 & 2), (3), (4 - 6) were used to evaluate the moisture content (MC) (w.b & db), drying rate (DR) and moisture ratio (MR) respectively for the onion slices (Agbede et al., 2020):

$$MC = \frac{W_w - W_d}{W_w} \quad (1)$$

$$MC = \frac{W_w - W_d}{W_d} \quad (2)$$

$$DR = \frac{M_{t1} - M_{t2}}{t_2 - t_1} \quad (3)$$

$$MR = \exp\left(-\left(\frac{t}{\alpha}\right)^{\beta}\right) \quad (4)$$

$$MR = \frac{M_t - M_e}{M_o - M_e} \quad (5)$$

$$MR = \frac{M_t}{M_o} \quad (6)$$

Where, MC is moisture content (%, wb) or (%, db); W_w is Total mass of wet sample (g);W_d is Mass of sample after drying (g); DR is drying rate (% hr^{-1}); M_{t1} and M_{t2} are moisture contents (% w.b) at t_1 and t_2; t_1 and t_2 are different drying times (hour) during drying; MR is moisture ratio, α is the scale parameter (min), which represents drying rate constant, β is the shape parameter, which relates to the drying rate and moisture transfer mechanism in the drying process; M_t is moisture content at any time (% wet basis); M_e is equilibrium moisture content (% wet basis); M_o is initial moisture content (% wet basis)

Equation (4) was used in calculating the MR of the onion slices during thin-layer drying. Oftentimes, values for the equilibrium moisture content (M_e) is relatively small compared with M_o or M_t. Then, Equ. (5) can be simplified as Equ. (6) (Süfer and Palazoğlu, 2019).

2.4 Determination of effective moisture diffusivity (EMD), total energy consumed, specific energy consumption (SEC) and activation energy (AE)

Numerous complex processes are involved in mass and heat transfer during the drying of agricultural and food items. Capillary tube movement, molecular penetration and hydrodynamic flow, or surface propagation are difficult to analyze. Fick's second law is normally employed to measure such processes (Agbede et al. 2020). As a result, effective moisture diffusion is described by Equation (7) (Kaveh et al., 2021) which is further expressed as Equation (8).

$$\frac{\partial M}{\partial t} = D_{eff} \nabla^2 M \quad (7)$$

$$\frac{dM}{dt} = D_{eff} \frac{d^2 M}{dr^2} \quad (8)$$

For long drying measure (MR < 0.6) and assuming rectangular geometry for the onion, negligible surface resistance to heat and mass exchange flow within the onion, uniform mass exchange and distribution of initial moisture for the onion and approximating the coefficient to a uniform value all through the experiment, Equ. (8) can be expressed as shown in Equ. (9) (Süfer and Palazoğlu, 2019)

$$D_{eff} = \frac{-4L^2}{\pi^2 t} In\left(\frac{MR\pi^2}{8}\right) \quad (9)$$

Where D_{eff} is effective moisture diffusivity (m^2s^{-1}), L is half the thickness of the slices (m), MR is moisture ratio and t is the drying time (Secs).

Total energy consumed (TEC) for MD could be computed by the expression in Equ. 10 (Agbede et al., 2020)

$$E_{tMD} = P_{MD} \times t_{MD} \quad (10)$$

The specific energy consumed (SEC) of the onion during the MD treatment, which is defined as the amount of energy utilized to evaporate one kilogram of H_2O from the material, was determined using Equ. (11) (Taghinezhad et al., 2020).

$$SEC_{MD} = \frac{P_{MD} \times t_{MD}}{M_w} \quad (11)$$

Where E_{tMD} is total energy consumed (kWhr), SEC_{MD} is the specific energy consumed (kWh $kg^{-1}H_2O$ removed), P_{MD} is microwave oven power (kW), t_{MD} is the entire drying duration (hr) and M_w is the weight of water evaporated (kg).

The activation energy (AE) for the MD (E_{aMD}) (W g^{-1}) was computed by the Arrhenius type model relating D_{eff}, mass (kg) and microwave power (W) as shown in Equ. (12) (Agbede et al. 2020).

$$D_{eff} = D_o \exp\left(\frac{E_{aMD} \times M}{P}\right) \quad (12)$$

Equ. (13) is obtained when (12) is expressed in a logarithmic form.

$$In(D_{eff}) = In(D_o) - \left(\frac{E_{aMD}}{P}\right)(M) \quad (13)$$

By plotting ln(D_{eff}) versus (m/P), the slope (K_2) (Equ. 14) is computed for the MD and needed for computing the AE for the MD system (Equ. 15).

$$K_2 = Slope = E_{aMD} \quad (14)$$

$$E_{aMD} = K_2 \quad (15)$$

TEC and SEC submitted for COD were determined by the expressions in Equs. (16) and (17) respectively (Agbede et al., 2020)

$$E_{tCOD} = AV\ell_a C_a (T_{in} - T_{amb}) \times D_t \quad (16)$$

$$E_{sCOD} = \frac{E_{tCOD}}{M_w} \quad (17)$$

Where, A is the area of the tray (m^2), the velocity of air (m s^{-1}), ℓ_a is the density of air (kg m^{-3}), C_a is the specific heat capacity of air (1828.8 kJ kg^{-1} $^oC^{-1}$), T_{amb} is the ambient temperature (^{o}C), T_{in} is inlet temperature (^{o}C), D_t is the entire drying duration (s) and M_{wthe} is the weight of water evaporated from the sample (kg)

The relationship between diffusion coefficient and the temperature was also expressed by an Arrhenius-type model (Equ. 18)

$$D_{eff} = D_o \exp\left(\frac{E_{aCOD}}{R_g T_a}\right) \quad (18)$$

Activation energy (AE) for the COD (E_{aCOD}) was evaluated by plotting the D_{eff} curve against the corresponding reciprocal of absolute air temperature (T_a) (Jebri et al. 2019).

Where D_o and R_g are constant and universal gas (8.3143 kJ mol^{-1}) constant respectively

Applying the logarithms, Equ. (18) could be expressed in linear form as shown in Equ. (19).

$$In(D_{eff}) = In(D_o) - \left(\frac{E_{aCOD}}{R_g}\right)\left(\frac{1}{T_a}\right) \quad (19)$$

By plotting the graph of In(D_{eff}) against ($1/T_a$), the slope K_1 can be obtained as shown in Equ. (20) which will enable the computation of the activation energy for the COD using Equ. (21).

$$K_1 = \frac{E_{aCOD}}{R_g} \quad (20)$$

$$E_{aCOD} \times R_g \quad (21)$$

2.5 Mathematical modeling of drying curves and fitting of models to drying data

The SPSS software (version 21) was utilized to fit the mathematical models in Table 1. Statistical parameters such as of SSE, RMSE, χ^2 and R^2 calculated from equations 22, 23, 24 and 25 respectively using Microsoft Excel and SPSS software (version 21) were utilized to select appropriate drying descriptors. Drying models with the greatest R^2 and least SSE, RMSE and χ^2 was chosen as the most suitable model for portraying the drying kinetics.

$$SSE = \frac{1}{N}\sum_{i=1}^{N}(MR_{\exp,i} - MR_{pred,i})^2 \quad (22)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(MR_{\exp,i} - MR_{pred,i})^2\right]^{1/2} \quad (23)$$

$$\chi^2 = \frac{\sum_{i-1}^{N}(MR_{\exp,i} - MR_{pred,i})^2}{N - z} \quad (24)$$

$$R^2 = 1 - \frac{\sum_{i=1}^{N}(MR_{pred,i} - MR_{\exp,i})^2}{\sum_{i=1}^{N}(MR_{pred,i} - \overline{MR}_{\exp,i})^2} \quad (25)$$

Where $MR_{pred,i}$ is the i^{th} predicted values of the moisture ratio calculated using the models, $MR_{\exp,i}$ is the i^{th} experimental moisture ratio calculated using the models, N is the number of observations and z is the number of constants in each model.

Table 1. Some empirical models used for the onion drying kinetics

S/N	Model Name	Model Equation	Constants/Coefficient
1	Linear	$MR = 1 + bt$	Karacabey (2016)
2	Newton	$MR = \exp(-kt)$	Doymaz (2012)
3	Page	$MR = \exp(-kt^n)$	Omari et al. (2018)
4	Henderson and Pabis	$MR = a\exp(-kt)$	Srikanth et al. (2019)
5	Two Term	$MR = a\exp(-k_o t) + b\exp(-k_1 t)$	Liter et al. (2018)
6	Approximation of diffusion	$MR = a\exp(-kt) + (1-a)\exp(-kbt)$	Abbaszadeh et al. (2011)
7	Midilli Kucuk	$MR = a\exp(-kt^n) + bt$	Doymaz (2018)
8	Wang and Singh	$MR = 1 + at + bt^2$	Agbede et al.(2020)
9	The linear-plus-exponential	$MR = a\exp(-kt^n) + bt + c$	Thanimkarn et al. (2020)
10	Modified Page	$MR = \exp(-(kt)^n)$	Ertekin and Firat (2017)
11	Logarithmic	$MR = a\exp(-kt) + c$	Jebri et al. (2019)
12	Modified Henderson and Pabis	$MR = a\exp(-kt) + b\exp(-gt) + c\exp(-ht)$	Ertekin and Firat (2017)
13	Two Term Exponential	$MR = a\exp(-kt) + (1-a)\exp(-kat)$	Ertekin and Firat (2017)
14	Cavalcanti-Mata	$MR = a_1\exp(-k_1 t^{n1}) + a_2\exp(-k_1 t^{n2}) + a_3$	Silva et al. (2014)
15	Verma	$MR = a\exp(-kt) + (1-a)\exp(-gt)$	Makokha et al. (2021)

2.6 Determination of bioactive compounds and vit. C content

2.6.1 Determination of phenolic content and flavonoid contents

The total phenol content was assessed with the Folin- Ciocalteu's measure utilizing gallic acid as standard (Sasongko et al., 2020).

Total flavonoid content was assesed by Aluminium chloride ($AlCl_3$) technique utilizing quercetin as a standard for the calibration curve (Azeez et al., 2012).

2.6.2 Determination of vitamin C content

Vit. C content (ascorbic acid) was assessed by utilizing 2,6 dichlorophenol–indo-phenol (Merck KGaA, Darmstadt, Germany) tritimetric technique according to AOAC method No. 967.21 (AOAC, 2000).

2.7 **Statistical analysis of data**

The outcomes acquired for the various properties of the dried *Allium cepa* were subjected to descriptive inferential statistical analysis using SPSS, version 21; Excel software, Windows 10; Multiple comparisons test with the mean values in ANOVA were performed utilizing the least significant difference (LSD) and Fisher ratio (F), and statistical significance was set at 5% ($p < 0.05$). The outcomes were expressed as mean values ± standard deviation.

3. Results and Discussion

3.1 Results

Table 1 presents the calculated values for all the MD (450W) and COD experiments (60, 80, and 100°C air drying temperature and air velocity of 1 m s^{-1}), the calculated values for the coefficient of regression (R^2), SSE, RMSE and χ^2 ranged between 0.516 - 0.999, 0.0002 – 0.1431, 0.0015 - 0.3783, and 0.0004 - 1.0017, respectively.

From the summary of the examined models (Table 2), the Weibull, Midilli Kucuk, Two Term, Wang and Singh and Modified Page were considered to be the best models that satisfactorily described the drying behaviour of onion slices (2, 4, 6, and 8 mm thickness) for both the COD (60, 80 and 100°C) and MD (450 W). The other different models showed no solid fit.

From Table 2, the Weibull model was seen to best depict the drying conduct of 2, 4, and 6 mm thick onion slices at 60°C; 2, 4, 6, and 8 mm thick onion slices at 80°C; 8 mm thick onion slices at 100°C during COD treatment; and 2 and 6 mm onion thickness during MD (450 W) treatment with highest R^2 (0.999) and least SSE (0.0002), RMSE (0.0123) and χ^2 (0.0004) values accomplished was during 2 mm thick COD treatment at 100°C drying temperature. Wang and Singh, Modified Page and Midilli Kucuk models were seen to perfectly describe the drying curve of 2, 4 and 6 mm thick onion slices respectively at 100°C. During COD treatment (450 W), the Wang and Singh model most appropriately fitted the 4 and 8 mm thick onion slices, with R^2 values of 0.982 and 0.979 respectively.

In model comparison among COD and MD, the Weibull model gave the overall general best fit (highest R^2=0.999; lowest SSE=0.0002, RSME=0.0123 and χ^2= 0.0004) when drying 2 mm onion slice at 100°C. For the drying characteristics and modeling of apple slices during microwave intermittent drying, Dai *et al*. (2019) reported Weibull as the best fit with R^2 = 0.999, RMSE = 0.0091, χ^2 = 0.0011. However, Agbede *et al*. (2020) reported Wang and Singh model as best fitted for both the thin layer open sun and solar drying of the green microalgae (Chlorella sp.) biomass paste while the logarithmic and two-term models were identified to best describe the drying kinetics of scent and lemon basil leave at 70 °C and 60 °C respectively (Mbegbu et al., 2021). Similarly, Kaveh et al. (2021) reported that the Page Model with the maximum values of R^2 (0.9997–0.9999), and the least RMSE (0.0159–0.0754) and χ2 (0.0003–0.0011) best described the drying kinetics of pomegranate arils under COD (50 – 70°) at 1 m s^{-1} air velocity and MD (270 – 630 W). Differences may be due to the drying system employed and type/nature of the biomass.

Table 2. Summary of statistical parameters of thin layer mathematical models for convective oven drying (60, 80 and 100°C) and microwave drying (450 W) of onion slices

Drying Type	Slice Thickness (mm)	Model Name(s)	Highest R^2	Lowest SSE	Lowest RMSE	Lowest χ^2
	2	Weibull	0.955	0.0062	0.0790	0.0137
COD 60°C	4	Weibull	0.971	0.0038	0.0015	0.0083
	6	Midilli Kucuk and Weibull	0.988	0.0013	0.0362	0.0021
	8	Two-Term	0.978	0.0025	0.0497	0.0039
	2	Midilli Kucuk and Weibull	0.985	0.0021	0.0462	0.0043
COD 80°C	4	Midilli Kucuk and Weibull	0.990	0.0012	0.0341	0.0023
	6	Midilli Kucuk and Weibull	0.993	0.0012	0.0345	0.0024
	8	Midilli Kucuk and Weibull	0.996	0.0005	0.0227	0.0010
	2	Wang and Singh	0.991	0.0011	0.0335	0.0016
COD 100°C	4	Modified Page	0.998	0.0014	0.0370	0.0019
	6	Midilli Kukuk	0.998	0.0004	0.0187	0.0008
	8	Midilli Kucuk and Weibull	0.994	0.0008	0.0279	0.0018
	2	Weibull	0.999	0.0002	0.0123	0.0004
MD	4	Wang and Singh	0.982	0.0023	0.0481	0.0008
	6	Weibull	0.982	0.0024	0.0493	0.0030
	8	Wang and Singh	0.979	0.0026	0.0510	0.0030

3.2 Discussion

3.2.1 Drying characteristics

During COD treatment, increased air-drying temperature from 60 to 100°C resulted in increased water activity and mass exchange ratio because of ascend in heat energy occasioned by the rise in air temperature, prompting the decrease in the drying time and energy consumption. MD significantly shortened the drying duration for all the slices. The shortest drying time of 120 min was achieved with the MD at 450 W (1 d), compared to COD method at 60°C (270 min) (1 a), 80°C (180 min) (1 b) and 100°C (150 min) (1 c) (Figure 1). Reduction in slice thickness also resulted in reduction in the drying times. MR decreased significantly during drying operations until complete dehydration of the onion slices was achieved, showing that by employing the two drying methods, moisture was effectively removed from the un-dried samples

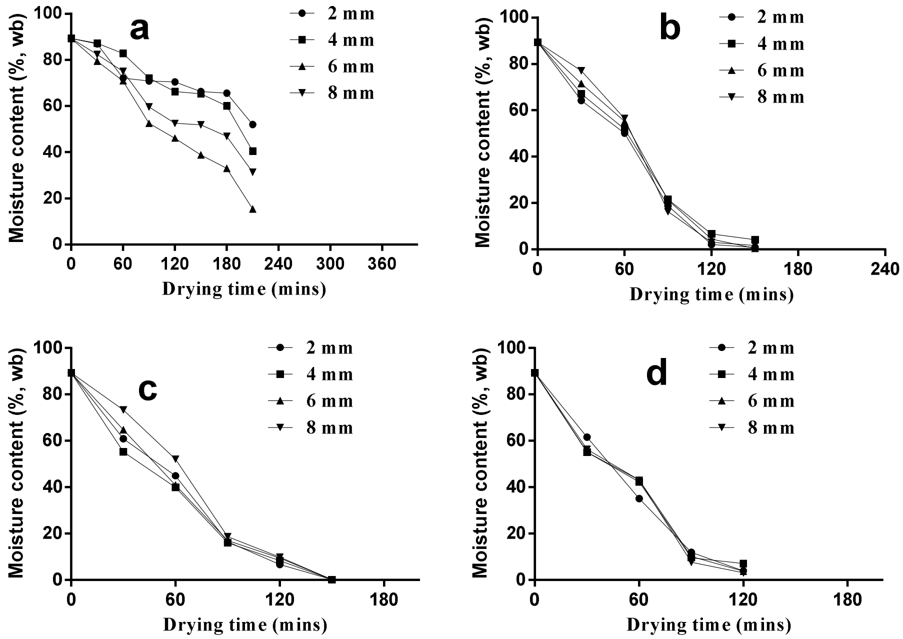

Figure 1. Curves of moisture content against drying time for various slice thicknesses submitted to convective oven drying, COD(a, 60°C; b, 80°C; c, 100°C and microwave drying, MD (d, 450 W)

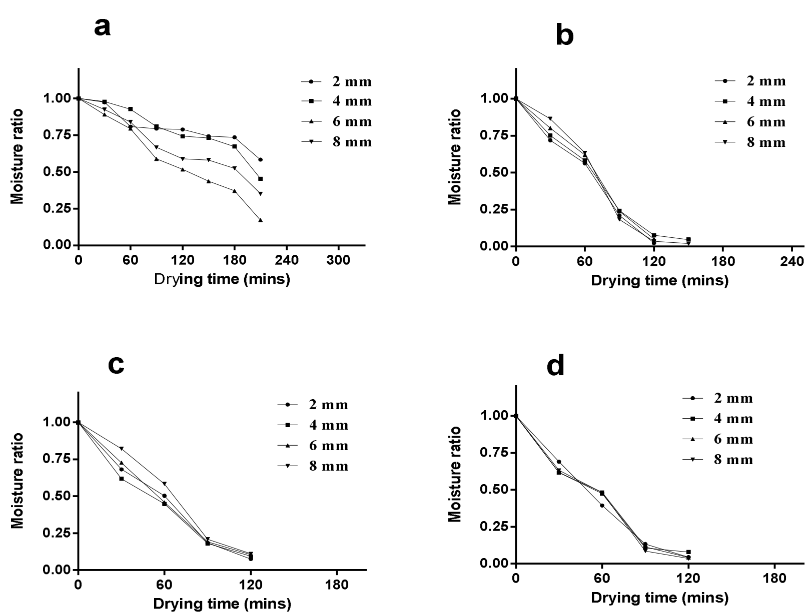

Figure 2. Curves of moisture ratio versus drying time for various slice thicknesses submitted to convective oven drying, COD(a, 60°C; b, 80°C; c, 100°C and microwave drying, MD (d, 450 W)

3.2.2 Effective moisture diffusivity, total energy consumed, specific energy consumption and activation energy

From Table 3, effective moisture diffusivity (EMD) is positively correlated to both drying temperature and slice thickness for COD treatment. This report affirms the direct relationships between EMD and drying air temperature, showing that increase in the drying air temperature results in an increment in EMD and a decrease in the drying time (Kaveh et al., 2021). The increase in drying air temperature could lead to the activation of water molecules within the samples, accelerating the transfer of water molecules thereby causing increased water diffusion (Liu et al., 2015). In the present study, values ranged between 1.1 – 6.12$\times 10^{-8}$ m² s⁻¹ for COD and 1.49 – 6.65 $\times 10^{-8}$ m² s⁻¹ for MD treatment. As slice thickness increased from 2 – 8 mm, EMD rose from 1.1 – 4.35 $\times 10^{-8}$ at 60°C, 1.1 – 5.6 $\times 10^{-8}$ at 80°C and 1.25 – 6.12 $\times 10^{-8}$ at 100°C.

Table 3. Effective moisture diffusivity of onion slices in different drying air temperatures

Slice thickness (mm)	Effective moisture diffusivity ($\times 10^{-8}$ $m^2 s^{-1}$)			
	60°C	**80°C**	**100°C**	**MD (450 W)**
2	1.1	1.1	1.25	1.49
4	2	2.28	3.31	4.25
6	3.32	2.59	3.37	4.31
8	4.35	5.6	6.12	6.65

SEC values in drying 2, 4, 6, and 8 mm onion slices under COD with temperatures of 60, 80 and 100°C and under MD with the power of 450 W are presented in Figure 3. It is obvious that SEC is negatively correlated to both drying temperature and slice thicknesses of onion slices. Increasing drying temperature resultedan an increase in the SEC. Similarly, as slice thickness increased SEC also increased (Kaveh et al., 2021). For the COD experiments, the SEC value obtained was in the range of 39.4 - 238.27 kWh/kg H_2O. The highest (238.27 kWh/kg H_2O, at 2 mm thickness) and lowest (39.4 kWh/kg H_2O, at 8 mm thickness) SEC values were utilized at drying temperatures of 60 and 100°C, respectively.

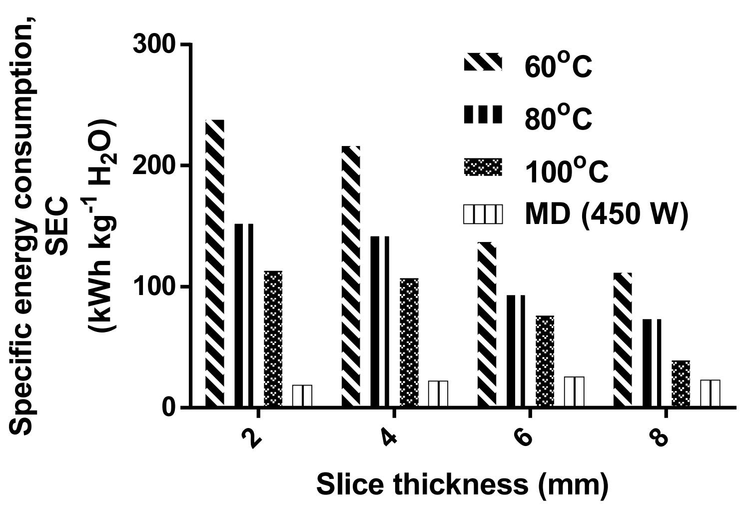

Figure 3. Effects of drying air temperature and onion slice thickness on the specific energy consumption

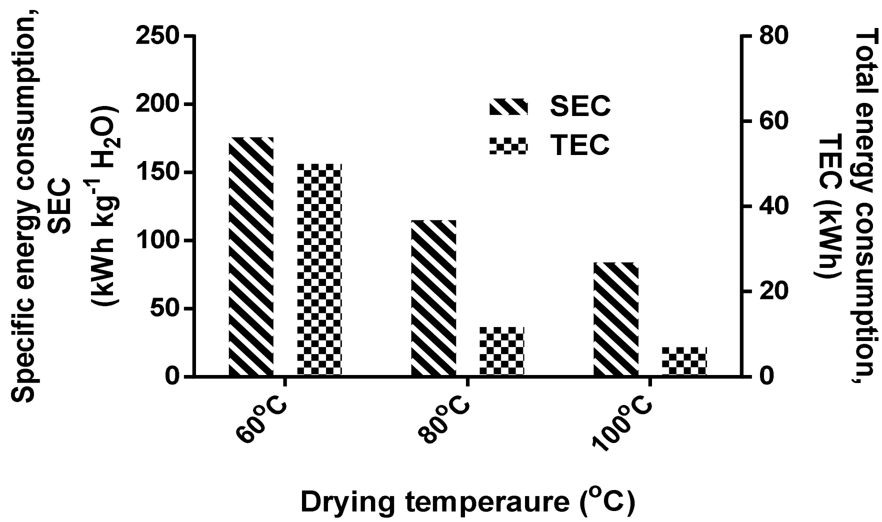

Figure 4. Graph of specific energy consumption (SEC) and total energy consumption (TEC) versus drying temperature

From Table 4, the highest values of activation energy (AE) obtained during onion drying under COD and MD systems were 71.42 kJ mol^{-1} (2 mm slices) and 34.52 W g^{-1} (6 mm slices) respectively (Table 5). MD treatments commanded the lowest AE values. Drying systems, air temperature and slice thicknesses were vital parameters influencing the AE. It is established that increasing temperature reduces the AE as a result of increased moisture loss and higher mass transfer from onions slices (Kaveh et al., 2021). In the present study, the mean AE values under MD (450 W), COD (60°C), (80°C) and (100°C) were 29.96 W g^{-1}, 66.80 kJ mol^{-1}, 56.51 kJ mol^{-1} and 59.32 kJ mol^{-1} respectively.

Table 4. Effects of slice thickness and temperature on total energy (E_t), specific energy (E_s) consumed and activation energy (E_a) submitted to microwave drying (MD) and convective oven drying (COD)

Slice thickness (mm)	**Energy for microwave drying (450 W)**			**Activation energy for convective oven drying E_{aCOD} (kJ mol^{-1})**		
	E_{tMD}(kWh)	**E_{sMD}(kWh/kg H_2O)**	**E_{aMD} (W g^{-1})**	**60°C**	**80°C**	**100°C**
2	1.35	18.70	27.82	71.42	65.18	68.48
4	1.13	22.02	25.79	68.22	63.31	66.87
6	1.35	25.33	34.52	64.03	50.52	53.16
8	1.35	22.88	31.69	63.52	47.04	48.76
MEAN	**1.295**	**22.23**	**29.96**	**66.80**	**56.21**	**59.32**

3.2.3 Bioactive compounds and vitamin C. content

Effects of convective oven drying (COD) (60°C, 80°C and 100°C) and microwave drying (MD) (450 W) on the flavonoid, phenolic and vit. C contents of onion slices is presented in Figure 5. MD (450 W) and COD (60, 80, and 100°C) treatments had significant effects on the flavonoid, phenolic and vit. C contents of onion. Significant ($p \leq 0.05$) increase in the flavonoid, phenolic and vit. C contents from 39.42 – 64.4%, 38.0 – 46.84%, and 3.7 – 4.23 mg 100 g^{-1} respectively were obtained for onion slices that were treated with MD at 450 W powers compared to the fresh un-dried (FUD) samples. This finding is consistent with the report of Ozcan-Sinir et al. (2018) that microwave drying and vacuum drying were able to yield higher quantity of bioactive compounds from kumquat (Citrus japonica) slices. A significant increase in the phenolic content was noticed in onion samples subjected to COD treatments at drying air temperatures of 80°C (40.19%) and 100°C (46.32%) except for 60°C (37.72%).

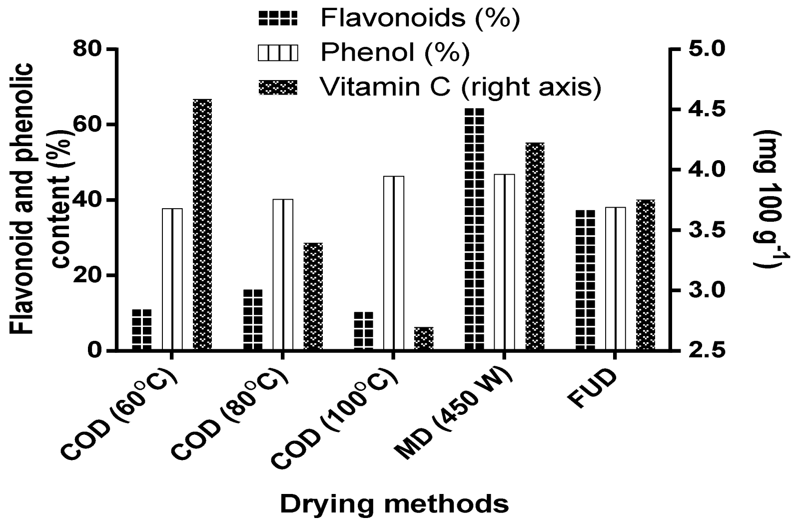

Figure 5. Effects of convective oven drying and microwave drying on the flavonoid, phenolic and vit. C contents of onion

Conclusion

The results revealed that drying air temperatures and slice thickness had significant effects ($p \leq 0.05$) on the drying kinetics, specific energy consumed (SEC), effective moisture diffusivity (EMD), flavonoid, phenolic and vit. C contents of onion slices dried under convective oven drying (COD) and microwave drying (MD). An increase in drying air temperature and reduction in slice thickness brought about decrease in the drying duration. Drying time of onion slices was shorter under MD than COD. Weibull model was the most appropriate in predicting the drying behaviour of 2 mm thick onion slices at 100°C (highest R^2=0.999; lowest SSE=0.0002, RSME=0.0123 and χ^2= 0.0004). As thickness increased from 2 – 8 mm, EMD rose from 1.1 – 4.35 $\times 10^{-8}$ at 60°C, 1.1 – 5.6 $\times 10^{-8}$ at 80°C and 1.25 – 6.12 $\times 10^{-8}$ at 100°C with MD treatments yielding the highest mean value (6.65 $\times 10^{-8}$ $m^2 s^{-1}$) at 8 mm. Maximum SEC for onion slices in COD was 238.27 kWh/kg H_2O (2 mm thickness) and the minimum was 39.4 kWh/kg H_2O (8 mm thickness) whereas maximum during MD was 25.33 kWh/kg H_2O (8 mm thickness) and minimum, 18.7 kWh/kg H_2O (2 mm thickness). MD treatment gave a significant ($p \leq 0.05$) increase in the flavonoid (39.42 – 64.4%), phenolic (38.0 – 46.84%) and vit. C (3.7 – 4.23 mg 100 g^{-1}) contents while COD treatment at 60°C and 100°C had positive effects on only vit. C and phenolic contents respectively.

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Conflict of interest

The authors state no conflict of interest

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NANOTECHNOLOGY- ENABLED INNOVATIONS IN AGRICULTURAL PRODUCTION

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Abstract

Serious research work aimed at identifying possible impacts of nanotechnology on agricultural production was initiated less than a decade ago, but already there is tremendous evidence that the technology offers solutions to most of the key problems in the agricultural sector. The problems associated with inadequate water supply, drought, pest, soil condition, seed growth problems, and use of fertilizers have been discussed. It has been demonstrated that nanotechnology has successfully handled those problems using controlled release of water, pesticides, herbicides, nano-fertilizers and plant nutrients. Plant growth has been enhanced by coating seeds with nano-formulations. Nanotechnology has used smart nano-biosensors and GPS systems to locate problems in remote locations in farmlands and solved the problems promptly. The role of nanotechnology in the packaging, preservation and quality of foods has also been highlighted.

Keywords : Nanotechnology, Nano-fertilizers, Pesticides, Nano-sensors, Bio-availability.

1.0 Introduction

Nanotechnology involves the manipulation or self-assembly of individual atoms, or molecular clusters into structures to create materials and devices with new or vastly different properties. Nanomaterials or nanostructured materials are materials possessing grain sizes on the order of a billionth of a metre (10^{-9} metre). Such materials manifest extremely fascinating and useful properties which are vastly different from the properties of bulk-size specimens of the same materials. The properties exhibited by nanostructured materials are exploited for a variety of structural and non- structural applications. Nanomaterials are generally produced using the top-down approach (which means reducing the material from the bulk-size to the smallest structures, and then to the nanoscale) or bottom-up approach (which involves manipulating individual atoms, molecules, or atom clusters into nanostructures, using an approach resembling the methods in chemistry or biology). Generally, nanomaterials are often produced using any of the following widely- known methods:

- Sol-gel synthesis
- Inert gas condensation
- Mechanical alloying or high-energy ball milling.
- Plasma synthesis
- Electro- deposition.

Use of nanomaterials has brought about several innovations in diverse fields of industry, and even more fascinating innovations are expected in the near future. Some of the present and projected developments include :

Better insulating materials, phosphors for high-definition television, low-cost flat panel displays, elimination of pollutants, high energy density batteries, high power magnets, high sensitivity sensors, automobiles with greater fuel efficiency, long-lasting satellites, longer- lasting medical implants, and ductile machinable ceramics. Some of the exciting innovations are in the medical field, where nanotechnology has facilitated medical diagnostics, drug delivery (bioavailability), and cancer therapy among other developments; and in the energy field where we now have efficient quantum dot light bulbs, high-power lithium ion batteries, nano solar cells, and so on. Examples of well-known nanostructured materials are Buckminster fullerenes (bucky balls) for composite reinforcement and drug delivery; carbon nanotubes, for composite reinforcement, conductive wire, fuel cells, and high-resolution displays; quantum dots, for medical imaging and energy efficient light bulbs; and gold nanoshells, for medical imaging and cancer therapy.

The field of agriculture is working very hard, like other fields such as the medical and energy fields cited above, to take advantage of the prospects offered by nanotechnology. Agriculture is the backbone of most of the developing countries of the world in which the major part of people's income comes from the agricultural sector, with more than 60% of the population depending on it for their livelihood. The current global population is nearly 6 billion, and with the high rate of population growth, it is projected that the population may grow to about 9 billion in 2050. At the present time, it is estimated that about 795 million people are in absolute hunger world-wide. Most of these people are in the developing or under-developed countries of Africa and Asia. The food shortages in these countries are due mainly to environmental impacts, pests, water shortage, and political instability.

In the developed world, there is often a food surplus, and the food industry is driven by consumer demand which is generally for healthier and fresher foodstuffs. In either case, nanotechnology is required for the improvement of crop yields and for the processing, packaging, transportation and storage of foods. The use of nanoscience and nanotechnology for agricultural production and for the food industries is, however, relatively new and is fast growing (Parisi et.al. (2015), Singh and Sengar (2020), and El-Temsah and Joner (2012).

2.0 Nanotechnology In Agricultural Research.

For more than a decade now, nanotechnology has been emerging as an important procedure not only for achieving higher crop yield, but also for lowering the various inputs such as pesticides, herbicides, and water requirement. Most of the contemporary nanotechnology research in agriculture is related to sensing the soil condition, growth of plant parts, and provision of adequate amounts of fertilizers, pesticides, and herbicides for agricultural farms. Efficient and smart sensors are required to sense the occurrence of drought or inadequacy of water in remote locations and trigger the immediate release of water to such locations. They should also be able to sense the presence of a disease and release the necessary pesticides or herbicides in adequate quantity.

The key focus areas of research in nanotechnology for agriculture are (Agrawal and Rathore, 2014).

- Nanogenetic manipulation of Agricultural crops
- Agricultural Diagnostics, Drug Delivery and Nano- complexes.
- Controlled release of nano-fertilizers and Nano-complexes.
- Nano-Biosensors.
- Nano pesticides and nano herbicides.
- Nano-Bio farming.

2.1 Nanoparticles Commonly Used in the Agricultural Sector (Priyom Bose, azonano.com/article.as)

Some of the more commonly used nanoparticles in the agricultural sector include:

a) Polymeric Nanoparticles – used in the delivery of agrochemicals in a slow and controlled manner. They are used because of their superior biocompatibility and minimal impact on non-targeted organisms.
b) Silver Nanoparticles – extensively used for their antimicrobial property against a wide range of phytopathogens. The nanoparticles also enhance plant growth.
c) Nano alumino-silicates – used because their formulations are an efficient pesticide.
d) Titanium dioxide nanoparticles – used as a disinfecting agent for water. They are biocompatible.
e) Carbon Nanomaterials – used for improved seed germination. They include graphene, graphene oxide, carbon nanodots, and fullerenes.

Other nanoparticles used in agriculture are zinc oxide, copper oxide, and magnetic nanoparticles.

3.0 Nanotechnology in the Food Industry

The agricultural raw products, after cultivation and processing, need proper packaging before they can reach the consumers. Most food product producing companies have now turned their attention to the use of nanotechnology for packaging, increasing the shelf life of products, maintaining colour, odour and taste of products, increasing food nutrition value, and so on. Some examples of the potential achievements of nanotechnology in this regard are as follows:

i. Nanotechnology can provide manipulations of food polymers and polymeric assemblages to achieve tailor-made improvements in food quality and food safety.
ii. Nanotechnology is the basis of many novel and functional foods, and food colours, flavours and textures can all be manipulated and altered at the nanoscale level. Much less nanoparticulate salt gives the same salty taste to foodstuffs as conventionally-sized salt grains.
iii. Omega-3 fatty acid reduces blood clotting, decreases platelet aggregation, improves insulin response in diabetic patients, reduces obesity and helps to prevent cancer growth. Fish (tuna and others), soyabean, tofu, etc are rich in omega-3. Tuna fish oil odour smells bitter and unpleasant making it difficult to take it in food. Scientists have encapsulated tuna fish oil in a biocompatible capsule which bursts only after reaching the stomach.
iv. Nylon-based nanocomposites are used to bottle beer to create a barrier for co_2 and O_2 so as to keep the clarity and flavor and to increase the shelf-life.
v. Emphasis in the food preservation and packaging industry is to use nanocapsules inside so that flavor and odour are triggered only when used. Colours and nutrients also get added only when the product is either opened or is being consumed. Capsules are dormant until then.

4.0 Nanotechnology and Precision Farming.

The overall goal of precision farming is to maximize farm output or crop yields, while minimizing farm input in the form of fertilizers, pesticides, herbicides, and so on. This is achieved by gathering information about spatial and temporal variations within a field. By thus monitoring and obtaining information regarding environmental factors in a field, it becomes possible to apply targeted intervention when necessary. Precision farming makes use of computers, global (satellite) positioning systems GPS and remote sensing devices so as to measure highly localized environmental conditions. This makes it possible to identify the precise location of problems and the precise nature of such problem which may be a hindrance that can prevent a crop from growing at maximum efficiency (Kaur, 2017). GPS systems are being employed in precision farming for field mapping, farm planning, crop scouting, soil sampling, yield mapping, and tractor guidance among other applications (Andreo, 2013). Nanotechnology makes possible the construction of tiny sensors and monitoring systems which are linked to the GPS receivers. These autonomous nanosensors connected to a GPS are efficient for real-time monitoring, and they may be spread in the field where soil conditions and crop growth can be tracked. Wireless sensors are already being used for these applications in some parts of the USA and Australia (Andreo 2013).

The union of biotechnology and nanotechnology in sensors will produce equipment of increased sensitivity, thereby making it possible for users to respond earlier to changes in the environment. For example, nanosensors using carbon nanotubes or nano-cantilevers are small enough to trap and measure individual proteins or even small molecules. Also, nanoparticles or nanosurfaces can be engineered to trigger an electrical or chemical signal in the presence of contaminants such as bacteria.

4.1 Nanotechnology for Increased Quantity and Quality of Crop Yields.

4.1.1 Sustainable use of Water.

To optimize use of water for sustainable agricultural production, nano-hydrogel can be used. This can absorb and release water and plant nutrients in cycles, leading to enhanced efficiency in the use of water (Vundavalli et.al, 2015). A study on silver-coated hydrogel showed that soils to which this hydrogel is added can hold 7.5 % more water than soils without it (Vundavalli et.al, 2015). Furthermore, the hydrogel can store between 130 and 290 times its own weight of rain water or irrigation water. Biodegradable hydrogels help to decrease the amount of contaminants, and are very useful in dry areas. The material is therefore very useful, as drought is considered the largest environmental risk for crop production (Jaleel et.al. 2019).

4.1.2 Treatment of Seeds

Seeds treated with nanoparticles can germinate and grow faster, with increased resilience to environmental stress (Adhikari et.al, 2016). Seeds coated with nanomaterials show increased seedling strength, growth, longevity, and water absorption. For example, a laboratory study showed that seeds coated with nano-silver recorded a highly increased water absorption (Adhikari et.al, 2016). Another study showed that nano-particle coated seeds showed a 73% increase in vegetable dry weight, and a three times higher vitamin content in seeds, which increases crop yield (Khodakovskaya et.al, 2009). Other studies showed 90% increase in drought resistance and 16.5% increase in seed longevity during storage.

4.1.3 Pest and Disease detection.

Plant diseases, pests and pollutants cause severe damage to crops, and need to be detected and handled as early as possible. Bio-sensors, such as specific enzymes are useful for this purpose. However, because of their size-related properties, nano-biosensors show increased accuracy, detection limits, sensitivity, selectivity, temporal response, and reproducibility compared to conventional biosensors, (Huang et.al, 2011). Therefore, nano-biosensors are a nice and precise tool for preventing pest outbreaks and for monitoring soil quality, leading to enhancement of the quality and quantity of yields (Rai and Ingle, 2012; Huang et.al, 2011).

4.1.4 Delivery of Nutrients (Fertilizers), and Plant Protection Products (PPPs).

About 70% of conventional fertilizers and PPPs do not reach their target because they are not easily taken up in the plant environment (Solanki et.al, 2015). Because of their size-related properties, nano-based smart delivery systems are capable of producing more efficient and targeted delivery to specific plant cells. The benefits from such smart delivery systems can be enhanced using nano-biosensors which enable them to precisely release nutrients and PPPs in response to environmental triggers and biological demands (Solanki et.al, 2015). This provides opportunities for real-time monitoring and control.

4.1.5 Nanotechnology Applications in Pollution Control.

There is the great potential for nanotechnology to be effectively used in agricultural production for reducing pollution resulting from fertilizers and PPPs, by efficiently remediating soils polluted with heavy metals. This remediation is important because it will make the soil in the environment good and productive again. Up to 90% of agrochemicals run-off in the environment (directly or indirectly) due to their uncontrolled application, and in the process leave heavy metals in the surroundings.

5.0 Conclusion and Perspectives.

There is ample opportunity for the application of nanotechnology in agriculture and food production. Research on the application of nanotechnology in agriculture is relatively new, being less than a decade old, but its impact so far is tremendous and is rapidly approaching its impact in other fields such as medicine, energy, communication, and transportation. The reason for this is that it has suddenly been recognized that the enormous problems confronting the agricultural sector – climate change, drought, pests, degradation of farm soils, and pollution – can be effectively and efficiently handled by research efforts based on nanotechnology. It has now been firmly established that agricultural diagnostics and controlled delivery of irrigation water, pesticides, herbicides, and nano-fertilizers and plant nutrients using nanotechnology principles, have been very effective in the pursuit of the objectives of precision farming. However, while nanotechnology for agriculture can be adequately implemented in advanced countries, sustained effort is required to make the new technologies available in the under-developed and developing countries. For example, it is currently difficult to make smart nanosensors and GPS systems commonly available to peasant farmers in poor countries. In spite of this, there is need for the public to be aware of the benefits of agricultural nanotechnology so that the basic aspects of the technology may be adopted in local farms.

For the full implementation of nanotechnology in agriculture, research must be undertaken to identify possible hazards and risk that may arise from the wide-scale use of certain nanoparticles. In the short-run, this may be unnecessary, but in the long-run, there may be need for detailed cost-benefit and risk-benefit analyses.

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THE APPLICATIONS OF SOLAR ENERGY IN AGRICULTURE

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Abstract

A lot of scientific and technological research has been undertaken in recent years to help in the solution of the energy problems of the world. Solar energy is one of the focal points in this research, and today we have a lot of solar energy input in diverse areas, such as solar energy for buildings, solar street lights, and solar energy applications in consumer products, including cell phones, watches, and computers. A survey is necessary, to assess the way solar energy is currently in use for solving another key problem of the world, food insecurity. This paper addresses the areas of application of solar energy in agriculture. Solar energy has found applications in diverse areas of agriculture, including drying of farm products, space and water heating, water pumping and irrigation, animal production, and the provision of electrical energy in remote farms.

Keywords: Renewable energy, greenhouse, photovoltaic energy, solar energy, irrigation.

1.0 Introduction

The sun is unarguably the most important source of energy for our planet, the earth. The distance between the earth and the sun is calculated to make life possible on the earth. There is generally a good balance in many parts of the earth between hours of the day and hours of the night, between light and darkness, and between heat and cold.

A tremendous amount of thermal energy reaches the earth daily from the sun, especially during the daylight hours. Modern scientific research has made it possible for us to trap and use small bits of this energy either directly (as thermal or heat energy) or as electrical energy or photovoltaic energy (based on the interaction of the photons of sunlight with semiconductor materials). Even without any effort on our part, we can feel the effect of solar energy all around us – from the drying of our agricultural products when we place them in the sun, to the drying of our clothes after washing them, and to our discomfort during perspiration on a hot day.

Solar energy comes to us naturally. It is one of the forms of energy that are classified as renewable energy (energy promptly replenished naturally as we use it). The other notable renewable types of energy are Wind energy, Geothermal energy, Hydro-energy. Biomass and Bio-fuel energy resources. Solar energy can readily be made available to us as electrical energy. Photovoltaic energy (PV) is solar energy that comes to us directly as electrical energy. For solar thermal energy, all we need is a collector and a means of converting the thermal or heat energy to electrical energy. The electrical energy derived from the sun is used for light or may be converted to mechanical energy for doing work. With a mechanical converter and a method of storing the electrical energy in batteries for use at night or during cloudy weather, solar energy is available to us for light and for mechanical work at all times.

Among the key problems in the world, we have insufficiency of food, energy, poverty and disease, insecurity and wars, and uncontrolled population growth. The growth of human population exacerbates most of the other problems, especially the inadequacy of food and energy. Intense scientific research on solar energy is fast helping to attenuate the problem of energy, and in turn the increase in solar energy availability has been of help in reducing the problem of inadequacy of food. Solar energy has applications in many areas of agriculture, and this paper has highlighted some of the important areas such as solar drying of grains, space and water heating, greenhouse heating, water pumping and irrigation, animal production, and energy from stand-alone systems in remote farmlands.

2.0 Renewable Energy Sources

Renewable energy may be defined, in simple terms, as energy which is naturally and autonomously available so that it can be replenished promptly by nature as it is being consumed. Among the well-known renewable energies, we have Wind Energy, Hydropower, Geothermal Energy, Biomass, and Solar Energy. Among these, hydropower is the only one that currently constitutes a significant percentage of the total energy linked to the national electrical power grid in most developing countries. However, solar energy must be recognized as the most abundant of the renewable energies. The exploitation of solar energy is cost-intensive, but with recent developments in the technology of solar cells and solar panels, there is now a dramatic drop in the cost of photovoltaic (PV) energy and a corresponding surge of interest in the use of solar power. With the meteoric rise of interest in photovoltaic energy in developing countries such as Nigeria, solar energy has risen fast to occupy its place as the most dominant form of renewable energy.

3.0 Solar Energy and Solar Energy Technologies

The sun is the most abundant source of energy for the earth. Naturally available solar energy falls on the earth at the rate of 120 petawatts, which means that the amount of energy received on the whole surface of the earth in just one day can (if it were totally exploited), satisfy the whole world's energy demand for more than 20 years (Chu, 2011). The estimated world-wide average power density is about 24 W/m^2 of the earth's surface (Cuidisine, 1997 and Sambo, 1994). Nigeria lies within the high sunshine belt of the world, receiving between 3.5 and 7 kW/m^2/day from the coastal latitude to the far North (Iwe, 1998). Solar energy is the cleanest and most abundant renewable energy source and is widely available, especially within the tropics.

Solar energy can be exploited either as solar Thermal Energy or Photovoltaic Solar Energy. Solar Thermal Energy is the energy from the sun absorbed directly as heat, but photovoltaic energy is energy from the sun converted directly to electrical energy. The solar thermal energy is often used for heating purposes, and can be used to obtain mechanical energy in a thermodynamic cycle. The mechanical energy so produced can be used to do mechanical work, or it can be used for production of electricity. Thus, we have two ways for converting solar energy to electrical energy: a system using photovoltaic (PV) technology, and another that uses solar capture heating systems (Hoogwijk, 2004).

4.0 Application of Solar Energy in Agricultural Production.

Both solar thermal energy and solar electrical energy (photovoltaic energy) can be used to produce mechanical energy. The electrical energy harnessed directly from the sun in photovoltaic systems, or from thermal-mechanical systems derived from solar thermal energy plants, can readily be used to produce light and to operate optical systems. The energy harnessed during sunshine hours, can be stored in batteries for use at night to produce light and do mechanical work. This means that the energy from the sun can be used both day and night for the production of light, heat and a wide range of mechanical operations. Thus, solar energy can readily be used in the agricultural sector for drying of grains, space and water heating, greenhouse heating, water pumping and irrigation, stand-alone PV systems in remote areas, poultry and piggery management and production, refrigeration and solar cooling systems, and a host of other purposes.

4.1 Crop and Grain Drying.

Drying of crops and grains in the sun is a well-known old application of solar energy. Drying of these agricultural products naturally in the field is simple and inexpensive, but the crops and grains are subject to damage by birds, rodents, wind, rain, and contamination by dust and dirt. Modern solar dryers protect the crops, grain and fruit against windblown dust and other hazards, giving much better quality products, (Avinash et.al., 2008).

The basic components of a solar dryer are an enclosure or shed, screened drying trays and racks. A solar collector may be incorporated, or otherwise a side of the enclosure may be glazed to allow sunlight to dry the material. If a collector is used, the air heated in the solar collector is made to move by natural convection or by means of a fan, up through the material being dried.

4.2 Space and Water Heating

Space and water heating is often required in dairy and livestock operations. Pig and poultry farms raise the animals in enclosed buildings, and it becomes necessary to control the temperature and air quality to promote the health and growth of the animal. The air in the enclosure needs to be replaced regularly to remove moisture, toxic gas odours, and dust. Heating the indoor air, when necessary, will require substantial amounts of energy. This may call for incorporation of well-designed air/space heaters into the farm buildings to pre-heat incoming fresh air. Systems like this can also be used to supplement natural ventilation levels during the summer or dry-season months depending on the region and weather. Solar water heating can provide hot water for pen or equipment cleaning, or for preheating water going into a conventional water heater (Goedseels, 1986; WFE, 2002). Water heating can ordinarily be very expensive, but a properly-sized solar water heating system can reduce costs by about 50%.

There are four basic types of solar water-heater systems. These systems share three similarities : a glazing (typically glass) over a dark surface to gather solar heat; one or two tanks to store hot water; and associated plumbing with or without pumps to circulate the heat-transfer fluid from the tank to the collectors and back again (Schnepf, 2005; Schnepf, 2007; Svejkovsky, 2006).Figure 1 is a schematic diagram showing the three major components in a solar-operated hot water system, namely (a) the collectors, (b) the pump, plumbing, storage tank and heat-exchanger coil, and (c) the differential thermostat that controls the whole system.

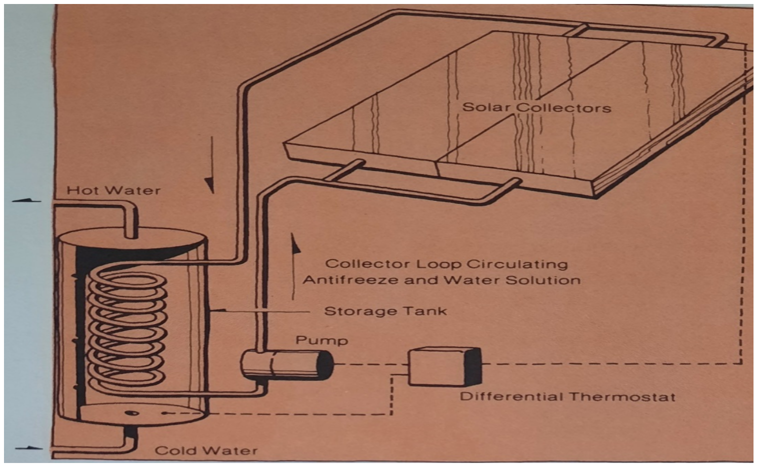

Fig. 1 Schematic Diagram of a solar hot water system

4.3 Greenhouse Heating

Commercial greenhouses depend on the sun for their lighting needs, but not for heating, as they rely on gas and oil heaters for their heat needs. Solar greenhouses, however, are designed to use solar energy for both heating and lighting (Chikaire et.al, 2010). A solar greenhouse has thermal mass to collect and store solar heat energy, with insulation to retain the heat for use at night or on cloudy days. It is oriented to maximize southern glazing exposure. Its northern side has little or no glazing and is well insulated. A solar greenhouse reduces the need for fossil fuels for heating. A gas or oil heater may serve as a back-up heater, or to increase carbon dioxide levels to induce higher plant growth.

Passive solar greenhouses are often choices for small growers, because they are a cost-efficient way for farmers to extend the growing season. Active greenhouses use supplemental energy to move solar heated air or water from storage or collection areas to other regions of the greenhouse (Svejkovsky, 2006).

4.4 Remote Electricity Supply (Stand-Alone Photovoltaics)

In remote areas where there are no utility lines, such as in remote farmlands, photovoltaic (PV) systems are often cheaper and require less maintenance than diesel generators, wind turbines, or batteries alone.

PV systems produce electricity without noise or pollution, from a clean renewable source. PV comes in handy in remote farms and ranches, and is useful not only for provision of light but also for electric fencing, small motors, aeration fans, gate-openers, farm irrigation valve switches, automatic supplement feeders, and so on. It can be used for operation of sprinkler irrigation systems, and for pumping water for livestock in remote locations. In remote areas, especially remote farms, PV is often much less expensive than the alternative of extending power lines to where electrical energy is required.

4.5 Water Pumping

Supply of water is a major challenge in many parts of the world. Pumping of groundwater is often a solution to water problems. Where electrical energy from the national grid is not available, the energy for pumping may be obtained using diesel or petrol engines, but this can be expensive apart from the fact that the environment will be exposed to unwanted noise and pollution. The use of solar powered irrigation systems (PV pumping) is a sustainable alternative for farmers in remote areas. A typical PV system for this purpose consists of a PV array as the energy source, an electric pump that can lift the water from underground to the desired height, and a water distribution system (with piping network, sprinkler system or drip irrigation, etc.). The PV water pumping technology has now become very attractive as prices for PV systems have dropped dramatically in recent times, while fossil fuel prices have remained high and are expected to keep rising.

5.0 Conclusion

Availability of food to meet the needs of the rising population of the world has become a major challenge. In order to address this challenge, agricultural technology has changed tremendously and has become more sophisticated. Agricultural machinery, farm buildings, and the processing, packaging and storage of farm products have undergone a lot of changes in modern times, and a tremendous amount of sustainable energy is now required in the agricultural sector. This paper has reported on the role of solar energy in agricultural production and has shown that solar energy has been very effective in meeting the energy needs of agriculture, especially in remote farmlands.

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EVALUATION OF YAM STORAGE PRACTICES IN KAURA LOCAL GOVERNMENT AREA OF KADUNA STATE

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Abstract

Yam *(Dioscorea spp)* is the second most important tropical root crop in West Africa with Nigeria being the highest producer globally. Existing yam storage structures have all that is required of improved storage but this study was designed to evaluate the storage method of yams in the study area. The study was conducted to analyze the various storage methods of yams in Kaura Local Government Area of Kaduna State. Both primary and secondary data were used for the study. The primary data was obtained by issuing questionnaires which were administered to 100 respondents who were randomly selected. Result obtained shows that Majority of the farmers/ traders store their Yam produce in pits (46%). Others store shelf store (20%) and Barn (24%). Thatched roof storage was least with 10%. The findings also show that one of their major concern and challenge to the adaption of modern storage techniques is the lack of expertise on the side of the farmers/ traders.

Key words: Yam, root crop, Storage, farmers, structures

1. Introduction

Yam (*dioscorea spp)* is an important staple food especially in the tropical and subtropical regions of the world (Okigbo and Ogbonnaya, 2006). It is a very important both from the economic and nutritional point of view. Nigeria is the global leader in yam production whose annual production amounts to about 75% of total world production. Yam is mainly produced in the savannah region of west Africa which amount to 92% (66.8 million tons) of production globally (FAOSTAT, 2020). Yam is a rich source of ascorbic acid, carbohydrate, manganese and potassium and also a very rich source of pharmaceutical compounds like sapogenins and saponins (Obidiegwu et al., 2020).

In Nigeria growth and production of yam is seasonal in nature. However, market glut usually occurs during peak harvest periods. This necessitates the use of storage systems which tends to ensure the availability of the products during off peak periods. Difficulty in Yam storage systems has over the years pose great challenges to the local farmers resulting to higher prices for the commodity especially in the urban areas (Kushwaha and polycarp, 2001). Yam is prone to infection by fungi, bacteria and viruses leading to rot during storage. Rot is a major factor that affects the post-harvest life of yams (Adioo, 2007). The quality of yam tubers is also affected by rots, which makes them unappealing to consumers. Yams rots as result of poor storage strategy. This affect the availability of the product and greatly reduces the revenue of farmers and traders. Lack of improved affordable yam storage facilities have left most farmers at the mercy of the marketers.

Successful storage of yams requires the use of healthy and sound tubers, proper curing if possible combined with fungicide treatment, adequate ventilation to remove heat generated by respiration of sprouts and rotted tubers that develop. Monitoring the presence of rodents and protection from direct sunlight and rain is necessary. Yams can be best stored in a cool, dry and well ventilated surrounding (Umogbai, 2013). Therefore, it becomes imperative that the existing yam tubers are stored in structures for later use (Umogbai, 2013). The most common challenges faced by farmers are post-harvest losses and lack of improved storage techniques at their disposal. According to Opara (1999) there are several traditional low-cost storage methods and structures for yam tubers; the most common of them includes leaving the tubers in the ground until it is needed, storage under tree shades, yam barns, underground storage such as pits, ditches and mud structures (Okodie-Okojie and Onemolease, 2009). There are also well ventilated weather proof, insects and rodent proof strong shelters for storage of yam tubers; unfortunately, the cost of these structures is a challenge and thus, using local materials for smallholder yam farmers has mostly been utilized.. Therefore, this research is carried out to evaluate yam storage practices in Kaura LGA, Kaduna state, Nigeria, to determine and evaluate the yam storage methods the farmers / traders are currently using and also to assess the farmer's awareness and adoption of improved yam storage method.

2.0 Methodology

Kaura is a town and a Local Government Area in southern Kaduna State, Nigeria. Its headquarters are in the town of Kaura in Asholyio (Moroa) Chiefdom. Other towns include: Manchok and Kagoro. Its population is about 174,626 according to 2006 Nigerian census. The postal code of the area is 801 (VON, 2020). With an Area Total of 178 sq mi (461 Km^2) and a Density1, 325/sq mi (511.4/Km^2). Data were obtained from 100 respondents through the use of structured questionnaire and from relevant journals. The data was collected in April, 2021 for previous late harvest of 2020 production season. The questionnaire was designed with simple and straight to the point questions, comprehensive enough to cover all the research objectives. Descriptive statistics was used in analysis. The data includes the use of frequency and distribution analysis.

3.0 Results and Discussions

3.1 **Yam storage methods in use**

Data obtained shows that 24% of the respondents use barns to store yams, 20% use shelf store to store their yams, 46% use pit store for yam storage and only 10% use thatched roof pit for storage. This indicate that majority of yam farmers at Kaura local Government Area of Kaduna State use pit store for yam storage. This could be due to financial constraint or available knowledge in the locality**.** The commonest among them is underground storage system, for instance pit and ditches which takes different shapes and sizes depending on the producers' capability and farming practices (Osuji,1985; Cooke *et al.,*1988; FAO 2004)**.** Table 1 shows the period of time that various farmers and respondents have been using, the various methods of storage practices that they are conversant with. From Table 1, majority of the famers/ traders have been using storage methods for 0 - 5 years, some have been using storage methods for 6 - 10 years while others have been using various storage methods from 11 – 16 years and above.

Table 1. Method of Storage and Duration of storage method by the Respondents

Variables	Frequency	Percentage
Method of storage		
Barn	24	24
Shelf store	20	20
Pit store	46	46
Thatched roof	10	10
Others	0	0
Duration of storage method		
0-5yrs		
6-10yrs	24	24
11-15yrs	52	52
>16yrs	12	12
	12	12

Table 2: Duration Before Storage

Variables	Frequency	Percentage
Duration before storage		
0 - 5days	48	48
6 – 10days	30	30
11 – 15days	10	10
>16days	12	12
Storage period of yam		
0-2months	24	24
3-5months	50	50
>6months	26	26

Table 2 shows the number of days the respondents keep their yams before storing .48% of the respondents keep the yams for 0 - 5 days before storing, 38% keep the yams for 6 - 10 days before storing, 10% keep the yams for 11 - 15 days before storing while 12% keep the yams for 16 days and above before storing them. The maximum storage life of yams is six months.

From Table 2, 50% of the farmers/traders store their yams for 3 - 5months, 26% store their yams for 6months and above while 24% store yams are stored for 0 - 2months. The period of storage beyond six (6) months can result in losses during storage. Losses are reported to be 10% to15% during the first three months and up to six months and were 30% to 50% after six months (Bencini 1991, Ezeike 1995).

3.2 Awareness and Adoption of Improved Yam Storage Method

Result shows the awareness and adoption of improved storage by yam farmers/traders in Kaura Local Government Area. 77% were not aware of the use of improved methods of yam storage. 23% were aware of the improved methods of yam storage. This indicates a low level of awareness and adoption of improved methods of yam storage. Similarly reported by Falola *et al.,* (2016), yam farmers in Kwara state had little awareness on improved storage methods such as cold storage and Gama radiation storage.

3.3 Constraints to Adoption of Improved Yam Method Storage Method Practices

The major constraints to adoption of improved storage methods in Kaura Local Government Area as obtained from the results shows the major constraints to financially related, lack of expertise, poor adoption of improved systems and after storage effects on yam storage. Lack of expertise is seen to be the major constraints due to its high frequency (45) followed by financial constraints (30), after storage effects on yam storage (15) and poor adoption of improved systems (10). This shows that the adoption of improved storage methods in Kaura Local Government area depends on farmers' knowledge and ability to utilise the improved methods. This finding are in agreement with the works by Zanknayiba and Tanko (2013); Ike and Inoni (2006); Maikasuwa and Ala (2013), who found that lack of access to farm inputs and high cost of inputs have negative effects to yam production and adoption of improved storage method.

4.0 Conclusion

From the results, it can be concluded that major yam storage practices utilized in Kaura local Government area is the traditional storage methods. Based on the findings, use of improved storage methods is low and this has made farmers to face postharvest losses. The constraints to the adoption of improved and affordable yam storage facilities include; high cost low capacity, difficulty to use, risk of failure and high maintenance. The traditional method in use includes: Barns, pit store, shelf store, thatched roof pit and or in store room covered with grasses which is found not effective for an average storage period above 6 months for the yam producers.

To facilitate the adoption of the recommended yam storage techniques in the study area, the following recommendation is proposed.

Modern techniques should be applied to further simplify the recommended storage method to avoid the risk of failure, reduce maintenance difficulties and make them easier to use. There should be sensitization on the importance of improved storage facility for yam informing them of the added advantage involved.

Conflicting Interest: The authors of this article declare that there are no conflicting interest on this article.

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EFFECTS OF DRYING METHODS ON THE DRYING RATE OF PLANTAIN (*MUSA PARADISIACA*)

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Abstract

The study was carried out to determine the effects of drying methods (solar, mechanical and sun drying) on the drying rate of Sliced Plantain (*Musa Paradisiaca*). The plantain was peeled and then sliced into 3mm, 6mm and 9mm with a kitchen knife and Vernier caliper for measurement. The different samples were weighed and placed in the dryers respectively and the weight loss was recorded at interval of time. The drying rate obtained for drying of Plantain slices at 3mm thickness using sun drying, solar drying and mechanical drying methods were 0.57g/min, 0.165g/min and 0.196g/min respectively, while the drying rate obtained for drying of Plantain slices at 6mm thickness using sun drying, solar drying and mechanical drying methods were 0.15g/min, 0.159g/min and 0.182g/min respectively. Drying rate obtained for drying of Plantain slices at 9mm thickness using sun drying, solar drying and mechanical drying methods were 0.151g/min, 0.121g/min and 0.176g/min respectively. Results obtained were subjected to Analysis of variance (ANOVA). The p-value of 0.049983 was obtained from the ANOVA. This implies that the drying methods significantly affects the drying rate of sliced plantain as the p-value is below the set value of 0.05.

Keywords: Plantain, Drying Methods, Drying Rate, Thickness, Effects

1. Introduction

Fruits and vegetables contain vitamins, minerals dietary fibre, phyto chemicals and antioxidants (Pereira, 2014, Conner *et al*; 2017). Therefore, there are abundant source of nutrients in a healthy human diet (Conner *et al*; 2017). According to the world health organization (WHO), approximately 16 million disability adjusted lives (Dalys) and 1.7 million of deaths worldwide is caused by low fruits and vegetables consumption (Mujcic, 2016). In 2000 alone, about 23.6 million of the world's population did not consume enough fruits and vegetables (Lock *et al*; 2005). Research studies indicate that the consumption of sufficient fruits and vegetables as part of a balanced diet, helps to reduce the risk of major non-communicable diseases, such as cardio vascular disease and certain cancers. An awareness of the reduced health risks associated with the consumption of fruits and vegetables has led to a rise in the demand for fruits, including plantain, mangoes, bananas, pineapples and passion fruit (Joosten *et al*; 2015).

Plantain (Musa Paradisiaca) is cultivated in the tropics and is an important staple food in sub-saharan African. About 63 million tonnes of crops are produced annually of which as much as 90% is consumed locally in the producing countries, allowing only a meager 10% for foreign financial earnings through exportation (Awodoyin, 2003, Baiyeri *et al;* 2011). Plantain is a rich source of nutrient, it is well patronized as a staple food in many parts of the West and Central Africa (Adeniyi *et al*; 2006). It is a rich sources of nutrients such as iron, zinc, potassium and sodium (Baiyeri *et al*; 2011).

Plantain falls under banana and it is a mono cotyledons perennial and important crop in the tropical and sub-tropical regions of the world (Baiyeri *et al*; 2011). In Nigeria, Cameroon, Cote'voire, and other plantain producing countries in Africa, the entire fruit of pulp of plantain either unripe or half ripe are roasted on hot charcoal and eaten with other delicacies such as roasted puns, avocado, roasted fish, or meat and kelat and sometimes in combination of hot stew. In Nigeria, as well as other west Africa countries. The unripe plantain is traditionally processed into flour (Ukhum and Ukpehor, 1991). This tropical crop is seasonal its abundance is hardly contained during the harvest season, leading to spoilage, while it is insufficient during its off season periods. It is highly perishable after harvest. This makes it necessary for it to be processed within the shortest period of time following harvest in order to increase the availability of the staple food produce although the year, thereby food security and also providing for themselves a means of financial income during the off season periods.

Although sun drying is the most common method used to preserve agricultural products in tropical and sub-tropical countries, this technique is extremely weather dependent, and has the problem of contamination with foreign matter. In addition, the required drying time can be quite long and the sensory qualities of the final product can deteriorate. Therefore, an effective means of overcoming these problems is to dry okra with solar dryer or oven drying (Doymaz and Pala, 2002). Drying is an industrial preservation method in which water content and water activity of the fruits and vegetables are decreased by treated air to minimized biological, chemical and microbial deterioration.

Drying is a process of simultaneous heat and mass transfer. The drying process should be such that it allows effective retention of colour, appearance flavor taste and nutritive value, comparable to fresh vegetables. With proper storage and handling, dried food products can be enjoyed several months after freshly grown local produces has disappeared from the local markets. Traditionally, sun drying is the common method used in processing plantain. The present mode for sun drying in the open air exposes the product to dirt, damage from insect, bacteria, infestation and the deposition of fungal spores, and a varying degree of other environmental toxicants, depending on the site location of drying. Thus the need for a hygienic effective drying method is apparent. Modern methods of drying include, oven, cabinet and solar drying. Both of these utilize heat to remove the moisture content in the food to the bearable level by evaporation. These modern methods of drying are used in drying plant materials at specific temperatures over a defined period of time. Also, for large scale production, there are various known limitations of sun drying some of which include: damage to crops by animals, birds and rodents, contamination by dirt dust and debris and intensive labour required as the crops have to be covered at night. The main aim of the study is to carryout comparative analysis of the different drying (Solar, sum and mechanical) methods in terms of the drying rate.

2. Materials and Methods

2.1 Sample preparation

Plantain was purchased from Mandate market in Ilorin West Local Government Area, Kwara State, Nigeria. Fresh plantain samples were manually sorted to remove the bad ones and washed with clean water. The samples were then sliced into different thickness (3mm, 6mm and 9mm) using a kitchen knife for slicing and a digital Vernier caliper for measuring the sizes. The different sample sizes were measured using a digital weighing scale. The samples were then divided into three equal parts to be dried using the different methods of drying.

2.2 Experimental Design and Layout

In order to investigate the effects of drying methods on the drying rate of plantain, a 3 x 3 factorial experiment was used for the study. The design included three levels of size of the samples (3mm, 6mm, and 9mm), and three drying techniques (solar drying, mechanical drying and open sun drying). All the tests were carried out in duplicates making a total of 18 experimental samples that were individually dried and measured.

2.3 Experimental Procedure

Before drying, the dryers were cleaned and the multi crop dryer which uses kerosene stove as source of heat was lighted to pre heat the dryer before the samples were put into it. Net were placed on top of the trays of the dryers to prevent the samples from falling off as a result of the small size of the crop to be dried. The initial temperature, relative humidity and air velocity of the dryers were taken with a thermometer, thermo-hygrometer and air flow meter respectively and it was recorded. The data logger was also set to take readings at one-hour interval so as to compare data taken. The different prepared samples were then placed in the trays and labelled accordingly before being loaded into the dryers. The samples to be dried using open sun drying was also placed directly under the sun. the initial mass of the samples was measured and recorded while the weight loss was measured hourly and recorded appropriately. The drying process continued until there was no more weight loss between three successive readings.

2.4 Equipment and Instrument

The following are the instrument and equipment used for the study:

i. Solar dryer: This was used for the drying of the crops. It consists of the following components part: solar collector, tray, chimney, air inlet and door for easy loading and unloading. It has been designed and fabricated to dry any agricultural material using sun as the source of heat.
ii. Multi crop dryer: This was used for the drying of the crops. It consists of the following components part: kerosene stove, tray, air inlet, chimney and door. It has been designed and fabricated to dry any agricultural material using kerosene stove as the source of heat.
iii. Digital measuring scale: An electronic digital weighing scale with an accuracy ±0/01g was used for the study to measure the mass of the crop before and after drying.
iv. Kitchen knife: A kitchen knife was used to slice the crop to different sizes
v. Vernier caliper: A carbon Fiber Composites Digital Caliper with resolution, accuracy and battery of 0.1mm/0.01″, ±0.1mm/0.01″ and SR44/LR44 1.5V was used to measure the sizes of the sliced crops.
vi. Data logger: Temperature and relative humidity data logger was used to take consecutive data of temperature and relative humidity inside and outside of the dryers.
vii. Air flow meter: An electronic air flow meter (anemometer) was used to measure the air velocity of the air flowing inside the dryers and also the ambient air.
viii. Thermo-hygrometer: An electronic thermos-hygrometer was used to measure the relative humidity and temperature of the air inside and outside of the dryer.
ix. Stainless tray and bowl: This was used to pack the crops during the experiment.

2.5 Performance Evaluation

The output parameter to be measured is the drying rate. The method used by Ajisegiri, (2006) and also by Balogun *et al;* (2018) was adopted. This was expressed below as:

$$D_r = \frac{W_w}{t} \quad (1)$$

Where;

D_r : Drying rate (g/min)

W_w : mass of water removed (g)

t : Time taken (min)

2.6 Statistical Analysis

Data obtained from the experiment were analyzed statistically using analysis of variance (ANOVA). The analysis of variance (ANOVA) was drawn to see the effect of the different drying methods on the drying rate while graphical representations were also made to show the trends of the variation.

3. Results and Discussion

The summary of the result obtained from the study were presented in table 1 below.

Table 1: Average Results for Drying of Plantain

Thickness	Methods of Drying	Average drying temperature (°C)	Average Air flow rate (m/s)	Average Relative humidity (%)	Time (min)	Total Water loss (g)	Average Drying Rate (g/min)
3mm	Sun	37.74	0.6	38.86	720	113.34	0.157
	Solar	40.26	0.54	33.4	720	118.80	0.165
	Mech.	43.52	0.7	35.67	600	117.61	0.196
6mm	Sun	37.74	0.6	38.86	600	90.23	0.150
	Solar	40.26	0.54	33.4	720	114.66	0.159
	Mech.	43.52	0.7	35.67	600	108.95	0.182
9mm	Sun	37.74	0.6	38.86	720	108.9	0.151
	Solar	40.26	0.54	33.4	840	101.64	0.121
	Mech.	43.52	0.7	35.67	600	105.6	0.176

From table 1, the average drying temperature obtained during the drying of Plantain by sun drying, solar drying and mechanical drying method were 37.74°C, 40.26°C and 43.52°C respectively. The average air flow rate obtained during the drying of Plantain by sun drying, solar drying and mechanical drying method were 0.6 m/s, 0.54 m/s and 0.7m/s respectively. The average Relative humidity obtained during the drying of Plantain by sun drying, solar drying and mechanical drying method were 38.86%, 33.4% and 35.67% respectively.
The drying rate obtained for drying of Plantain slices at 3mm thickness using sun drying, solar drying and mechanical drying methods were 0.157g/min, 0.165g/min and 0.196g/min respectively. The drying rate obtained for drying of Plantain slices at 6mm thickness using sun drying, solar drying and mechanical drying methods

were 0.150g/min, 0.159g/min and 0.182g/min respectively. The drying rate obtained for drying of Plantain slices at 9mm thickness using sun drying, solar drying and mechanical drying methods were 0.151g/min, 0.121g/min and 0.176g/min respectively.

Table 2: Analysis of Variance (ANOVA) for the Drying Rate of Plantain

Groups	Count	Sum	Average	Variance
sun drying	3	0.458	0.152666667	1.43E-05
solar drying	3	0.445	0.148333333	0.000569
mechanical drying	3	0.554	0.184666667	0.000105

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.002362889	2	0.001181444	5.14417	0.049983	5.143253
Within Groups	0.001378	6	0.000229667			
Total	0.003740889	8				

***Significant at p≤0.05.**

The p-value 0.049983 obtained from the ANOVA shows that the model is significant at $p \leq 0.05$. This implies that the different drying methods significantly affects the drying rate of sliced plantain. This is in line with the work of Olaniyan *et al;* (2013) and Balogun *et al;* (2014).

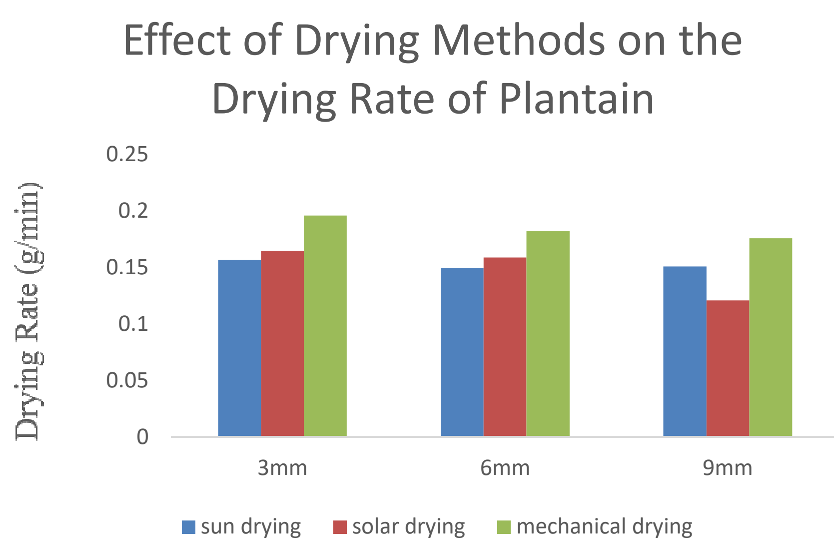

Figure 1: Effects of Drying Methods on the Drying Rate of Plantain

Figure 1 above depicts the effects of the different drying methods on the drying rate of sliced plantain. It was observed from the graph that mechanical drying has the highest drying rate followed by solar drying while sun drying has the least drying rate. This could be attributed to the stable drying conditions in the dryer compared to sun drying which the conditions depend on the current weather conditions.

4. Conclusions

Three drying techniques (Solar, Mechanical and Sun) were used to reduce the moisture content of Plantain (*Musa Paradisiaca*) using Slices (3mm, 6mm and 9mm). From the study, the following conclusions were drawn:

1. The drying rate increases with an increase in temperature
2. The different drying methods significantly affect the drying rate of the crops as different drying methods have different drying rate
3. The different drying methods help to dry the crops to safe moisture level for storage.

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TOWARDS PROMOTING AFRICAN INDIGENOUS ADDITIVE FORMULATIONS TO VEGETABLE OIL BASED CUTTING FLUIDS FOR SUSTAINABLE MACHINING

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Abstract

The search for environment friendly substitutes to mineral oils as base oils in lubricants has become a frontier area of research in the lubricant industry (Sankaranarayanan et al (2021). Vegetable oils are perceived as good alternatives to mineral oils for lubricant base oils due to certain inherent technical properties and their ability to be biodegradable. Hence the attention of scientist community has been focused on recent research on vegetable oils as base oil for lubricant production. Besides, attention is being drawn to their economic implications on the continent of Africa. Mineral oils pose the challenge of poor oxidative and hydrolytic stability, high cost, food versus energy debate, high temperature sensitivity of tribological behaviour and poor cold flow properties. All these are reckoned to be the limitations of vegetable oils for their use as base oils for industrial lubricants. The current effort to overcome these limitations includes the use of non edible oils, additives, chemical modifications and thermal modifications. Scientist communities have recommended more research efforts and legislation in other to favour the use of vegetable oil lubricants. At present, little consideration is given to trade imbalance of vegetable oils (USDA 2013) and (Table 7). The trade balance is tilted to the industrialised nations; although the situation could be revised with appropriate policy formulation to help the less industrialized nations. One efficient way of reducing friction and wear is the use of lubrication. When introduced between two moving parts it reduces friction, minimizes wear, distributes heat, remove contaminants, and improve efficiency. Basically an industrial lubricant consists of base oil and an effective additive package. Depending on the characteristics of the additive package, the performance and longevity of lubricants can be improved. This paper argues that with the right choice of right additives, economic trade can be tilted to favour of African continent (Rizvi, 1999).

Keywords: Metal Cutting Fluids, Vegetable oils, Oil Trade, African indigenous oil, Additive formulations

1. Introduction

Upwards of 10,000 different lubricants exist in the market today that satisfy more than 90% of all lubricant applications that are specifically formulated worldwide (Mang, and Dresel, 2006) The global lubrication market as of 2004, indicate that lubricants consumed roughly 37.4 million tons of lubricant (Mang, and Dresel, 2006) of which automotive and industrial lubricants are the most prevalent. Industrial lubricants amount to 32% and were composed of 12% hydraulic oils, 10% other industrial oils, 5% metalworking fluids, 3% greases, and 2% industrial gear oils (Bartz, 2006 and Lingg, and Gosalia, 2008) . The 10% of other industrial oils within the industrial lubricants section consist of a wide range of lubricants such as air and gas compressor oils, bearing and circulating system oils, refrigerator compressor oils, and steam and gas turbine oils. In the automotive lubricants section, the most commonly used liquid lubricants were engine oils (petrol and diesel engine oils), automatic transmission fluids, gearbox fluids, brake fluids, and hydraulic fluids. Lubricants are very important consumables in virtually every industry, within the last decade the annual worldwide consumption of lubricants is over 40 million metric tonnes. According to Ajithkumar (2009) a lubricant consists of over 90% base oil and less than 10% additive package. Vegetable oils are perceived to be alternatives to mineral oils for lubricant base oils due to certain inherent technical properties and their ability to be biodegradable.

Vegetable oils are obtained from oil-bearing seeds; for example corn (maize), cottonseed, peanuts, palm nuts (coconuts), and soybeans, that are 100 percent fat and remain liquid at fairly low temperatures. They can be further processed to achieve neutral to yellow colour and to eliminate odour or produce mild odour. When used as vegetable oils in the lubricant sector, they are monounsaturated oils, which combine good stability to oxidation and thermal degradation with liquidity at lower temperatures. For some higher temperature applications, lauric oils such as coconut or palm kernel may be used for optimal stability. Most importantly, vegetable oils are biodegradable, less toxic, and renewable and reduce dependency on imported petroleum oils. Additionally, using lubricants and greases made of soybean oil help reduce soybean surpluses and helps stabilize soy prices for farmers in developed countries like America.

Saudi Arabia, Nigeria and Angola supply South Africa's crude oil; they have supplied 89% of South Africa's total crude imports for 2018 (Bartz , 2006). She is very reliant on palm oil from Asia, soya bean oil from South and North America and sunflower oil from Europe. Canola is predominantly supplied locally but is also imported from Europe or Canada. Worldwide, supplies of vegetable oils are tight - primarily palm oil, soya oil and rapeseed oil, (Lawal, 2014). South Africa imports Crude Petroleum primarily from: Nigeria ($2.14B), Saudi Arabia ($1.87B), Ghana ($506M), United Arab Emirates ($208M), and United States ($114M). The fastest growing import markets in Crude Petroleum for South Africa between 2019 and 2020 were Brazil ($81.4M), Spain ($45.1M), and Russia ($42.3M). In Southern Africa, such as Angola, Botswana, Comoros, Democratic Republic of the Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe; Vegetable oils are used in divers industries for example, cosmetic industry. An overview of the oils used in cosmetic industry (https://en.wikipedia.org/wiki/Essential_oil) was presented . All these oils have emollient, and skin/hair conditioning properties. Most vegetable oils are produced by cold pressing seeds or kernels.

In metal cutting industries, lubricant fluid possesses the ability to keep the work piece at a stable temperature (critical when working to close tolerances); very warm is acceptable, but extremely hot or alternating hot-and-cold are avoided. They maximize the life of the cutting tip by lubricating the working edge and reducing tip welding. Furthermore cutting fluids (CF) are to ensure safety for the people handling it (toxicity, bacteria, and fungi) and for the environment upon disposal; they prevent rust on machine parts and cutters.

Owing to its technical properties and cost implications, mineral oils have been traditionally used as basis for cutting fluids (Vaibhav,2012). The oil crisis experienced in 1979 and 1983, resulted in the notion that the mineral oil is a limited resource. It is poorly biodegradable and has long term environmental pollution and the attendant problems and poses health challenges to workers. Initial research work had been based on vegetable oils largely available in the developed world for use of biodegradable vegetable oil as cutting fluids. These include mustard oil, neem, coconut oil, groundnut oil, cotton. The growing demand for biodegradable materials has increased the wider search for vegetable oils as alternatives to petroleum based polymeric materials. Bio-based oils are gaining overwhelming interest and recognition worldwide due to the health, safety, and environmental concerns associated with the conventional mineral oil. Hence a wider search to include vegetable oils from African origin such as groundnut oil, palm kernel oil, and shear butter oil, cashew oil, soya bean oil and their various percentage combinations.

This paper provides a synopsis of wider prospects of oil producing seeds indigenous to Africa that can serve as suitable alternatives to mineral oils and provide broader applications with comparable technical properties. It also examines the potential economic advantages under favourable policy formulation.

2. Additives part of vegetable oils for machining applications

2. 1. Review methodology

Water is the mother of all (Metal Cutting Fluids) MCFs. It was the only source applied on grindstones for cutting purposes in the cutting fluid history. Animal fat (Tallow) is considered as the second known cooling medium next to the water that was utilized as lubricants in the wax form. Subsequently, simple oils were joined in the club of MCFs. Soap was blended with water for MCFs applications in the early periods of the last century [38]. Straight cutting fluids also registered their presence with exclusive applications for specific machining operations. Many researches have undergone methodical and review-based approach on conventional and contemporary MCFs. The survey of research articles is executed at three stages namely review planning, source discovery, and know-how for the systematic approach towards the preparation of the review article. Valuable review approaching inputs are acquired (Sankaranarayanan et al, 2021). They mentioned that a well-executed review work provides an excellent platform for the advancement of technologies and lays a strong foundation for future research. Integration of all discoveries and perspectives from the reviews opens the way to address the real challenges (Hill, 2000) which are considered for the present research work. A segmental approach is followed for the review planning stage from collection to the finalization of resource materials as specified by Van Voorst,. and Alam, (2000) Razak et al. (2022) and Mang 1997). The respective approach includes the identification of resource materials, screening of identified databases, exploring the eligibility of screened sources, and inclusion of appropriate works within the current review article. The respective approach assists to integrate all positive aspects and challenges with respect to these bio-friendly MCFs. The planning stage targets bringing all latest and historically important, empirical and research findings together in this paper.

The sources for the current survey article are derived from Elsevier, Springer, Scopus, Google Scholar, Web pages, Books, etc. The selection of papers and other related information is purely based on the ground of relevance to the intended review work irrespective of sources where the quality of collections is uncompromised. Appropriate keywords such as Metal cutting fluids, Vegetable oils, Sustainability, Green etc.

The literature survey of current review work overviewed other peer-reviewed review-literatures associated with vegetable oils and explored that limited numbers of vegetable oils were discussed in the available review works. Hence, a wide survey is attempted and about 14 distinct vegetable oils are included in the current work for the review. Lawal et al. (2012) and Lawal et al. (2014) broadly considered the technical aspects of vegetable oils for the review and discussed the possibilities of deploying these green oils as MCFs for various machining operations.

The present review work realised the significance of such a balanced approach and respective contents are incorporated while article preparation.

2. 2. Common additives in vegetable oils

Additives are desirables in vegetable oils to enhance the characteristics and performance of cutting fluids. They are categorised based on what function they perform, their source. For example, corrosion inhibitors, boundary lubricants, extreme pressure lubricants, biocides, antifoams, emulsifiers, dispersants, and viscosity index modifiers. In case of anti-wear additives they include zinc dithiophosphates, various organic and/or acid phosphates, organic sulphur and chlorine compounds, sulphurised fats, sulphides, and disulfides.

An additive could be a modern engine oil formulation. It can be in the form mineral, semi-synthetic, or synthetic. When produced by reputable manufacturers they are marvels of chemical engineering. Without the addition of chemically engineered additives the basic lubricity of base oil, including synthetic base oils is very poor. Modern engine would not last for more than a few hours at best before seizure. A closer look at engine oil additives and how they function are considered in this article.

Since base engine oils are very poor lubricants, oil formulators add a package of additives to a base oil to produce a lubricant that is reasonably stable in terms of its viscosity over a wide range of temperatures, and resists corrosion and the formation of harmful deposits of sludge and carbon, while at the same time, improving fuel economy and extending engine life.

Additive packages generally account for about 15% to 25% of the total volume of the packaged product (Woma et al, 2019); each package has the recipe owned by each oil formulator. Oil formulations vary greatly between brands and oils and actual substances and relative concentrations are never published. It poses therefore a challenge to the scientific community in Africa through rigorous research efforts to find unique recipe for additives peculiar to Africa or of African origin that can boost the characteristics of vegetable oils for machining operations. Since a lot of advanced chemical engineering goes into formulating modern lubricants most additives are sacrificial, that is, “wear out”

Owing to stricter environmental regulations, the scientific community is developing new lubricants with greater biodegradability and less toxicity (Lingg, and Gosalia (2008) ; Mohammed, 2017).. Consequently, the lubricants obtained from bio-based sources (biolubricants) have emerged as potential alternatives to replace traditional mineral oils synthesized from petroleum (Ajithkumar, (2009); Habibullah et al. (2009) Nair et al; (2017). Biolubricants display excellent physicochemical properties, such as high viscosity indexes and flash points as well as good resistance to shear and high biodegradability, in such a way that these compounds can be considered renewable and readily biodegradable (Bartz, 2006; Vaibhav et al., 2012 Lawal et al, 2014) (Table 2, 3), allowing them to be used in various industrial applications, including as emulsifiers, lubricants, plasticizers, surfactants, plastics, solvents, and resins (Vaibhavet al 2012; Lawal et al 2014; Timothy and Lawal, 2019). (Table 1 and 2). Using appropriate starting oil to synthesize a biolubricant is important, since, in most cases, vegetable oils are used in the food chain. The use of these oils for industrial applications could cause an increase in speculation, thereby increasing prices and social imbalances. Considering these data, the most sustainable alternative is the use of vegetable oils, which do not interfere with the food chain (Jayadas, and Nair, 2006; Nair et al. 2017; Kalhapure et al. 2015).

Table 1. Advantages of bio-lubricant use.

Advantages
- Higher boiling point (less emissions) - Higher biodegradability (free of aromatics) - Higher lubricity - Lower volatility - Better skin compatibility - Higher shear stability - Higher tool life - Higher viscosity index ….Higher safety on shop floor

Table 2. Main applications of several vegetable oils.

Vegetable Oil	Main Applications
Canola oil	Transmission fluids, hydraulic fluids, penetrating oils, metal-working fluids, food grade lubes
Castor oil	Greases, gear lubricants
Coconut oil	Engine oils
Crambe oil	Greases, surfactants, chemicals
Cuphea oil	Motor oils, cosmetics
Jojoba oil	Greases, cosmetics, lubricants
Linseed oil	Vanishes, paints, coatings, stains
Olive oil	Engine oils
Palm oil	Greases, metal-working fluids
Rapeseed oil	Greases, hydraulic fluids, chainsaw oils
Safflower oil	Diesel fuels, resins, enamels
Soybean oil	Engine oils, hydraulic oils, transmission fluids, biodiesel fuel, paints, printing inks, coatings, detergents, shampoos, pesticides (when machining aluminum, titanium and stainless steel)
Sunflower oil	Greases, diesel fuels
Tallow oil	Hydraulic oils, cosmetics, soaps, plastics

3. Some examples of eco-friendly biodegradable vegetable oils for machining applications

A comparative study concluded that jathropha oil performed better than oil-based commercial lubricating oil; viscosity for jatropha was 16 mPa·s was lower than that for commercial engine oil which was 1 8.8 mPa·s, however, the average for the wear scar area for jatropha oils was 0.160 mm^2, which was lower than that of mineral base engine oil which was 1.124 mm^2[29]. Also the friction torque for jatropha oil (0.01392 Nm) was less than half of that of engine oil (0.06089 Nm) while the coefficient of friction for engine oil (0.07977) was more than Jatropha oil which had coefficient of friction of 0.0346. It was also concluded that the jatropha oil performed better than the mineral oil in terms of wear and friction while the mineral oil has a better viscosity.

Stojilković and Kolb (Erhan, et al 2000; Stojilković, et al 2016; Habibullah, et al 2014) carried out a study on the tribological properties of biodegradable universal tractor transmission oil by using three vegetable oils: rapeseed oil (RE), soybean (SO) oil and sunflower oil (SU), by comparing their properties with a commercial mineral oil based universal tractor transmission oil (MN). Tribological tests for all four samples were conducted on annealed alloy steel 16MnCr5 (Č4320) having the hardness of 35 HRC block on disc tribometer TPD-93, with a sliding speed in the contact zone of 0.8 m/s and contact duration of 60 minutes. Results obtained showed that the coefficient of friction of tested vegetable oils samples was lower than that of the reference mineral oil universal tractor transmission oil, especially at higher loads. Also sunflower oil had the lowest wear scar width of 1.345 millimetres while the mineral based oil had the highest wear scar width of 1.585 millimetres. From the study it was concluded that rapeseed oil had the best performance with regards to coefficient of friction while sunflower oil performed best in terms of wear scar width, thus all the vegetable oils are better in tribological performance compared to the universal tractor transmission oil. The properties of the studied oils are shown in Table 3 for the purpose of comparison.

Table 3 Rheological and tribological properties for sesame oil, coconut oil, sunflower oil and SAE 20W40 oils

Oils	Viscosity at 40°C (cst)	Viscosity at 100°C (cst)	Viscosity Index	Coefficient of friction	Wear scar diameter (mm)
Sesame oil	31.86	7.46	213.5	0.0862	0.650
Coconut oil	27.8	6.1	176	0.0901	0.836
Sunflower oil	29	6	159	0.0742	0.685
SAE 20W40	112.6	14.8	135.57	0.107	0.470

4. Classical Methodological Approach

The methodological approach of the scientific community commences by first determining the rheological properties of various vegetable oils and the various Compositions of Cutting fluids (Table-3 and Table 4). This is followed by using classical approach to test the performance of the CF and their ability to meet the environmental requirements.. For example, Table 5 presents the Classification of indigenous Southern African vegetable oils used in cosmetic industry.

For the purpose of testing, a new water based grounding fluid formulation able to meet both the performance and environmental requirements accommodating Cubic Boron Nitride (CBN) grinding would be prepared. The CBN is structurally analogous to diamond with similar or even superior properties for certain applications. The Taguchi method of is a statistical experimental design often used. A new water based grinding fluid formulation of a high concentration (up to 40%) of sulfonate oil in water is prepared and tested. In this way it would be possible to combine high lubricity, better heat conductivity and good environmental properties in one fluid. The results from practical test using the new fluid would show good performance vitrified CBN grinding comparable to those obtained with mineral oil.

Table 3 Thermal properties of sesame oil, coconut oil, sunflower oil and SAE 20W40 oils

Oils	Thermal Properties (°C)		
	Flash Point	Fire Point	Pour Point
Sesame oil	315	319	-15
Coconut oil	320	325	22
Sunflower oil	332	337	-18
SAE 20W40	204	209	-20

Table 4: Composition of Cutting fluids

Name	Type	Description	S-add	P-add
RM (reference oil)	Commercial oil	Mineral oil-based, general purpose, 20cSt at 40°C	-	-
RV	Commercial oil	Vegetable oil-based, general purpose, 19 cSt at 40°C	-	-
A	Formulated oil	Blend of rapeseed oil and ester oil, general purpose, 20 cSt at 40°C	++	++
B	Formulated oil	Blend of rapeseed oil, ester oil and meadow foam oil, general purpose, 20 cSt at 40°C	++	++
C	Formulated oil	Blend of rapeseed oil and ester oil, mild duty, 20 cSt at 40°C	+	+
D	Formulated oil	Blend of rapeseed oil, ester oil, and meadow foam oil, mild duty, 20cSt at 40°C	+	+

Source: W. Belluco and L. De Chiffre (2004), Performance evaluation of vegetable-based oils in drilling austenitic stainless steel, *Journal of Materials Processing Technology* 148 (2004), pp. 171-176

A basic determination of physical properties of the water based vegetable oils and the5r formulations will determined. Based on the results obtained, various formulations from African vegetable oils and mineral oils would be selected. For example, groundnut oil, palm kernel oil, and shear butter oil, cashew oil, soya bean oil. mineral oil based Cutting fluid (CF). In addition, to two (2) mineral oil based Cutting fluid (CF) making a total of eight will form part of the CF combinations at varying percentages of formulations.

Table 5. South Africa Vegetable oils; sunflower seed or safflower oil and their fractions, crude, not chemically modified imports by country in 2018

Partner	Trade Value 1000USD	Quantity	Quantity Unit
World	104,950.86	135,763,000	Kg
Bulgaria	48,831.30	63,772,800	Kg
Romania	21,388.86	26,825,600	Kg

Netherlands	12,696.42	16,806,500	Kg
Spain	6,964.09	9,120,390	Kg
Portugal	5,485.37	6,978,710	Kg
France	5,051.06	6,005,050	Kg
Argentina	2,960.68	4,157,840	Kg
United Kingdom	736.37	1,018,660	Kg
Brazil	633.33	799,810	Kg
Ukraine	198.00	263,440	Kg
Nigeria	2.49	9,160	Kg

(**Sources**: USDA February 2013 for vegetable oils and Wikipedia for population)

5. Conclusion

(i.) Huge potential impacts of vegetable oils in machining applications have drawn the attention of scientific communities to research into the use of vegetable oils for machining operations. About 16-30% of the entire expenses for machining material up to the disposal of fluids (see Table5)

(ii.) These have led to key insights on vegetables Oil based Cutting Fluids, environmental consciousness, comprehensive analysis of different cooling operations, Physicochemical properties of vegetable oils give promising results in machining applications, Categorisation of vegetable oils based on their source, end-use, and availability and Research challenges and future research directions envisage huge potential impact of vegetable oils in machining applications (see Table 5 and 7)

(iii.) There is need to experiment many oil producing seeds of African origin that have not been tried before. Various combinations of various proportions by weight or volume could give rise to potentially profitable formulations.

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CONVERSION OF COCONUT BIOMASS MATERIALS TO ACTIVATED CARBON AND ITS APPLICATIONS: A REVIEW

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Abstract

The potential of coconut biomass as activated carbon has been reviewed. This biomass includes the shell and the husk. The proximate analysis conducted by various researchers on the produced activated carbon were particle size, moisture content, ash content, volatile matter content, fixed carbon and bulk density while the ultimate analysis carried out were carbon, hydrogen, nitrogen, sulphur (CHNS) and oxygen. The review revealed the use of coconut residue activated carbon as potential energy storage and electromagnetic absorbent. It was found suitable as electrode for supercapacitor application. The amount of pores in the activated cabon produced from coconut has been found to influence the capacitive characteristics. At temperature of 500°C, coconut residue activated carbon can produce long lasting heat due to its abundant carbon content and the number of pores that is formed. Coconut residue activated carbon can be an alternative source of renewable energy because of its high fixed carbon content, good electrical and thermal properties.

Keywords: Renewable energy, biomass conversion, energy storage

1.0 Introduction

Biomass are mostly agricultural wastes generated on the farm or during the processing of agro-products like woods, sugar cane, rice, coconut etc. This material from their parent material utilizes sunlight to store their energy during photosynthesis. Biomass is utilized in conversion form as renewable fuel to power electricity plants, heaters, automobiles etc. This energy stored in biomass can be utilized for renewable electricity or heat generation. Among these biomass resources, solid biomass constitutes about 69 % of the biomass components for energy generation as shown in figure 1. Global forests generate the greater percentage of the solid biomass. Wood waste is generated both in the forest and in wood mills though three to six times more is generated in the forest compared to the mills (Jasinskas et al., 2020). Tropical and sub-tropical species grows in zone with warm and moist climate, occupies 7% of the global surface, and 44% of the global forest area (Jasinskas et al., 2020). According to Adam et al., (2018) and Park et al., (2020), it is estimated that over 40% of the oxygen produced in the world comes from these vegetative areas, which have undergone large-scale desertification in recent years, rapidly reducing the ecosystem around the world. Among these trees is coconut. Within the coastal belt of West Africa and Caribbean countries lies abundant coconut belt which generates massive residue of coconut shells yearly. This coconut shell can provide substantives energy to improve the energy needs of the people. Coconut shell activated carbon showed a wider, meso and macro porosity, which is an important source of biomass.

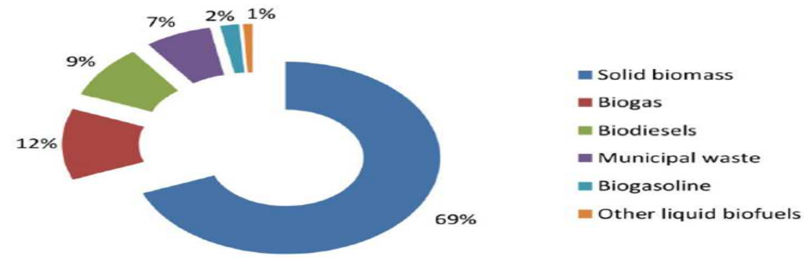


Figure 1: Energy consumption from biomass and bio-waste in Europe (AEBIOM, 2019).

Biomass from coconut is large enough to make African and indeed Nigeria one of the major potential providers of bioenergy. Coconut is deduced from a latin name Cocos Nucifera. This crop has been proven to be a useful tree crops. Erlinda et al (2015) has reported that every parts of coco nut tree has one benefit or the other. This tree can only compare to palm tree in terms of useful benefits of every parts of a tree. Because of the environmental hazards posed by the poor disposal of the waste materials from coconut, it is therefore imperative to process this waste coconut shell as a feedstock. Research by Erlinda et al (2015), found that coconut shell activated carbon can be utilized as fuel in place of coal. Production of activated carbon not costly and the procedure is not complex. Densely textured hard coconut shell has become a mainstay for as activated carbon production. Furthermore, the percentage yield of activated carbon produced has been found to be influenced by the precursor material (coconut shell) quality and the process of pyrolysis. More research is now visible in the manufacture of pallet for coal energy using coconut shell activated carbon due to the abundance of coconut shell as waste materials and as well the energy crisis effects (Erlinda et al 2015). Figure 2 shows samples of waste materials from coconut.

Figure 2: (a) Coconut shell (b) Coconut Husk.

2.0 Activated Carbon

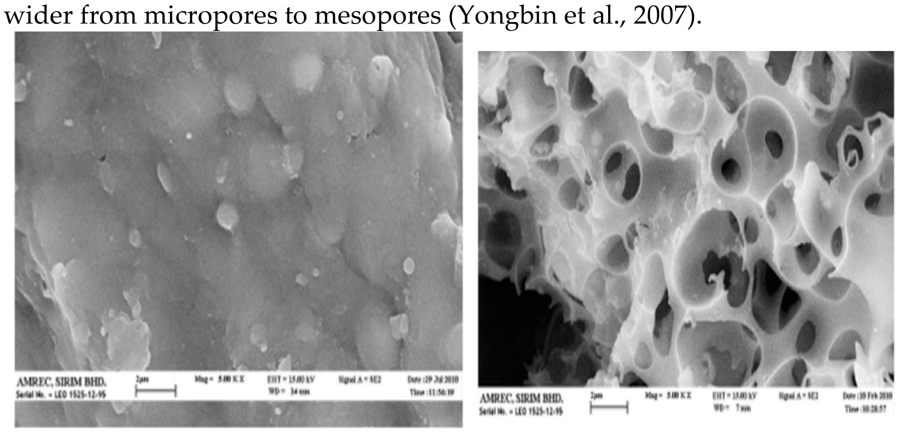
Materials known to have well developed porosity and internal surface area are referred to as activated carbon. Saygili et al. (2015) has listed some of the usage of activated carbon to include storage or separation of gases, drug manufacturing, serves as catalyst, it can be used as deodorizer, remediation of polluted environment, energy storage in capacitors, and wastewater treatment. Its properties include low toxic, relatively less expensive in production and can be prepared from precursor material such as plant and animal plant waste (Ahmed and Theydan, 2012; Nowicki et al., 2015). The structural characteristics of activated carbon are associated to its raw material and the technique of preparation. Due to its abundance in carbon and deficient in ash content, precursor materials used for activated carbon are mostly organic matter. With reference to the protection of the environment, waste produced from agricultural or industrial activities are critical precursor because of its abundant, inexpensive and renewable characteristics (Ahmed and Theydan, 2012). Commercially produced activated carbons have internal surface area between the range of 500 to 1500 m²/g. International Union of Pure and Applied Chemistry have classified the pore development of an activated carbon into three categories namely micropores (size < 2 nm), mesopores (2–50 nm) and macropores (size > 50 nm) (Pandolfo and Hollenkamp 2005). Activated carbon can be prepared from feedstock having abundant carbon, but low in inorganic content. The most common precursor used for activated carbon production are wood, coconut shell, bituminous coal and peat etc. The chars obtained from them could be activated easily to produce reasonably high-quality activated carbons. There are three categories of pores that can be identified on activated carbon; they include macropores which are above 50nm in diameter, mesopores which are 250 nm in diameter and micropores which are under 2nm in diameter. The desirous activated carbon pore structure is attained by combining the right raw material and suitable activation procedure. According to Zanzi et al., (2001) activated carbons with very much developed internal surface area and porosity have enormous capability for absorbing chemicals.

2.1 Production of Activated Carbon from Biomass

With the growing concern on the environmental impact of biomass waste, several researches have been reported on the production of activated carbon from waste biomass such as date stone, durian shell, soybean oil cake, cherry stone, palm shell and coconut shell (Bouchelta et al., 2008; Chandra et al., 2009; Tay et al., 2009; Marin et al., 2009; Daud and Ali, 2004). Carbon absorbent has been developed from saw dust (Mallick, 2001) for dye removal. Also the adsorption behavior on Reactive Black 5 and Reactive Red 3 has been studied by Nourouzi and Chuah, (2009) using palm activated carbon made from kernel shell. Gao et al., (2013) used produced tea seed shells based activated carbon. They produced activated carbon with BET surface area of 1530 m2/g. The precursor material was activated chemically using zinc chloride and pyrolyzed in a tubular furnace at 500oC for one-hour duration at a heating rate 5oC/min. Halanet al., (2008) used the process of chemical activation to produce activated carbon from hazelnut bagasse. The surface area achieved was as high as 1489 m2/g. The activated carbon was for the removal of sandolan blue from the water. These activated carbon materials were well developed as seen from their exhibited characteristics of large surface area and improved porosity. Because this characteristics, this material has been commercialized as absorbent for detoxication of the environment and water bodies other. The cost of producing activated carbon is a function of precursor's type. Activated carbon has found usefulness in so many industries, due to its low cost and efficiency in the mass separation of dyes and surfactants or mixtures. They have been adopted as purifier for liquid and gases. The desorption or adsorption power of any activated carbon depends on the nature of organic chemical and the type of liquid-solid phase present. Porosity and surface area also plays a major role in activated carbon accomplishing its function which is determined using the BET and SEM techniques respectively or the application of porosimeter for pore volumes. The larger the pores the better the adsorption . Several methods have been used to produce activated carbon from coconut with varying degree of physical properties. For example Li et al., (2009) and Yang et al., (2010) used microwave oven with high specific area and micropores which made the activated carbon suitable for super capacitor electrodes. Due to large literature from the production of activated carbon from coconut materials this is further discussed in the next section below.

2.1.1. Activated Carbon from Coconut Residue

Mohd et al., (2013) produced activated carbon from coconut shell precursor using microwave-induced potassium hydroxide for activation. They evaluated three major properties of the activated carbon which includes the surface area, porosity and specific capacitance. Investigation were carried out to study usefulness of the activated carbon to produce electrode used in supercapacitor application. The process of activation was carried out at 600W with varying irradiation times of 10 to 30 minutes. They used a modified probe to monitor the activation temperature of the activation process. The irradiated sample that became lumpy was washed using 50% hydrochloric acid and water with pH 6.5 – 7.0 to remove excess KOH. The sample was then dried in an oven at 100 °C for 2 hours. The result showed that higher surface area ranging from 1244.0 m^2g-1 to 1768.8m^2g-1 were obtained from activated carbon compared with the inactivated carbon, 36.5m^2g-1. These results showed good agreement with the scanning electron micrographs which revealed highly porous surface structure. During carbonization, most volatile matter was released. However, no pores were observed as a result of no activating agent. The scan electron microscope (SEM) micrographs of coconut shell carbon (CSC) and coconut shell activated carbon (CSAC) showed large differences in surface morphology as depicted in Figure 2. In the study of Mohd et al., (2013), revealed that the activation process had significant influence by time. There was a corresponding increase in irradiation time from 10 to 20 minutes, as the pore size of coconut shell activated carbon (CSAC) increased from 2.3 to 2.7 nm. However, due to the sintering process which destroyed and widened the pore during the process, the pore size of CSAC slightly increased from 2.7 to 2.9 nm (Yuen and Hameed, 2012). This observation was explained by two factors that affect the pore development of the carbon material (Mohd et al., 2013). When the irradiation time is above 20 min, the activation reaction is over because the activating agent is used up. This means that pore development during the activation process is influenced by the ratio of KOH. Yongbin et al., (2007) used similar technique previously. The increasing irradiation time causes the activation temperature to increase significantly. In the study of Liu et al., (2010), pores formed were destroyed simultaneously during the activating period. It was further observed that at certain activation temperature, activation reaction between KOH and carbon within the sample increased thereby promoting more pore formation, this led to increased surface area of CSAC. However, the destruction of the pore formation becomes dominant and consequently decreases the surface area when the activation temperature reaches its limit. Hence, pore size becomes wider from micropores to mesopores (Yongbin et al., 2007).



(a) (b)

Figure 4: Scan Electron Microscope (SEM) micrographs of (a) coconut shell carbon and (b) coconut shell activated carbon. (Mohd et al., 2013).

Therefore the observed activation temperature of the method showed a significant increased with rise in the irradiation time. The obtained surface area of the non activated coconut shell (CSC) was lower than coconut shell activated carbon (CSAC). Comparatively the pore sizes CSAC surface was higher by 1768.8 m^2g-1 compared with coconut shell carbon (CSC) at only 36.5 m^2g-1 by chemical activation. This shows that the activation process has successfully increased the surface area and porosity of char derivative from carbonized organic precursor (Marin et al., 2009).

According to Taer et al., (2018), the thermal stability properties of coconut husk were analyzed using thermogravimetry analysis (TGA) with nitrogen pyrolysis gas flowing at the rate of 100 ml per minute and at a temperature range 300^{o}C -600 ^{o}C. This is to determine the maximum temperature reduction that will yield a resistant temperature to pyrolysis process. Two TGA cures were presented which includes the Thermal Gravimetry (TG) and Differential Thermographymetry (DTG) curve to determine the percentage mass shrinkage in proportional to temperature. Also the DTG curve measures the loss of mass or weight from the product per unit time and temperature in consonance with the thermal stability of a material. The scan rate temperature of 10^{o}C min^{-1} and the weight of about 7 mg of sample were used. The decay of cellulose and lignin led to the downward trend of the TG curve. The TG curve showed four phases. The initial phase occurred at about 93.3°C resulting in a loss of 5.6 % of the mass as water evaporate while the second phase occurred at 244 °C resulting in loss of 9.37% which is high due to mass transfer of lignin and hemicelluloses as they evaporate (Brebu and Vasile, 2010). The third phase is characterized by high mass shrinkage of the entire mass. Brebu and Vasile, (2010) stated that this value can be up to 41.97% as the constituents (cellulose, hemicellulose, and lignin) decomposes simultaneously. Following this case, the sample mass still showed further shrinkage at a temperature of 574.4°C at the fourth stage. The reduction in size at this stage was due to the collapse of the lignin compound which was ongoing until it reached the temperature of 900°C. The decomposition of material indicated that the sample has good thermal stability at temperatures above 600 °C. The DTG curve showed a significant reduction in mass at a temperature peak of 321.8°C with a decomposition rate of 0.470 mg min-1. The study concluded based on observed curve trend that the optimum temperature of 321.8°C is the possible thermal resistance for biomass generated from coconut husk. This temperature of 321.8°C was used in the pyrolysis process with 60 minutes residence time. The residence time of 60 minutes was chosen to produce activated carbon of premium quality (Taer et al., 2018). Figure 3 gives the XRD curve characteristics of active carbon electrode produced from coconut.

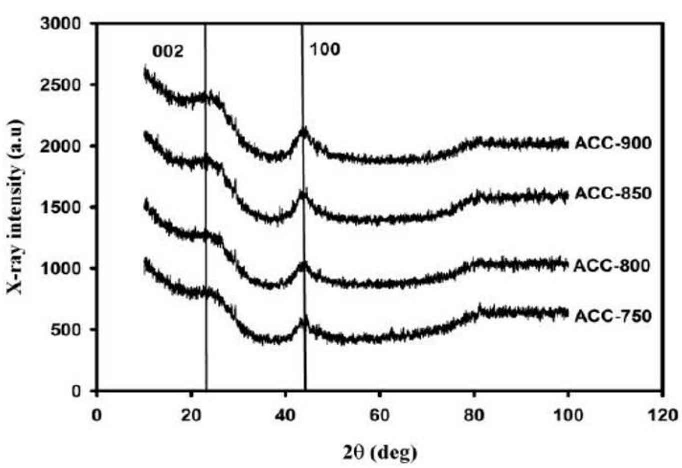


Figure 3: X-ray diffraction curve (Taer et al., 2018).

The crystallinity of the carbon sample showed the presence of an amorphous carbon. The study of Taer et al., (2018) on coconut husk showed that for the production of electrodes for supercapacitors from coconut husk the 900 °C activation temperatures gives the best physical properties. This is because the electrode produced has higher surface area and porosity with lower density and smaller diameter of the nanofibers. This same observation was made by Satyabrata and Ramgopal, (2016) for storage of gases using coconut activated carbon. Though they separated the coconut husk into two varieties namely AX21 and IndoCarbGCD612, however they stated that AX21 has better storage capacity but IndoCarbGCD612 is less expensive and readily available. Despite their less storage capacity compared to AX21, they suggested that if gravimetric storage capacity is not the preference, IndoCarbGCD612 is more economical compared to AX21. Nevertheless they suggested more studies due to other factors that influence gas sorption like heat and mass transfer and material characteristics. Erlinda et al., (2015) processed coconut shell activated carbon into renewable fuel that can replace coal. The process of producing the precursor into activated carbon was by drying, pyrolysis, and carbonization. After Differential Scanning Calorimetry (DSC) and Scanning Electron Microscopy (SEM) examinations on the samples, the coconut shell activated carbon obtained at temperature of 500°C produced suitable long lasting heat capacity because of the high amount of carbon content and the number of pores formed (Erlinda et al., 2015). From the study of Erlinda et al., (2015), the shrinkage mass occurred at the maximum temperature 500 °C. The produced samples where verified using the scan electron microscope at a carbonization temperature range of 300 °C and 500 °C. The obtained results showed that porosity and carbon content increased with temperature and surface area due to loss of volatile constituents and impurities. The activated carbon samples in Figure 5 and Figure 6 contain O, C, K, Al elements. These images reflect an increase of carbon elements in both samples. However shrinkage was due to the loss of volatile matters and impurities at higher temperature

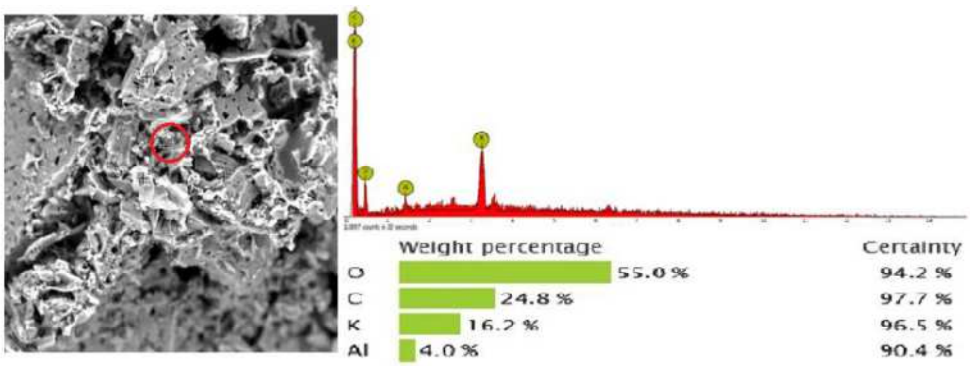


Figure 5: The activated carbon image at temperature of 300°C as observed from SEM (Erlinda et al., 2015).

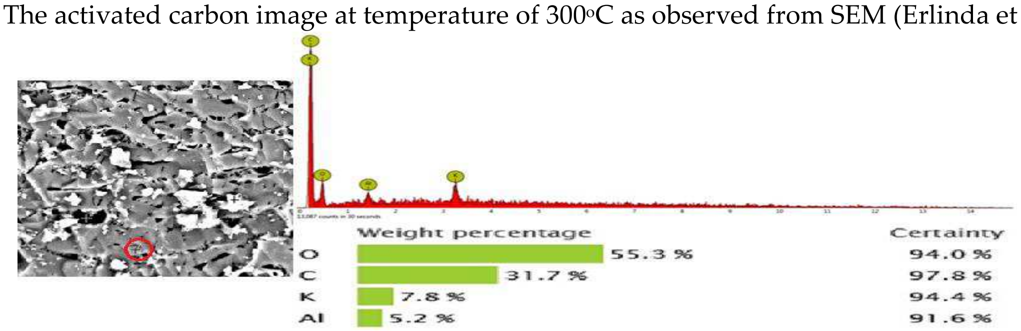


Figure 6: The activated carbon image at temperature of 500 °C as observed from SEM (Erlinda et al., 2015).

2.1. Process of activation

Generally two procedures are adopted in the production of activated carbon which are the physical or chemical activation methods. Physical activation procedure involves a two-step process. Carbonization precedes steam activation unlike chemical activation where the two process occurs at the same stage. However in physical activation the activation agent might be nitrogen, CO_2 or oxygen while it can be potassium hydroxide (KOH), phosphoric acid (H_3PO_3) and zinc chloride (Yuen and Hameed, 2009; Ncibi et al., 2009). Carbonization of the raw material is without oxygen and activation with water vapour or carbon dioxide. Nowadays, samples are usually carbonized by pyrolysis in a flow of steam. The first step in activation process is thermal decomposition of the coconut feed stock followed by multi-component steam distillation, which will help accelerate the loss of the volatile matter. This has been reported to help form a solid prodeuct of premium quality free from any impurities or organic compounds (Zanzi et al. 2001). Solid residue is activated leading to the activated carbon formation.

2.2 Applications of Activated Carbon

Presently other uses of coconut husk exist. Apart of its usage in combustion as biomass, coconut husk has found usefulness as cooling pads or water absorbent in evaporative cooling (Ndukwu et al., 2013, 2016 and 2018). Therefore conversion to produce activated carbon has furthered its usage in industrial application as air filters and air conditioning applications.Water treatment and food industries carryout their filtration process using activated carbon while in mineral industries, it is used for gold from leached liquors (Zanzi et al., 2001). Activated carbons are also used in medical and pharmaceutical industry. However the use of activated carbon in the production of capacitors and electromagnetic devices has been studied. The subsequent section will explore this uses in details and review the research findings.

2.2.1 Activated Carbon from coconut residue as energy storage material

Highly porous electrodes with very high surface area are important for a supercapacitor. Specific capacitance of activated carbon can be achieved by increasing the surface area of carbon material (Yuan et al., 2005). Yuan et al.(2005) has proven this in their research when they achieved a specific capacitance increase of about 55 % by activating the material. This material with the high level of capacitance is suitable as electrode for supercapacitors. From this study it was evident that waste coconut shell material has high composition of carbon and high potential to produce activated carbon. There was significant increase in the percentage of carbon produced after carbonization and activation process for development coconut shell activated carbon (CSAC). Activated carbon is raw graphite with large surface area and high porosity originating from loss of volatiles at high temperature during activation and also due to the effect of activating agents (Li et al., 2008; Wang et al., 2009). is also well applied for production of electrode for supercapacitor. For ions to migrate and occupy the pores of carbon continually to form layers at the interface of electrode-electrolyte in electrochemical storage device, the porous structure of the activated carbon is of great importance (Pandolfo and Hollenkamp, 2005). Supercapacitors have been proven to be a good reservoir of energy, with longer life and powerful discharge capability (Yuan et al., 2005). In electronic industry, activated carbon are used for supercapacitor electrode. Supercapacitor can provide high power ability (60–120s), excellent reversibility (90–95% or higher) and long-life cycle (> 105) (Zhang et al. 2009). For supercapacitor applications, the main criterion for a double electric layer to have high capacity and charge exchange is the quality of the porous texture of the activated carbon. The pore structure of the activated carbon used is vital for optimal performance of carbon materials as an electrode for supercapacitor (Babel and Jurewicz, 2004). In the study of Mohd et al., (2013), the cyclic voltammogram curves of CSAC at different irradiation times indicated that the sample of CSAC 20 min had the largest rectangular shape behavior while the sample of CSAC 10 min, the smallest which shows that the specific capacitance of the activated carbon increased (up to certain irradiation time) with increasing irradiation time because of the increasing surface area and pore size. This phenomenon occurs with the significant that ions can migrate and occupy all pores of carbon repetitively to form layers at the interface of electrode-electrolyte (Pandolfo and Hollenkamp, 2005). Therefore, the higher the specific capacitance, the larger the amount of electric charge stored in carbon, resulting in high energy storage density. One of the methods used to measure the electrodes chemical properties for supercapacitors includes cyclic voltametry. This methods measures the current (charge and discharge) density during charging and discharging of ions into the pores formed in the electrodes at different potential differences (Taer et al.,2018; Taer et al., 2015; Inagaki et al., 2010). The area of the current curve is used to determine the specific capacitance produced by the supercacitor cells (Taer et al. 2015). Study carried out by Taer et al., (2018) has shown coconut husk with very excellent specific capacitance (184Fg-1.) for a good supercapacitors. Activation was at a temperature of 750 - 900 °C. They determined the capacitive characteristics using cyclic voltametry. Other analysis carried out where thermogravimetry analysis, surface area, crystallinity , surface morphology etc. In their study, they used a combination of physical and chemical activation methods to produce activated carbon from coconut husk. Activation agents were carbon dioxide and potassium hydroxide.

2.2.2 Activated Carbon fro coconut residue as electromagnetic energy absorbent

Current research focus now is to identify a new electromagnetic interference (EMI) absorbing material from renewable material such as agro biomass and some crops and forestry products (Chandra et al., 2009, Chengwen et al., 2014). Coconut shell power (CSP) and coconut shell activated carbon (CSAC) has been adopted and utilized by several researchers (Daud et al., 2004; Sivakumar et al., 2010; Ami et al., 2012 and Tay et al., 2009) as a carbonaceous material. Coconut fibers and shells are agro biomass and they are carbonecious materials. Several researchers (Yusof, 2004; Yusof et al., 2005; Liyana et al., 2013 and Menendez et al., 2010) reported that unwanted electromagnetic signals are easily absorbed by carbon materials at an elevated temperature which is the main element in organic carbonaceous materials. This has created an opportunity to utilize agro biomass in electromagnetic industries. Activated carbon posses large surface area to absorb high thermal losses. Siti et al., (2016) investigated the capability of coconut shell activated carbon and the powder as an electromagnetic interference absorber with positive results. High frequency was observed with variation in dielectric factors from 3.341-7.240 for the two by products of the coconut shell. They concluded that because of mesopores porosity, high carbon element and thermal conductivity of the activated carbon, they gave a better result compared to the powder. Also they noted that activated carbon possess better dielectric properties and surface mophorlogy. It can also be concluded that the coconut shell activated carbons offers greater potential as absorbing material rather than CSP. The rate of electromagnetic absorption was indicated by the speed of propagated signal and the wavelength of the transmitted waves. For the activated carbon the wavelength decreased rapidly compared to the powder due to slow wave propagating speed. This is as a result of the large refractive index of the activated carbon (Siti et al., 2016). This stems from the lower carbon content of the coconut shell powder Cazetta et al., (2011). It is evident that the higher carbon content of CSAC compared to CSP was as a result of the processes involved in the production of activated carbon as this process utilizes the pyrolysis of coconut shells into char, followed by steam activation in a fluidized bed reactor (FBR).

3.0 Future Direction

From the findings of the review of the various researches conducted on the use of coconut shell activated carbon for alternative energy, coconut shell activated carbon (CSAC) possess better carbon composition. The resulting activated carbon of up to 97% pure has been reported by Siti, et al., (2015). Siti, et al., (2015) observed the presence of mesopores in n the porosity range of 2um and 1um respectively. Good surface morphology and thermal conductivity shows that coconut fibers or shell activated carbon possess good bioenergy potentials. Future perspectives should be directed towards the fundamental studies and device configuration optimization to achieve a high level of sustainability. This requires integrated collaboration of ideas between engineers, materials scientists, environmental scientists, chemists, and other relevant professionals. We hope that this review has provided inspirations towards developing novel renewable carbon materials for next generation energy storage devices and sustainable alternative bioenergy.

4.0 Conclusion

This review was carried out to evaluate the characteristics of coconut shell activated carbon with respect to its application as source of bioenergy. The proximate and ultimate analysis assessed by various researchers in their studies were particle size, moisture content, ash content, volatile matter content, fixed carbon, bulk density. The thermal properties of the coconut shell activated carbon sample analyzed included thermo gravimetric analysis (TGA) , density, chrystallinity, surface morphology, surface area, specific capacitance, porosity, and thermal conductivity. Also, the characterization of CSAC samples by researchers were done using scan electron microscope (SEM), BET surface area, x-ray diffraction (XRD) analysis while the electrical properties of CSAC sample studied were by dielectric properties measurement. From the above review, the potential of coconut shell activated carbon as bioenergy was found to be highly visible. The thermal properties of coconut shell activated carbon are associated to the degree of pore and particle size. Coconut shell activated carbon at temperature of 500°C can produce long lasting heat due to the high amount of carbons contained and the number of pores that were formed. Coconut shell activated carbon can be a source of bioenergy from the results of many researchers conducted yielding high absorption and good thermal properties. Selection of coconut shell as main precursor for activated carbon production is due to its good thermal characteristics as can be viewed from the heat of combustion, glass temperature (Tg) and melting temperature (Tm). The charcoal powder does not melt quickly due to high glass transition temperature. Therefore, it has combustion heating value. From this review, the ultimate analysis of coconut shell activated carbon was found to possess high carbon content of 64.28%.-80.13%. There was notice of mass shrinkage of manufactured coconut shell activated carbon in the pellets form with variations in carbonization temperature. Following this review, it was concluded that reduced volatile matter and substance impurities in the sample led to shrinkage of the mass at each temperature increase thereby leaving empty spaces (pores) in the samples. Calorific value increase was attributed to evenly distributed pores with greater surface area. Coconut shell activated carbon samples were also found to be thermally stable by thermo gravimetric analysis. Due to its carbon as dominant element, mesopores, porosity and thermal properties, high temperature carbonization leads to loss of volatiles and impurities resulting in high carbon content. conductivity, coconut shell activated carbon show desirable potential to be used as electromagnetic interference (EMI) absorbing material and electrodes for supercapacitors. Using biomass such as coconut shell shows clear direction towards making renewable carbon materials for future energy storage devices.

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DEVELOPMENT OF A BUILDING ENERGY MODEL FOR SELECTED GREENHOUSE DESIGNS CLADDED WITH POLYOLEFIN UNDER TROPICAL CONDITIONS

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Abstract

Greenhouse technology, although an energy-consuming sector, can represent an indispensable solution to the shortage of food production due to the inadequacy of commonly used methods of crop production. However, there is a need to provide optimal growing conditions for crops cultivated within the structure to optimize the output yield of the technology. A possible option is the use of building energy simulation to predict the output conditions of the structure. This study was designed to present a report on the simulation of three greenhouse designs: gable, split-gable, and tunnel, cladded with polyolefin to investigate the microclimatic conditions under tropical conditions. Greenhouse length, width, height, roof height, and floor area were 10 m, 5 m, 4 m, 1 m, and 50 m^2, respectively. Each of the three greenhouses was evaluated with the ventilation systems enabled and disabled and temperature buildup within the greenhouses, Relative Humidity (RH), and Vapour Pressure Deficit (VPD) obtained were subjected to analysis of variance tests and Tukey's Honest Significant Difference (HSD) test at $\alpha_{0.01}$ and $\alpha_{0.05}$. Climatic data and greenhouse temperatures differed significantly, and the test also proved that the RH and VPD values differed from greenhouse to greenhouse. The result of the simulation showed a similarity in temperature within the greenhouses when the ventilation systems were enabled and relatively high temperatures were recorded in the gable and tunnel greenhouses when the ventilation systems were disabled. The findings in this paper will aid greenhouse growers, engineers, and researchers in predicting greenhouse temperature and the size of renewable energy systems based on seasonal energy usage. In conclusion, this report provides information that TRNSYS have great potential for agricultural buildings energy simulation along with renewable energy resources and energy-saving techniques.
Keywords: Microenvironment; Tukey's HSD; BES; TRNSYS; greenhouse

1. Introduction

Greenhouse cultivation is widely applied around the world, and today, it is estimated that about 405,000 ha are cultivated under different types of permanent structures, in addition to about 1,000,000 ha of "solar greenhouses" in China, on which not many statistics are available. Cultivation undercover has several advantages, among which the possibility to control the climate conditions and increase water use efficiency (WUE) are included (Katsoulas and Stanghellini, 2019). A greenhouse is an enclosed environment or structure where crops are grown, protecting the crops grown within from pests' infestation, diseases, and even adverse climatic conditions (Reddy and Parvatha, 2016). Akpenpuun et al. (2021a) defined a greenhouse as a structure covered with glass or plastic, whose microclimate is controlled for crop production. A greenhouse should maintain temperature, relative humidity, vapour pressure deficit (VPD), and light levels optimal for crop production (Gruda, 2005; Jayasekara et al., 2018). The greenhouse environment consists of a series of factors directly influencing the internal microclimate, these factors include light, ambient temperature, soil temperature, humidity, soil moisture, and CO_2. These climatic factors play an important role in the growth rate of crops cultivated within and the output quality of the system (Asolkar and Bhadade, 2015). Adequate control strategies are required to keep the main variables within the required limits, these variables must be considered as they will directly influence the output efficiency of the system (Rodríguez et al., 2015). Greenhouses enable practices that guarantee food safety, better food quality, extend the growing season, and allow year-round production of crops (Gruda, 2005; Taki et al., 2018).

According to Frantz et al. (2004), fast growth, rapid yield, and productivity can be achieved in a controlled environment by controlling root and aerial environments. Achieving an appropriate environment in greenhouses, especially in tropical regions, is one of the major challenges faced by greenhouse designers and producers, due to a large amount of solar radiation transmitted into the greenhouse and then converted into sensible and latent heat (Al-Helal and Abdel-Ghany, 2010). Multiple cooling strategies can be used in greenhouses to provide an appropriate microenvironment such as (i) shading methods, such as applying whitewash or using plastic nets or thermal screens, (ii) evaporative cooling systems using fans and wet pads, fogging (using high-pressure nozzles) and roof evaporative cooling (using sprinkling water over greenhouse roof), and (iii) ventilation systems; forced ventilation, by using exhaust fans or natural by using sidewalls and roof windows on greenhouse frames (Ganguly and Ghosh, 2011; Ahmed et al., 2016; Shamshiri et al., 2018a)

Natural ventilation is one of the cheapest ways to regulate the internal greenhouse temperature. However, it is paramount to protect crops grown within the structure from pest attacks by utilizing insect-proof screens in cladding the structure thereby altering air-exchange rates in such greenhouses. Bailey et al. (2003); Kittas et al. (2005) reported a reduction in ventilation efficiency by about 50% when insect-proof screens were used. Flores-Velazquez et al. (2014) also reported that greenhouse climate control by natural ventilation is highly dependent on outside environmental conditions, and went further to propose mechanical ventilation as a better alternative in screened greenhouses.

Greenhouses can be a power-consuming sector, especially commercial greenhouses. Hence, energy-saving technologies are increasingly used in the greenhouse industry to reduce fossil fuel consumption, which will invariably reduce the cost of production (Hernández et al., 2017). Rabiu et al. (2022) observed that when using energy-saving screens for the greenhouse energy simulation (TRNSYS), the screen's permeability must be considered. Greenhouse thermal screens allow the control of light, temperature, and humidity more precisely, resulting in a better climatic microenvironment inside the structure (Akpenpuun et al., 2021a). By utilizing the right screen, thereby isolating the greenhouse during cold periods, heat loss can be reduced, invariably resulting in fuel conservation and a reduction in operational costs (Frangi et al., 2009; Rasheed et al., 2018). Thermal screens save energy, yet they affect the greenhouse micro-environment, hence, influencing behaviours of crops grown within (Katsoulas and Kittas, 2008; Hernández et al., 2017; Akpenpuun et al., 2021c).

TRNSYS (Transient System Simulation program) is a multipurpose, component-based and extensible energy simulation tool that can be used for both simple and complex systems, as well as for complete energy analysis of single/multi-zone buildings (Rasheed et al., 2015). TRNSYS consists of a series of programs and add-ons to enable the simulations of complex designed projects. The main features of the program are; the TRNSYS simulation studio, simulation engine (TRNDLL), executer (TRNExe), building input interference (TRNBuild), and

Editor (TRNSEdit), with add-ons Google sketch up for 3D modelling. Beckman et al. (1994) called TRNSYS the most complete solar energy system modelling and simulation software available today (Rasheed et al., 2015). The benefit of this software to the agricultural sector cannot be over-emphasized as Carlini and Castellucci (2010) stated that the software demonstrates extreme flexibility and can be used to improve on various case studies, hence continuing and improving on previous works in structure and energy analysis and allow simulation of the best situation by adding different components (Rasheed et al., 2015).

BES software is gradually becoming a commonly used tool that can be used to estimate the total energy use of industrial, commercial, and agricultural buildings/structures for real-time building control and operation (Wei et al., 2020). The developments of several simulation models have been reported by different authors: Takakura et al. (1971); Kindelan (1980); Zhang et al. (1997); Pieters and Deltour (1999); Wang and Boulard (2000). Fitz-Rodríguez et al. (2010) developed a greenhouse environment model based on energy and mass balance principles. Vanthoor et al. (2011) developed an integrated greenhouse climatic model to design greenhouses for a broad range of climatic and economic conditions. Vanthoor et al. (2012) demonstrated the feasibility of a model-based design approach that produced suitable greenhouse designs for given climatic and economic conditions. Goto et al. (2015) developed an integrated model with a high level of extensibility for greenhouse environments using TRNSYS.

The objective of this research was to model three greenhouses, gable, split-gable, and tunnel under two conditions: ventilation systems turned on and ventilation systems turned off), thereby, evaluating the temperature buildup within the greenhouses, the relative humidity, and the vapour pressure deficit.

Materials and Methods

Greenhouse Models

The 3-D geometries of the greenhouses were drawn in SketchUp software with the Trnsys3d extension. The dimensions of the greenhouses were 10 × 5 × 3 m and a roof height of 1 m with a total floor area of 50 m². The sides and roofs of the greenhouses were covered with 150 μm polyolefin sheets. Next, windows were created within the walls to represent almost 90 - 99 % of the greenhouse surface using SketchUp.

Greenhouse specifications

Specifications, conditions, and properties of the designed greenhouse to be simulated are summarized in Table 1.

Table 1. Specifications of the Greenhouses

Parameters		Conditions for the BES model
Greenhouse type		Single-span
Roof types		Split-gable
		Tunnel
		Gable
Roof glazing		Polyolefin
Side glazing		Polyolefin
Roof height (m)		1
Length (m)		10
Width (m)		5
Height (m)		4
Vented Area (m²)	Split-Gable	35

	Tunnel	30
	Gable	30
Volume (m^3)	Split-Gable	168.75
	Tunnel	248.17
	Gable	175.00
Floor Area (m^2)		50
Cover Area (m^2)	Split-Gable	149.50
	Tunnel	186.24
	Gable	147.33
Ventilation		Natural ventilation, four fans placed on opposite sides

Polyolefin Properties

The properties of the polyolefin sheets used as inputs in the simulation process were obtained from Rasheed et al. (2020) and Akpenpuun et al., (2021b)

BES modelling

Pre-processing

After the 3-D models of the greenhouses have been designed, the pre-processing of the model was conducted using the following programs and add-ons: Google SketchUp™ and Trnsys3d. Google SketchUp™ is a 3-D modelling software and was used in combination with Trnsys3d, which is an add-on of TRNSYS software for Google SketchUp™, to prepare the 3-D modelling of the single-span greenhouse.

Modelling

The 3-D model input as well as the selection of outputs and complete description of the 3-D model were then imported into TRNBuild and the basic project data were created. TRNBuild allows basic input data of the project hence, the 3-D model files prepared by Transys3d were imported here as .idf files (readable by TRNSYS).

Next, outside weather data; temperature, relative humidity, and solar radiation, were all inputted into the TRNSYS 18 simulation studio using the weather data component, Type 9, and were used as inputs for the building simulation model. The model simulated the greenhouse thermal performance during free-floating to investigate the effectiveness of the system to maintain the greenhouse temperature within the required range.

The introduction of ambient air through the greenhouse covering materials affects greenhouse loads. Hence, to simulate the natural ventilation effect in the greenhouse, a model accounting for it considering the greenhouse material properties, structure, location, orientation, and wind speed will be utilized. TRNFLOW (an add-on to TRNSYS) was used to design the airflow network of natural ventilation of the greenhouse; It uses the airspeed, air direction, and ambient pressure as inputs to calculate airflow inside the greenhouse. TRNFLOW coupled the internal and surrounding greenhouse environments with a consideration of wind direction, wind speed, wind pressure, and internal and external temperatures. The airflow network in the model was defined by linking the external node (ambient environment) to the thermal node (internal greenhouse) through the open windows using the TRNFLOW interface within TRNBuild. In addition, the weather data were connected with Type 56 in the simulation studio to make them available for the TRNFLOW interface.

Simulation

After the physical and light properties of the cladding materials have been inputted, the three BES models of the greenhouses were developed as BES programmes using an add-on of TRNSYS 18; Simulation Studio. The TRNSYS simulation studio was used to link all the components by applying external weather conditions to the hot box using TYPE 56. The Transient System Simulation (TRNSYS) model generated after the importation into Simulation Studio is shown in Figure 1.

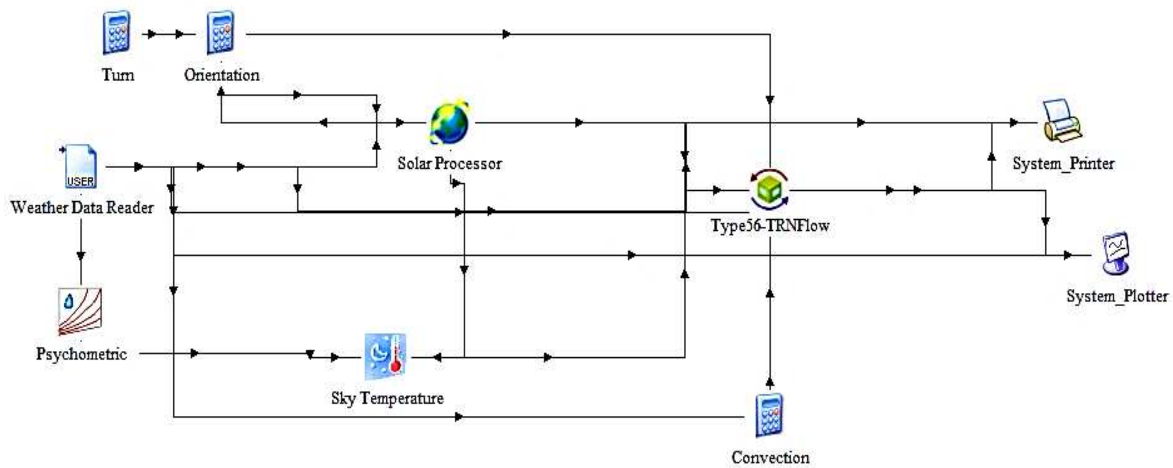

Figure 1. The Greenhouse model in the simulation studio

Table 2 provides a full overview of the various components generated after the importation into the Simulation Studio.

STable 2. Components of the greenhouse model in TRNSYS Simulation Studio

Component	Type	Description
Weather data reader	9e	This component served the purpose of reading data at regular time intervals from a data file, converting it to the desired unit system
Solar radiation processor	16c	Estimated total, beam, reflected and diffused radiation on all greenhouse surfaces by utilizing total solar radiation on horizontal
Sky temperature calculator	69b	Input: dew temperature, beam, and diffused radiation on horizontal to calculate sky temperature for long-wave radiation exchange, the calculated sky temp
Psychrometric chart	33e	This component calculated dew point temperature by utilizing inputs including, dry bulk temperature and humidity ratio.
Greenhouse building model	56a	This type used TRNBuild to process a physical greenhouse 3D model.
	56-TRNFlow	Calculated natural ventilation airflow within the model
Printer	25d	This type was used to print results on the external user-provided file
Plotter	65c	This type was used to plot the results in an online plotter

Controller	165	This type controlled signals for deployed and retracted screens and for closing and opening of vents for natural ventilation.

Next, the calculated values of ventilation rate, capacitance, and building loss coefficients for each greenhouse design were defined in each of the building models (type 56a) in the TRNSYS simulation studio and each programme was run in the simulation studio to generate the basic database.

Simulations were performed to investigate the effect of greenhouse design parameters on the internal temperature buildup taking into consideration the following orientations: 0^o, 45^o, and 90^o, and ventilation options: ventilation systems turned on and ventilation system turned off. The effect of orientation and ventilation on the internal temperature buildup and relative humidity within the greenhouses was evaluated.

Vapour Pressure Deficit (VPD)

Vapour pressure deficit was obtained taking into account the internal temperature and relative humidity values obtained in each of the greenhouses under each simulation condition specified. VPD was calculated using equations 1-4 (Carli et al., 2020).

$$T_d = \dot{T} - \left(\frac{100-RH}{5}\right) \quad (1)$$

$$e_s = 6.11 \times 10^{\frac{7.5\times\dot{T}}{237.7+\dot{T}}} \quad (2)$$

$$e = 6.11 \times 10^{\frac{7.5\times T_d}{237.7+T_d}} \quad (3)$$

$$VPD = (e_s - e) \times 0.1 \quad (4)$$

Cooling load estimation

The cooling load is the amount of energy required to cool down the temperature buildup within the greenhouse. The climatic condition of the research location is such that there is a need to provide means of cooling down the greenhouse microclimate when maximum temperatures are exceeded. The maximum temperature will be determined by the types of crops cultivated within the greenhouse. The most effective cooling system for a greenhouse is an evaporative cooling system. Evaporative cooling is the process of having particles of water evaporate, which leads to a drop in temperature through increased humidity.

The cooling load of the greenhouses were evaluated throughout the period of simulation taking into account the mean values of temperature.

The cooling load is given by the following equations:

$$H_t = (H_w + H_v + H_s) \times f_w \quad (5)$$

$$H_s = F \times L_s \times (\Delta T - \theta) \quad (6)$$

$$H_v = p_i \times C_p \times N \times V \times (T_i - T_o) \quad (7)$$

$$H_w = U \times A_c \times (T_i - T_o) \quad (8)$$

Data Analysis

The simulation results were grouped based on the orientation and ventilation type selected during the simulation process as shown in Table 3. Next, comparisons among values obtained for the roof types in each condition were made. Data obtained at the end of this simulation and the ambient data were subjected to descriptive statistics and analysis of variance (ANOVA) using Microsoft Excel 2021 statistical package. The results were further subjected to Tukey Honestly Significant Difference (HSD) test for mean separation.

Table 3. Simulation conditions

Parameter	Condition (Orientation and Ventilation)	Roof Type	Glazing Material
PO_G_SG_T_00	0°, Ventilation: Off		
PO_G_SG_T_01	0°, Ventilation: On		
PO_G_SG_T_450	45°, Ventilation: Off	Split-gable, Gable, and Tunnel	Polyolefin
PO_G_SG_T_451	45°, Ventilation: On		
PO_G_SG_T_900	90°, Ventilation: Off		
PO_G_SG_T_901	90°, Ventilation: On		

Results and Discussion

The results of the simulation demonstrated the response of the greenhouse system over a period of one year. Although many possible scenarios and outputs can be demonstrated depending on the user-selected input choices, this simulation is limited to the greenhouse thermal environment: temperature, relative humidity and vapour pressure deficit.

Temperature

The minimum temperature obtained for gable, split-gable, and tunnel roof types when the greenhouses were positioned at 0° and ventilations disabled turned off were 13.78 °C, 13.77 °C, and 14.16 °C, respectively. The maximum temperature buildup in each of the greenhouses was 54.69 °C, 36.08 °C, and 53.55 °C, respectively. The greenhouse temperature was found to be greater in gable and tunnel greenhouses. While at the same position and the ventilation systems turned on, the minimum values obtained were 14.35 °C, 14.36 °C, and 14.38 °C, respectively, and the maximum values obtained were 40.47 °C, 37.79 °C, and 40.94 °C, respectively. The internal temperature was found to be greater in gable and tunnel greenhouses than in the split-gable greenhouses.

When the greenhouses were positioned at 45° with the ventilation systems off, minimum temperatures recorded for gable, split-gable, and tunnel roof types were 13.78 °C, 13.77 °C, and 14.16 °C, respectively, while the maximum temperatures were 54.34 °C, 36.08 °C, and 53.50 °C respectively. The highest temperature across all the greenhouses was 54.34 °C in the gable greenhouse and the least temperature across the greenhouses was 13.77 °C in the split-gable greenhouse. The simulation was executed again with ventilation systems switched on and the minimum values obtained were 14.35 °C, 14.36 °C, and 14.38 °C, respectively, while the maximum values obtained were 40.51 °C, 37.79 °C, and 40.98 °C, respectively. The lowest temperature value was 14.35 °C in the gable greenhouse while the highest temperature value was 40.98 °C in the tunnel greenhouse.

Finally, the simulation was carried out at a greenhouse position of 90° and ventilation systems off, and minimum temperature values of 13.78 °C, 13.77 °C, and 14.16 °C were recorded for gable, split-gable, and tunnel greenhouses, respectively. Maximum temperature values recorded were 54.87 °C, 36.08 °C, and 53.74 °C, respectively. The least recorded temperature value across the greenhouses was 13.77 °C, in the split-gable greenhouse and the highest temperature value was 54.87 °C in the gable greenhouse. With ventilation systems turned on, minimum temperature values were 14.36 °C, 14.36 °C, and 14.38 °C for gable, split-gable, and tunnel roof greenhouses, respectively, while maximum temperature values were 40.52 °C, 37.79 °C, and 40.99 °C, respectively. In this condition, a minimum value of 14.36 °C was obtained in the gable and the split-gable greenhouses as the least temperature value. A maximum value of 40.99 °C was recorded in the tunnel greenhouse. Figure 2 shows the trend of the temperature inside and outside the greenhouses with vents on at 90° orientation.

The mean temperature values obtained for the greenhouses at 0° orientation and vents closed were 30.04±9.12 °C, 24.43±3.43 °C, and 30.54±8.66 °C for gable, split-gable, and tunnel greenhouses, respectively. Hence the temperature buildup was found to be higher in the gable and tunnel greenhouses, while the least temperature was obtained in the split-gable greenhouse. With the vents opened, the mean temperature values recorded were 26.24±4.49 °C, 25.49±3.78 °C, and 26.42±4.55 °C, respectively. At an orientation of 45° and ventilation systems disabled, the mean temperatures obtained inside the greenhouses were 30.34±9.25 °C, 24.43±3.43 °C, and 30.82±8.77 °C for the gable, split-gable, and tunnel greenhouses, respectively. Mean values of 26.28±4.50 °C, 25.49±3.78 °C, and 26.46±4.56 °C were obtained when the vents of the greenhouses were opened. An orientation of 90° and vents closed gave mean values of 30.55±9.43 °C, 24.43±3.43 °C, and 31.02±8.92 °C for gable, split-gable, and tunnel greenhouses, respectively, and mean values of 26.30±4.51 °C, 25.49±3.78 °C, and 26.49±4.58 °C were obtained when the vents were opened. The simulated results obtained for each condition were further subjected to the analysis of variance and Tukey's Honest Significant Difference (HSD) tests to determine the amount of variability between results. The result of the analysis of variance showed that the p-values obtained from all the comparisons of internal temperature in each roof shape at a significant level of 0.05 (df1 = 3; df2 = 35036) were less than 0.05, hence the results are considered to be statistically significant.

Tukey's HSD test was carried out to compare the pair of treatment (T_{GABLE} vs $T_{SPLIT\text{-}GABLE}$, T_{GABLE} vs T_{TUNNEL}, $T_{SPLIT\text{-}GABLE}$ vs T_{TUNNEL}) and conditions (orientation and ventilation). The Tukey-Kramer HSD $Q_{statistic}$ was obtained based on the number of treatments (k = 3) and degrees of freedom for the error term (v = 25276) at the significance levels of α = 0.01 and 0.05 (p-values) in the Studentized Range Distribution Table. The Tukey-Kramer HSD $Q_{critical}$ obtained were: $Q_{critical}^{\alpha=0.01,k=3,v=25276} = 4.1208$ and $Q_{critical}^{\alpha=0.05,k=3,v=25276} = 3.3147$. The Tukey HSD tests results showed that all comparisons were significant at $p<0.01$ except comparisons between gable vs tunnel at 0°, 45°, and 90° orientations which were only significant at $p<0.05$.

The temperature variation obtained can be attributed to the greenhouse roof type, orientation, and ventilation system. Kittas et al. (2005); Shamshiri et al. (2014); Xu et al. (2015); Shamshiri (2017) reported that extended periods of high air temperature limited the plants' evapotranspiration, causing tomato plants to wilt, fruit abortion, and flaccid leaves subsequently eliminating possibilities of successful production in temperatures higher than 30 °C, they further went on to report 22 °C as the optimum air temperature for tomato cultivation. In general, the optimum temperature range for most greenhouse vegetable growth is 18.3 – 32.2 °C as the temperature has a significant effect on biomass production and partitioning, development, and fruit growth period (Shamshiri et al., 2018b; Palmitessa et al., 2020)

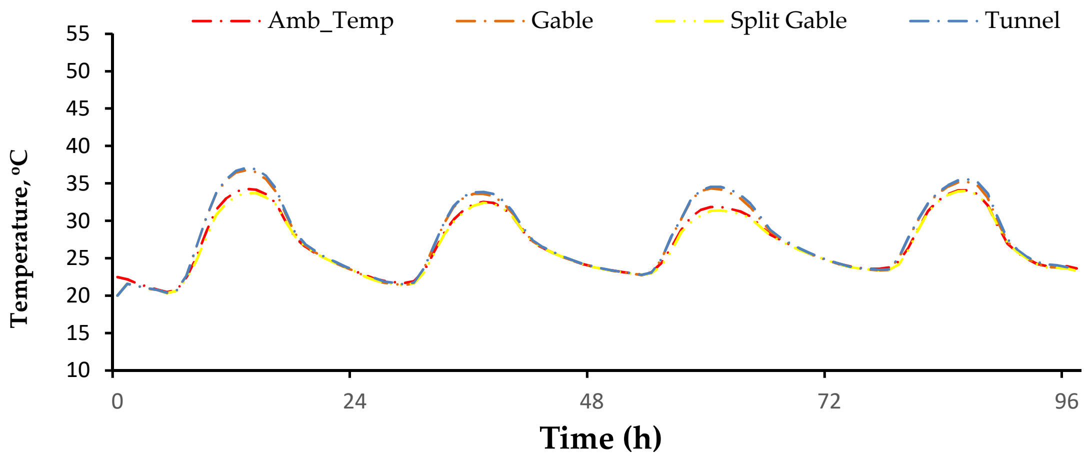

Figure 2. The trend of the temperature inside and outside the greenhouses with ventilation system turned on at 90° orientation

Relative Humidity

Relative humidity values for each condition and orientation were also obtained from the simulation. The values obtained were also subjected to descriptive analysis, analysis of variance, and Tukey HSD test. The minimum RH values obtained for the gable, split-gable, and tunnel greenhouses, respectively, at an orientation of 0° and ventilation systems, turned off were 2.44%, 19.58%, and 7.96% and maximum values of 69.54, 74.27, and 72.41%. Still at the same angle and the vents open, the minimum values observed across the greenhouses were 9.27%, 11.49%, and 9.78%, and maximum values were 99.93%, 100.00%, and 100.00%, respectively.

When the greenhouses were positioned at 45° and ventilation systems off, minimum recorded values for gable, split-gable, and tunnel greenhouses were 2.44%, 19.58%, and 7.98%, respectively. The maximum values were 69.55%, 74.27%, and 72.41%, respectively. The simulation was executed again with ventilation systems switched on and minimum values obtained were 9.28%, 11.49%, and 9.79%, respectively, while maximum values obtained were 100.00% for all.

The simulation process was repeated at a greenhouse orientation of 90° and ventilation systems disabled, and minimum RH of 2.41%, 19.58%, and 7.89%. were recorded for gable, split-gable, and tunnel greenhouses, respectively, while maximum RH values recorded for the same condition were 69.54%, 74.27%, and 72.40%, respectively. With ventilation systems enabled, minimum RH values were 9.28%, 11.49%, and 9.78% for gable, split-gable, and tunnel roof greenhouses, respectively, while maximum values were all 100%.

Mean relative humidity values of 23.06±15.11%, 39.07±7.76%, and 30.16±12.66% were obtained for gable, split-gable, and tunnel greenhouses, respectively at a greenhouse orientation of 0° and vents closed off, while mean values of 71.34±22.40%, 75.72±21.04%, and 72.55±22.08% were obtained when the vents were opened in the greenhouses. At an orientation of 45° and ventilation systems disabled, the mean relative humidity values obtained were 22.61±15.30%, 39.07±7.76%, and 29.79±12.79% for the gable, split-gable, and tunnel greenhouses, respectively. Mean values of 71.14±22.36%, 75.72±21.04%, and 72.37±22.05% were obtained when the vents of the greenhouses were opened.

The mean relative humidity values obtained for gable, split-gable, and tunnel greenhouses at 90^{o} orientation and vents closed, were 22.41±15.40%, 39.07±7.76 %, and 29.58±12.90%, respectively. With the vents opened, the mean relative humidity values recorded were 71.04±22.41%, 75.72±21.04%, and 72.28±22.10%, respectively. The p-value corresponding to the $F_{calculated}$ of one-way ANOVA was found to be lower than 0.01 (df1 = 2; df2 = 26277) suggesting that one or more of the treatments are significantly different. The Tukey HSD test comparison was carried out next to identify which of the pairs of treatments are significantly different from each other. The values of relative humidity obtained in each simulation scenario were then further subjected to the analysis of variance and Tukey's HSD tests to determine the amount of variability between results. Tukey's HSD test was carried out by pairing and comparing the relative humidity values for gable, split-gable, and tunnel greenhouses in each condition (orientation and ventilation). The Tukey-Kramer HSD $Q_{statistic}$ was obtained based on the number of treatments (k = 3) and degrees of freedom for the error term (v = 26277) at the significance levels of α = 0.01 and 0.05 (p-values) in the Studentized Range Distribution Table. The Tukey-Kramer HSD $Q_{critical}$ obtained were: $Q_{critical}^{\alpha=0.01,k=4,v=35036} = 4.1208$ and $Q_{critical}^{\alpha=0.05,k=4,v=35036} = 3.3137$. The Tukey HSD tests results showed that all the comparisons were significant at p<0.01. Tukey HSD test was also carried out to compare the relative humidity values obtained in the greenhouses when the ventilation systems were enabled and disabled in each orientation. The Tukey-Kramer HSD $Q_{statistic}$ was obtained based on the number of treatments (k = 2) and degrees of freedom for the error term (v = 17518) at the significance levels of α = 0.01 and 0.05 (p-values) in the Studentized Range Distribution Table. The Tukey-Kramer HSD $Q_{critical}$ obtained were: $Q_{critical}^{\alpha=0.01,k=2,v=17518} = 3.6432$ and $Q_{critical}^{\alpha=0.05,k=2,v=17518} = 2.7720$. The trends of relative humidity were found to be lower within the greenhouses when the ventilation systems were disabled. Optimum RH values of 65-75%, 80-90%, 50-60%, 60-65%, 65-80%, 50-65%, 70-80%, and 70-80% are for the cultivation of eggplant, cucumber, tomato, pepper, lettuce, strawberry, beans, and peas, respectively (Darrow, 1966; Tazawa, 1999; Heuvelink, 2005; Kang et al., 2013; Somerville et al., 2014; Shamshiri et al., 2018a). Rabbi et al. (2019) reported that low relative humidity results in stunted growth in crops grown inside the structure. Extremely low or high humidity conditions affect both plant vegetative growth, and fruit quality and increase the likelihood of disease (Dorais et al., 2010). Peet et al. (2002) presented 60-80% as the ideal relative humidity for cultivating various plants, tropical or otherwise, and 90-100% as an ideal relative humidity range for germination of seeds and growth of seedlings. Hence, the greenhouses with ventilation systems are more suitable for seed germination and seedling growth as they recorded a peak RH value of 100%. Lieten (2002) recommended the optimal range of 65 - 75% RH for good strawberry growth and yield during the day, while the American Society of Agricultural Engineers (2003) standards recommends relative humidity in the range of 60 – 90% as the most appropriate for greenhouse vegetables. The greenhouses not vented peaked at a relative humidity value of 74.27% while those vented had a maximum value of 100% relative humidity.

Vapour Pressure Deficit

The average hourly temperature and relative humidity values obtained inside each greenhouse for each condition were used to evaluate the Vapour Pressure Deficit on an hourly. At a greenhouse orientation of 0^{o} and the ventilation systems disabled, the mean values of VPD were 2.99 kPa, 1.68 kPa, and 2.85 kPa in the gable, split-gable, and tunnel greenhouses, respectively, while mean values of 1.07 kPa, 0.87 kPa, and 1.05 kPa were obtained when the simulation was repeated with the ventilation systems enabled.

When the greenhouses were positioned at 45°, with no vents, the mean values were 3.06 kPa, 1.68 kPa, and 2.90 kPa for gable, split-gable, and tunnel greenhouses, respectively. The values dropped to 1.08 kPa, 0.87 kPa, and 1.06 kPa in the greenhouses when the vents were opened.
When the ventilation systems were disabled, the mean values were 3.11 kPa, 1.68 kPa, and 2.95 kPa, respectively, for gable, split-gable, and tunnel greenhouses. With the ventilation systems enabled, the mean values of 1.09 kPa, 0.87 kPa, and 1.06 kPa were obtained for the greenhouses.

The simulation data were subjected to ANOVA with the degree of freedom between groups was 2 and 26277 within groupss The result of the analysis of variance showed that the p-values obtained from the vapour pressure deficit calculation in each orientation and ventilation option were less than 0.005, hence the results are considered to be highly statistically significant. These values of p showed that there were statistically significant differences between the obtained vapour pressure values in each greenhouse design for each orientation and ventilation control.

Furthermore, Tukey's HSD test was carried out to compare the values of VPD for gable, tunnel, and split-gable greenhouses in each condition (orientation and ventilation). The Tukey-Kramer HSD $Q_{statistic}$ was obtained based on the number of treatments (k = 3) and degrees of freedom for the error term (v = 26277) at the significance levels of α = 0.01 and 0.05 (p-values) in the Studentized Range Distribution Table. The Tukey-Kramer HSD $Q_{critical}$ obtained were: $Q_{critical}$ (α = 0.01) = 4.1208 and $Q_{critical}$ (α = 0.05) = 3.3147. i.e. $Q_{critical}^{\alpha=0.01,k=4,v=35036} = 4.1208$ and $Q_{critical}^{\alpha=0.05,k=4,v=35036} = 3.3147$. The Tukey HSD tests results showed that the comparisons were significant at $p<0.01$ except for comparisons between gable vs tunnel at 0°, 45°, and 90° orientations which were found to be insignificant at both values.

The mean VPD inside the greenhouses were within the range of 1.68 - 3.11 kPa which is considered to be too high for most crops to flourish. Mukazhanov et al. (2017) reported that low relative humidity and the high temperature usually increase VPD, which in turn heightens stomatal resistance and increases transpiration. Santosh et al. (2017) also reported that low VPD is associated with reduced plant transpiration, causing dehydration, wilting, and necrosis (Rabbi et al., 2019). However, Iraqi et al. (1995); Katsoulas and Kittas (2008) reported 0.8 to 1.11 kPa as the ideal VPD range for most plants, and the mean VPD values in the greenhouses when the ventilation systems were enabled were found to make conducive environments for cultivation of most crops as they were within this range. In conclusion, the greenhouses were found to contain higher volumes of dry air, hence a higher VPD value when the vents were closed, and lesser VPD values with the venting systems enabled.

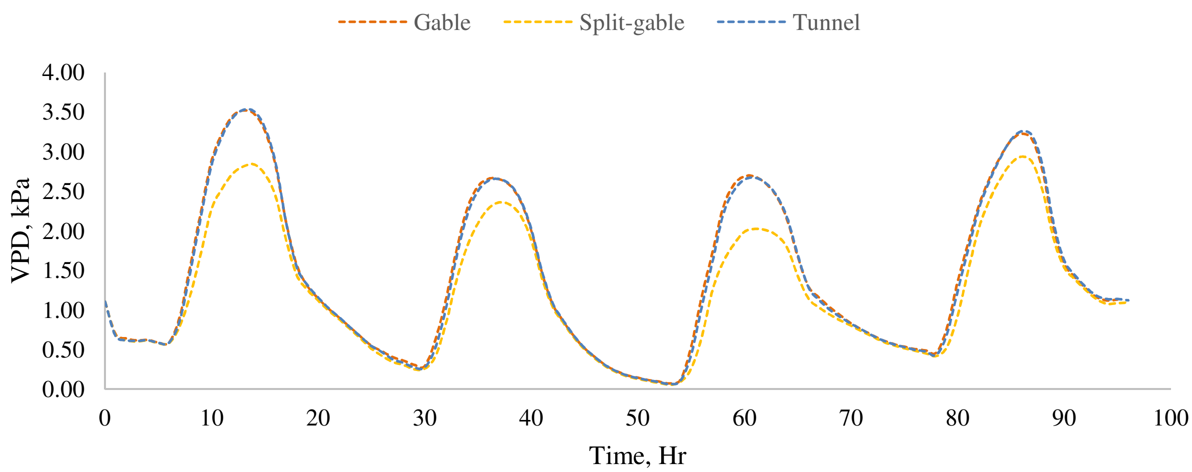

Figure 3. The trend of VPD inside the greenhouses with vents opened at 90° orientation

3.3 Cooling Load and Energy Demand

Figure 4 shows the estimated cooling costs for the greenhouses in kcal/h/m². From the bar chart, the tunnel roof greenhouse design without a ventilation system required the most cooling cost at 399.57 kcal/h/m² while the lowest cooling cost was found in the vented split-gable greenhouse to be 5.47 kcal/h/m². This is because the tunnel greenhouses were found to give the highest temperature buildup within the greenhouse. Thus, at a rate of ₦38.53 per kWh, the tunnel greenhouse at 90° without vents required the highest energy demand at ₦7,869,236/yr, while the split-gable greenhouse at 0° with the venting system would require ₦107,757.2/yr, the lowest energy demand.

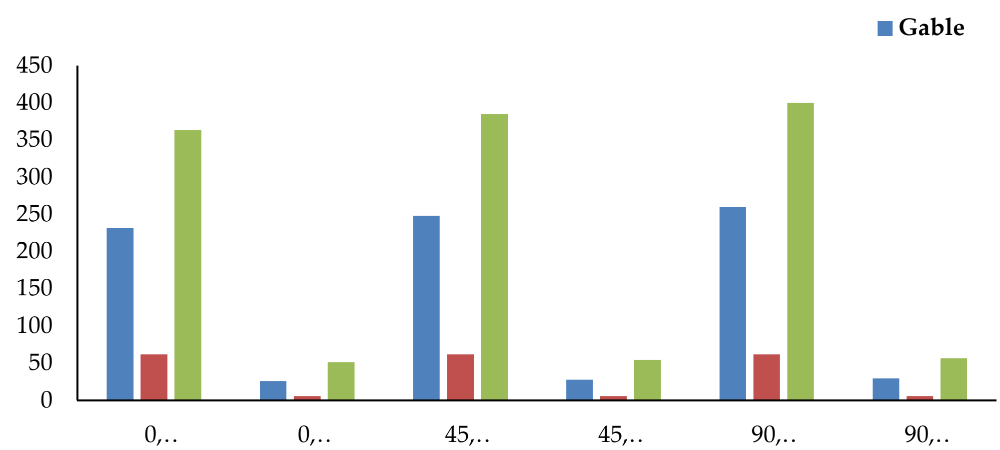

Figure 4. Greenhouse Cooling Load

4. Conclusions

This study shows the simulation of the thermal environment of three greenhouse designs cladded with polyolefin and two conditions each per design (ventilation system turned on and ventilation system turned off) over a period of 1 year using the TRNSYS program. The following conclusions can be deduced from the results:

i. the variation observed between the ambient temperature and the temperature buildup inside the greenhouses shows the independence of the greenhouse climate from the ambient;
ii. the tunnel greenhouse, positioned at 90° and ventilation systems switched off, offered the highest temperature buildup within the greenhouses;
iii. the split-gable greenhouse, at 0° orientation and vents disabled, offered the lowest temperature buildup within the greenhouses;
iv. the temperatures within the greenhouses were similar with the ventilation systems enabled;
v. the tunnel greenhouses required more cooling than the other two greenhouses;
vi. humidity readings were relatively higher in the greenhouses when the ventilation systems were enabled.

For subsequent research and improvement on this project, the following are advised:

a) validating results with measured variables in an actual greenhouse located in or close to Ilorin, Kwara state;
b) incorporating thermal curtains or double-glazing screens in the BES models;

Nomenclature

Symbols

A_c	Greenhouse cover area, m^2
C_p	Specific heat of indoor air, J/kg.°C
e	Actual Vapour Pressure, mbar
e_s	Saturated Vapour Pressure, mbar
F	Heat loss coefficient per unit length of outer periphery, W/m.°C
f_w	Correction factor according to wind speed
H_s	Underground heat transfer load, W
H_t	Greenhouse cooling load, W
H_v	Interstitial ventilation heat transfer load, W
H_w	Through-flow heat load, W
L_s	Greenhouse length, m
N	Interstitial ventilation rate, times/s
θ	Load reduction reference temperature difference, °C
p_i	Indoor air density, kg/m^3
RH	Relative Humidity, %
ΔT	Indoor and outdoor temperature difference, °C
$\dot{T}$	Greenhouse Temperature, °C
T_d	Dew Point Temperature, °C
T_i	Indoor setting temperature, °C
T_o	Design outside temperature, °C
U	Greenhouse heat transmission rate, W/m^2.°C
V	Greenhouse volume, m^3
VPD	Vapour Pressure Deficit, kPa

Abbreviations

BES	Building Energy Simulations
G	Gable greenhouse
PO	Polyolefin
$PO\_G\_SG\_T$	Polyolefin, gable, split-gable, and tunnel greenhouses
RH	Relative Humidity
SG	Split-gable greenhouse
T	Tunnel greenhouse
$T_{AMBIENT}$	Ambient temperature
T_{GABLE}	Temperature inside the gable greenhouse
T_{SPLIT_GABLE}	Temperature inside the split-gable greenhouse
T_{TUNNEL}	Temperature inside the tunnel greenhouse
$TRNSYS$	Transient System Simulation
VPD	Vapour Pressure Deficit
WUE	Water Use Efficiency

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DESIGN AND FABRICATION OF LOW COST PEANUT COATING MACHINE

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Abstract

Coated peanut snacks exist in many super markets in Nigeria. However, machines used in their production are limited in existence. Where the machine exist, the costs of acquisition are exorbitant and beyond the reach of household and small scale peanut producers which still coat peanut with flour and egg manually. Therefore a low cost machine for coating peanut was designed and fabricated using locally available materials to improve small – large production output. The machine components which consists of a rotating drum, frame, shaft, speed regulator, the electric motor and the driving and driven pulleys was tested for coating 2.0kg of peanut with 2.7kg of wheat flour wheat flour and 0.51kg of egg suspension. The comparison between manual method and mechanical method shows that the production increase. The machine coating efficiency of 98.7% and effective coating capacity of 118.4kg/hr were obtained. The estimated cost of production of the machine was ₦110,410.00 ($184).

Keywords: peanuts, coating, performance, cost.

1.0 Introduction

Peanut is a legume crop that belongs to the family of Fabaceae, genus Arachis, and botanically named as *Arachishypogaea*. They are believed to have originated in Central American region from where they spread to other parts of the world (Settaluri*et al.*, 2012).

Peanuts are consumed all over the world in a wide variety of forms (Guimon and Guimon, 2012). Almost every part of groundnut is of commercial value. Apart from oil, they are widely used for production of peanut butter, confectionaries, roasted peanuts, and snack products, extenders in meat product formulation, soups and desserts and it has notably been the source of elimination of malnutrition amongst the population in many African countries in the recent years (Guimon and Guimon 2012).

Snacks are prepared mainly by frying and coating of the peanut kernel (Varela and Fiszman, 2011). It can also be obtained by roasting or cooking of ground nut. Snack peanuts can be consumed wherever food is allowed. According to Senhui *et al*., (2005) snack peanuts are most frequently consumed at home. Snacks are often eaten at working site. They are also consumed in many other places or events, including bars, cars, sporting events, parties, and restaurants (Senhui*et al*., 2005). Snack peanuts are favorites for mid-afternoon snacks and after-dinner snacks (Senhui *et al*., 2005).

Coatings are especially important in the snack food industry where the base often have an unattractive appearance and tastes bland, mealy, sticky, dusty or dry. The secret to the popularity of these snacks is coatings, which give an appealing colour and flavour (Barringer 2002). Coating of peanut can be done manually or mechanically.

Many machines have been design for coating seeds or /and nuts. Bao *et al* (2003) developed a seed coating machine by using a controlled volume pump providing seed coating as well as an outer-grooved sheave supplying constantly seed to the machine to achieve the ratio of weights of seeds and seed coating precisely and steadily.The cost of this machine is very high being completely automated and the machine is only suitable for coating seed with liquid additives therefore its construction will not be suitable for coating peanut with powdered flour and egg suspension and also not affordable for small – medium peanut burger producers in Nigeria.

Oyekale (2014) developed a peanut coating machine. The machine was tested by varying its operating speed (10, 20, 30rpm), time (5, 10, 15, 20, 25mins), with two different mass of flour and eggs.The optimum coating efficiency was found to be 89.84%.In his machine, the motor speed is reduced to 30 rpm by a gear system but its speed is varied by changing ratio of pulleys diameters. This set up is too cost compare to electrically speed controller and also the operator can only vary the speed by changing pulleys after operation which is seemed tedious.Therefore the machine to be designed will be equipped with electrically speed controller varying the speed of motor attached to a system of pulleys. This will reduce the cost of production and eradicate the fatigue when varying speed by changing pulleys.

The objective of this study is to design, fabricate and test the performance of alow cost machine suitable for coating peanuts with powdered flour and egg suspension taking the cost of production into consideration.

2.0. Materials and Method

2.1 Machine Design Consideration

The ease of fabrication or availability of component parts, the operators' safety, the simplicity of operation, Cost of materials used in fabrication,Portability of the machine and ease of maintenance

2.2 Design Analysis

Requiredcapacity of coated peanut per batch= 6kg

2.2.1 Determination of coating drum (hopper) volume (Vd)

$$\text{Volume} = \frac{\text{mass}}{\text{density}} \quad (1)$$

$$Vd = \frac{Vc}{\sin\emptyset} \quad (2)$$

Where: Vc is the volume of coated peanut,∅is the tilt angle from horizontal plane.

The density of the groundnut kernel (peanut) is 752.34kg/m^3 and that of wheat flour is 767kg/m^3. Other ingredients are negligible since their values are comparatively small. The average density of peanut and flour in a mixture is 759.67kg/m^3.

Volume of coated peanut Vc in 6kg is 7898.2 cm^3

The volume of the coated peanut Vc is to be contained in a drum rotating at an angle ∅.

Since the angle of tilt of the machine drum is adjustable between 12^o – 90^o from the horizontal plane. For $\emptyset = 12^o$ (least angle of tilt is chosen), Vd is **37988.24cm^3**

The drum capacity 37988.34 is four times greater than volume of coated peanut 7898.2 cm^{3}therefore at least 6kg of coated peanut will be produced an any tilt angle above 12^o

2.2.2 Determination of Minimum Power Required for Operating the Machine (P)

$$Ws = \frac{2 \times \pi \times N4}{60} \quad (3)$$

$$Ts = Rd \times Fs \quad (4)$$

$$P = Ts \times Ws \quad (5)$$

Where: Ws = angular speed of shaft in rad/sec, N4 = speed of the drum shaft ,Ts= torque of the shaft and Rd = radius of the drum in metre

Fs = maximum force or weight on the shaft,

P= power required to operate the machine

$Ws = \frac{2 \times \pi \times 80}{60} = 8.38\ N$

Ts= 0.23 × (4 × 6 × 10) = 55.2Nm

$P = Ts \times Ws$= 55.2 × 8.38 =462.57 watt **= 0.46kw.**

(0.75kw motor used).

2.2.3 Determination of Shaft Diameter (D)

According to Robert, O.P. (1985), for a shaft having little or no axial loading, the diameter may be obtained using ASME code given as

$$D^3 = \frac{16}{\pi Sa}\sqrt{(Kb \times Mb)^2 + (Kt \times Mt)^2} \quad (6)$$

D = diameter of the shaft, Mb = bending moment, Mt = torsional moment,
Kb= combined shock and fatigue factor applied to bending moment, Kt =combined shock and fatigue factor applied to torsional moment
Sa = allowable stress, For rotating shafts,when load is suddenly applies (minor shock)
For shaft with key way, allowable stress is 40M N/M²

2.2.4 Torsional Moment on the Shaft (Mt)

$Mt = \frac{9550 \times kwh}{rev/min}$, $Mt = \frac{9550 \times 0.46}{80}$ = **54.91Nm.**

Bending moment on the shaft (Mb)

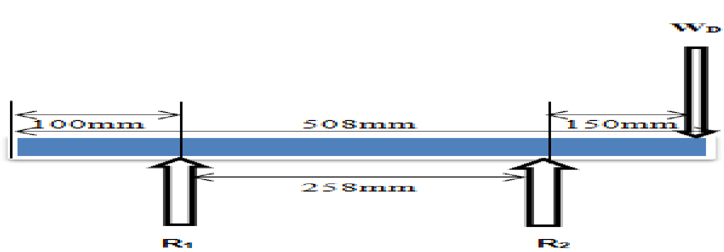


Figure1. Loads distribution on the shaft

From the computation, the maximum bending moment **Mb = 17.66Nm**

$D^3 = \frac{16}{3.142 \times 40 \times 10^{\wedge}6}\sqrt{(1.5 \times 17.66)^2 + (1.5 \times 54.91\,)^2} = 0.0000110116$

$D = \sqrt[3]{0.00000400369} = 0.0222m = 22.3.0mm$

(**25mm**is used to accommodate factor of safety).

2.3 Coater Description and Operation

The peanut coater has a rotating drum (hopper) powered by an AC motor. The speed of the motor is reduced for the drum by a simple set of pulleys system .The switch at the top side of the handle is used to power and at the same side to control the speed of the drum figure 4.

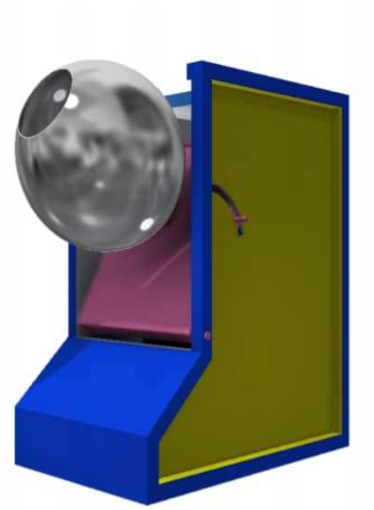


Figure 2: The conceptual design of the peanut coater

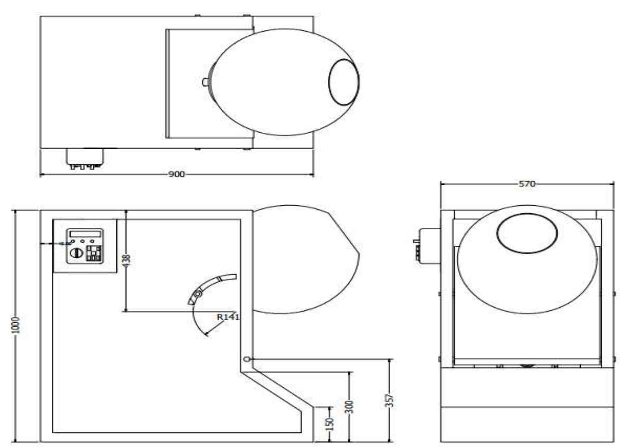
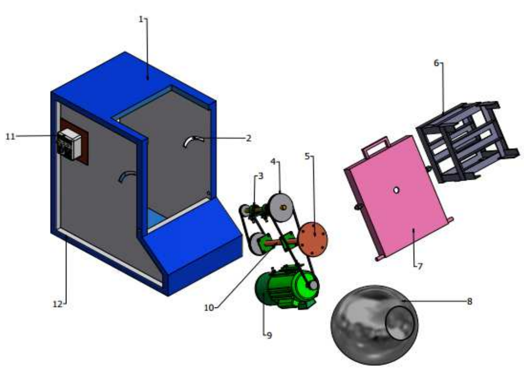


Figure 3. The orthographic view of the machine



PART LIST		
S/N	DESCRIPTION	QTY
1	MACHINE COVER	1
2	TILT ANGLE ADJUSTMENT GROOVE	2
3	BEARING	2
4	V-BELT AND PULLEY	1
5	DRUM SEAT	1
6	ELECTRIC MOTOR FRAME	1
7	MOTOR FRAME-FACE COVER	1
8	COATING DRUM	1
9	ELECTRIC MOTOR	1
10	SHAFT	1
11	SWITCH/SPEED REGULATOR	1
12	MACHINE FRAME	1

Figure 4: Exploded view of the machine

2.4 Fabrications of components

The machine was fabricated in Agricultural and Bio- environmental workshop at FUT Minna. The machine parts and materials selected are detailed in Table 1

Table 1: Materials Selected and Their Dimensions or Specifications

S/N	PARTS	MATERIALS SELECTED	DIMENSION
1	Shaft	Mild steel	25mm
2	Motor	AC	0.75hp
3	Pulleys	Mild steel	D1 = 100mm,D2 = 270mm, D3 = 100mm, D4 = 188mm
4	Coating drum	Mild steel	Top and bottom= 20mm Mid = 460mm Height =45mm
5	Bearing	Ball bearing	25mm
6	Frame	Angle iron	40mm

Machine Testing

The peanuts, wheat flour, eggs, sugar and vanilla flavourfor testing the machine was purchased at new market Minna, Niger state.

The purchased flour will be sieved into a clean bowl. The salt, sugar and baking powdered will be added and mixed together. Eggs will be broken into another bowl whisked until it becomes watery.

Another bigger bowl was carried and groundnuts were poured into it. Hot water waspoured inside the bowl of groundnut for 15 minutes after selecting the bad groundnuts; stones and dirt out, the peanut were washed and allowed to drain water. They were then sprayed in a tray to dry for testing the machine.Mass of 2.0kg of peanut, 2.7kg of wheat flour and 0.51kg of egg (total 5.21kg) were used as a sample for each runs.Weight of the constituents were poured into the drum and mixed at four levels of coating speeds of 20, 30 35 and 45rpm and four level of coating time of 15, 20, 25 and 35 mins with two replicates in each treatment.

Machine coating efficiency

The coating efficiency wasrecordedat different speeds of 20, 30 35 and 45rpmand varying time (15, 20, 25 and 35mins).The Coating Efficiency is calculated by the equation below as reported by (Atiku *et al*., 2004).

$$C.E = \frac{M1}{MT} \times 100\% \qquad (7)$$

Where: C.E = Coating Efficiency,M1 = Mass of peanutcompletely coated. MT = Total mass of the peanut fed into the coating chamber

3.1.1 Effective Coating Capacity

The effective coating capacity(E.C.C) of the machine will be determined by theMass of peanut completely coated per hour

4.0 Result And Discussions

4.1 Result

The table 2 shows the result of coating efficiency and coating and effective coating capacity of the machine

Table 2: Coating Efficiency C.E and Effective Coating Capacity E.C.C

Speed		20 rpm		30rpm		35 rpm		45 rpm	
		C.E (%)	E.C.C (kg/hr)	C.E (%)	E.C.C (kg/hr)	C.E (%)	E.C.C (kg/hr)	C.E (%)	E.C.C (kg/hr)
Runs	**Time(mins)**								
1	**15**	59.3	71.1	81.0	97.2	96.2	115.4	77.8	93.4
2	**20**	62.1	74.5	85.2	102.2	98.7	118.4	70.3	84.4
3	**25**	63.0	75.6	86.9	104.3	90.8	108.9	68.1	81.7S
4	**35**	70.8	85.0	88.5	106.2	88.3	106.0	57.2	68.6

4.2 Discussion

From the table, it is observed that the C.E of the machine increases with time when the coating drum speed is at 20 rpm and 30 rpmbut decreases when the drum rotates at 45rpm.

This implies that the machine at 20 rpm needs to work for long time to achieve complete coating or mixing. At 30 rpm, the machine C.E at any time which is higher than that of any C.E at 20rpm confirms that more complete and good coating is achieved.

The C.E at 35 rpm increases with time from 15 to 20 minutes and then decreases when the time is above 20 minutes.The sudden decrease in C.E from operating time of 20 to 35 minutes at speed of 35 rpm reveals that more bad coatings (broken coated peanut) were recorded.

The decrease in C.E with coating time when the coating speed is 45 rpm indicates that more coated peanut were damaged with increasing coating time.

Also it was observed that the C.E values at 35 rpm appear to be the highestand best among other speeds, having optimum C.E of 98.7% and E.C.C. of 118.4 kg/hr at 20 minutes and therefore choose as the best operating condition of the machine.

5.0 Conclusion

The coating machine was fabricated and tested and the Performance was very satisfactory. Also the cost was found quite affordable and from the test performance the efficiency was encouraging and the machine is capable of eliminating drudgery associated with production of peanut production by small scale producers.

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MASS AND ENERGY BALANCE ANALYSIS OF MODIFIED PNEUMATIC FLASH DRYERS FOR CASSAVA

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Abstract

This study focuses on analysis of pneumatic dryers for cassava processing. Its significance relates to further our understanding of performance of the existing models of pneumatic dryers and to identify new ways to improve drying performance of flash dryers being used for production of high quality cassava flour. The flash dryers were subsequently modified based on the optimum conditions. The highest energy efficiency was recorded for the positive single cyclone system which increased from 63.27 to 78.55% while the specific heat consumption was reduced from 3.79 to 3.00 MJ/kg after modification.

Keywords: Cassava, heat transfer, drying

1.0 Introduction

Cassava has transformed greatly into high yielding cash crop, a foreign exchange earner, as well as a crop for world food security and industrialization. An increase in cassava processing has been shown to contribute to sustained growth in cassava production in Nigeria (Ugwu and Ukpai, 2002). The inherent high moisture content of fresh cassava root promotes both microbial deterioration and unfavorable biochemical changes in the commodity (Wenham, 1995). Consequently, cassava roots need to be processed into more shelf stable product like 'High Quality Cassava Flour (HQCF)' in order to improve it flavor and reduce post-harvest losses. However, the diversification of cassava products, processing and utilization are presently constrained in Nigeria for the reason of inadequate processing machinery and equipment. Current challenges for the cassava industry in Nigeria, is the area of cassava processing in general and drying in particular. This include reducing the drying time, improving throughput and product quality as well as reduction in the production cost per kg of product through appropriate equipment design or modification as opined by (Precoppe, et. al., 2015). Mechanical drying ensures improved and consistent product quality. Hence, the need for innovative cassava processing technologies is enormous. Consequently, the evaluation of the existing flash dryers is required for better improvement and optimization.

Several studies have shown that mass and energy balance analysis can yield important information on how to improve dryer performance (Kemp and Gardiner 2001; Mittal 2010; Precoppe*et al*. 2013; Strumiłło*et al*. 2014), but none have dealt specifically with cassava drying (Precoppe et al. 2015). The mass and energy balance analysis of any drying process should account for the water sorption properties and the specific heat of the product being dried (Pakowski and Mujumdar2014). This work is focus on the evaluation of the pneumatic flash dryer models operated by cassava processors in Nigeria using mass and energy balance analysis and carry out the modification of those dryers in order improve the drying efficiency.

2.0 Materials and Methods

2.1 Production of High Quality Cassava Flour

High Quality Cassava Flour was produced using IITA cassava root variety TME 419 which was obtained from local farm around the processing centers.

2.2 Measurements and experimental procedure

Measurement and data collection was performed using the procedure as described by (Precope et. al., 2015). Measurements were performed after steady-state conditions of the dryers were achieved. The temperature of the hot air inlet, $T_{in}1$ (^{o}C), was measured by placing the thermocouple at the base of the drying duct. Also, the temperatures along the drying ducts were measured by installing the thermocouples at three other points ($T_{in}2$, $T_{in}3$and $T_{in}4$) on the drying duct before the cyclone.

The air velocity was measured at the exhaust air outlet. Air velocity was recorded simultaneously at different radial positions in the cross-sectional area using two miniature hot-wire anemometers (TVS-1008; Omega Engineering Inc.) connected to a data logger (HC2-S; Rotronic, Bassersdorf, Switzerland).The feed rate of the wet product, M_{wp} (kg_{wet} product/h), and the output rate of the dried product, M_{dp} (kg_{dried} product/h),were measured using a digital industrial balance. The fuel consumption ($\dot{m}_{fuel}$)was also measured using the digital industrial balance. The temperature of the wet product, T_{wp} (^{o}C), and temperature of the dried product, T_{dp} (^{o}C), was measured by keeping oneHC2-S probe inserted into the pile of material being loaded into the dryer, and another HC2-S probe inserted into the pile of material being removed from the dryer. All the sensors were connected to a computer using a data acquisition system. Measurements were recorded on 10 seconds intervals basis.

2.3 Energy Analysis

Specific energy consumption (q_s) was calculated according to (Kudra 2009) based on the heat rate added by the dryer's heating unit to the ambient air ($\Delta\dot{Q}_{in}$) and the water evaporation rate ($\dot{m}_{\omega}$) as shown inEquation 1:

$$\text{Specific energy consumption } (q_s) = \frac{\Delta\dot{Q}_{in}}{\dot{m}_{\omega}} = \frac{\dot{m}_{air}(h_{in} - h_{amb})}{\dot{m}_{\omega}} \quad (1)$$

Where $\dot{m}_{air}$ is the air mass flow rate and h_{in} plus $h_{amb}$are the enthalpy of inlet and ambient air,respectively. The value for $\dot{m}_{air}$ was calculated from the air density, air velocity and cross-sectionalarea of the exhaust air.While the air density was determined based on the air temperature, relative humidity and pressure, using the CIPM-2007formula (Picard *et al*. 2008).

Energy efficiency (η_e) was calculated by dividing the heat used for water evaporationby the heat added to the ambient air by the dryer's heating unit ($\Delta\dot{Q}_{in}$):

This was evaluated according to Kudra (2009)

$$Energy\ efficiency\ (\eta_e) = \frac{Q_w}{\Delta\dot{Q}_{in}} = \frac{m_w \cdot \lambda}{\Delta\dot{Q}_{in}} = \frac{m_w \cdot E_{st}}{\Delta\dot{Q}_{in}} \quad (2)$$

Where $\boldsymbol{\lambda}$ is the latent heat of the vaporization of water at the inlet temperature of the product (Chapuis et. al., 2017)

Thermal efficiency, (η_T), was defined according to Strumiłło et al. (2014) based on the inlet air temperature (T_{in}), the outlet air temperature (T_{out}) and the ambient temperature (T_{amb}), as shown in Eq. (3):

$$Thermal\ efficiency\ (\eta_T) = \frac{T_{in} - T_{out}}{T_{in} - T_{amb}} \quad (3)$$

2.4 Determination of Heat losses to the ambient

Heat losses to the ambient, $Q_{,amb}$(kJ/h), consists of radiation and convection heat losses which were determined from the dryer's energy balance, as suggested by Rotstein andCrapiste (1997). This calculation took into considerationthe heat input rate into the dryerQ_{in} (kJ/h), the energy input rate of the wet product, Q_{wp} (kJ/h), the heat output rate from theexhaust air, Q_{out} (kJ/h), and the energy output of the dried product, Q_{dp} (kJ/h), was

$$Q_{amb} = (Q_{in} + Q_{wp}) - (Q_{out} - Q_{dp}) = (h_{in} \cdot \dot{m}_{air} + h_{wp} \cdot m_{dm}) - (h_{out} \cdot \dot{m}_{air} + h_{dp} \cdot m_{dm}) \quad (4)$$

Where h_{out} (kJ/kg$_{dry}$ air) is the specific enthalpy of the exhaust air, h_{wp} (kJ/kg$_{dm}$) is the specific enthalpy of the wet product and h_{dp} (kJ/kg$_{dm}$) is the specific enthalpy of the dried product.

2.5 Determination of minimum air flow rate

Minimum air flow rate ($\dot{m}^*_{air}$) was determined considering the heat and hydrodynamicdemand of the dryer, as suggested by Kudra (2012). The highest allowable outlet air relative humidity (ϕ^*_{out}) and the lowest allowable outlet air temperature (T^*_{out}) was determined based on the sorption isotherm of cassava. The determination of $T^*_{out}$and ϕ^*_{out}alsotook into consideration the measured enthalpy of the outlet air (h_{out}), aiming to keep it at the same level ($h^*_{out}= h_{out}$). The parameters for desorption presented by Aviara and Ajibola (2002) were used, entering atarget final product moisture content of 11% on wet basis (wb). $Y^*_{out}$is thehighest possible outlet absolute humidity as shown in Equation 5:

$$\dot{m}^*_{air} = \frac{\dot{m}_\omega}{Y^*_{out} - Y_{amb}} = \frac{\dot{m}_{dm}(X_{wp} - X_{dp})}{Y^*_{out} - Y_{amb}} \quad (5)$$

Where $\dot{m}_{dm}$ is the dry basis feed rate and X_{wp} and X_{dp} are the moisture content in dry basis of the wet product and of the dried product, respectively. The hydrodynamic demand took into consideration that the minimum air velocity at the drying duct should be higher than the wet product terminal velocity.

2.6 Determination of Heat losses via exhaust air

Heat losses via exhaust air, Q_{Lout}(kJ/h), were determined according to Kudra (2009), taking into consideration theminimum air flow rate required to supply both heat andhydrodynamic demand. Q_{Lout} was calculated by subtracting from Q_{out} the exhaust heat rate based on a minimum airflow rate, Q_{out} * (kJ/h):

$$Q_{Lout}\left(\frac{kj}{h}\right) = Q_{out} - Q^*_{out} = (h_{out} \times m_{air}) - (h_{out} \times m_{air^*}) \quad = h_{out}(m_{air} \times m_{air^*}) \quad (6)$$

Where Q_{Lout} is the heat losses via exhaust air

2.7 Analyses

Wet product and dried product samples were analyzed for Moisture Content, Water Absorption Capacity, Color, Swelling Index Power and Pasting Properties of the dried samples; all analyses were performed in triplicates.

2.8 Statistical Analysis

Analysis of variance (ANOVA) was adopted in analyzing the data. SPSS version 17.0 software package was used to statistically analyzed the data obtained for all treatments. The significance of treatment means was tested at $P < 0.05$ probability level using Duncan's New Multiple Range Test (DNMRT) (Steel and Torrie, 1980).

3.0 Result and Discussion

3.1 Dryers Performance and Evaluation

The result of the dryer performance for all the model of flash dryer's evaluated before modification is presented in (Table 1). Significant variation ($p \geq 0.05$) was found in all the performance indices for all the model of flash dryers except for the specific energy consumption of the two dryers at Open door Ltd. Flash dryer at Niji had the highest energy efficiency (63.4 %) while the lowest value of (47.47 %) was recorded for the single cyclone dryer at Open door. Also, the lowest value of (3.63 MJ/kg) for specific consumption of energy was recorded for dryer at Niji while the single cyclone dryer at Open door had the highest value (5.07MJ/kg). The specific consumption of energy range between 3.50 to 5.04MJ/kg, Tolmac*et. al.,* 2005. According to Kudra (2012), energy efficiency and specific heat consumption are the most frequently exploited to assess the dryer performance of all the indices from the energy view point. The thermal efficiency of pneumatic dryers range between 50 to 75% according to (Rotstein and Crapiste 1997).

Heat losses to the ambient range from 19.3 % Open (-1C) to 32.7 % Open (+6C) while heat losses via the exhaust air range from 13.7 % Open (+6C) to 17.5 % (Niji). These heat losses is an indication of necessity for modification so as to improve on the utilization of the loss heat for drying. Exhaust heat losses are frequently high in convective dryers (Kudra 2012), and usually range between 15 and 40% (Strumiłło et al. 2014). Although the heat losses for all the dryers evaluated fall within this range but the losses can still be minimized. Such losses can be reduced by re-circulating a proportion of the drying air. However, this requires extensive modifications to be made to the dryer (Gong et al. 2011). Heat losses to the ambient depend on the thermal properties of the dryer walls, the dimensions of the dryer and its operating conditions (Rotstein and Crapiste 1997). It was observed that none of the flash dryers is insulated and the heat control system were not incorporated on the burners of the heat exchangers which result into low heat utilization. This would have regulate the dosage of fuel for heat combustion, hence higher heat utilization in the dryers

Table 1: Values of the dryer performance of the three models of flash dryers before modification

Dryers Models	Energy efficiency (%)	Specific energy consumption (MJ/kg)	Thermal efficiency (%)	Heat input rate (kW)	Heat losses to ambient (%)	Heat losses via exhaust (%)
Open door (+6C)	$52.02^{b} \pm.09$	$4.59^{a} \pm.41$	$87.23^{a} \pm.41$	$106.51^{b} \pm.44$	$32.67^{a} \pm.45$	$13.60^{c} \pm.36$
Open door (-1C)	$47.47^{c} \pm.47$	$5.07^{a} \pm.15$	$54.46^{c} \pm.48$	$127.47^{a} \pm.51$	$19.30^{c} \pm.60$	$16.07^{b} \pm.40$
Niji(+1C)	$63.40^{a} \pm.48$	$3.63^{b} \pm.47$	$80.55^{b} \pm.46$	$100.60^{c} \pm.45$	$21.53^{b} \pm.40$	$17.53^{a} \pm.35$

3.2 Modified dryer performance

The essence of dry modification is to improve the dryer performance and the reduction in the production cost, hence higher return on investment. Usually the improvement of efficiency and product quality and reduction of energy consumption and drying time are the most important reasons for change in drying system (Salem et. al., 2017). Table 2 presents the drying results for both dryers (modified and unmodified) while maintaining the same drying procedures. There was no significant difference in the outlet air enthalpy as predicted despite the reduction in the air flow rate and air velocity for all the dryer models. Also, no significant difference was observed in the air inlet temperature of the six cyclone dryer at Open door while significant differences were observed in the remaining parameters. The variations in the products feed rate and output discharge rate are due to human error as a result of manual method of feeding used.

Table 2: Drying performance for unmodified dryers and the modified dryers

Dryer model	Dryer type	Wet product federate (kg/h)	Dry product output rate (kg/h)	Air inlet temperature (^{o}C)	Air enthalpy (kJ/kg	Air flow rate (m^3/s)	Air velocity (m/s)
Open door (+6C)	Modified	238.10^b ±.10	174.60^b ±.10	152.39^a ±.55	133.76^a ±.10	377.82^b ±.20	9.76^a ±.02
	Unmodified	239.01^a ± .01	176.80^a ±.05	151.85^a ± 05	133.52^a ± .06	505.12^a ±.12	7.38^b ±.10
Open door (-1C)	Modified	229.70^b ±.20	174.60^a ±.05	112.30^a ±.06	129.97^a ±.10	598.24^b ±.02	9.89^a ±.01
	Unmodified	231.81^a ±.05	151.40^b ±.40	109.46^b ±.01	130.13^a ±.03	799.53^a ±.03	7.40^b ±.05
Niji (-1C)	Modified	238.7^a ±.05	125.6^a ±.05	133.6^b ±.10	133.76^a ±.10	546.26^b ±.06	9.45^a ±.05
	Unmodified	239.01^a ±.01	118.4^b ±.40	134.10^a ±.10	133.56^a ±.06	701.38^a ±.02	7.39^b ±.01

Table 3 also present the drying performance of the unmodified dryers in comparison with the modified dryers. There were significant difference between all the performance indices except the thermal efficiency of the dryer at Niji. There were significant improvement in the performance of modified dryers for all the dryers, as it could be reflected in table that the energy efficiencies of all the dryers increased while their specific heat consumption reduced with the exception of the (-1C) Open door dryer. Even though the reduction in the air velocity brought about the reduction in heat rate, this does not have negative effect on the dryer performance. Furthermore, the results revealed that 94.1g/kg, 89.8g/kg and 88.2g/kg (Open door +6C & -1C and Niji +1C respectively) of fuel shall be required to dry 1kg of wet product for unmodified dryers. Whereas in the modified dryers, these values reduced to 73.1g/kg, 77.1g/kg and 75.9g/kg. This reduction (22%, 14% & 14%) in fuel consumption is directly proportional to production cost, hence, improvement of the return on investment return.

Table 3: Comparison of performance data of unmodified and modified flash dryer models

Dryer model	Dryer type	Fuel consumption (kg/h)	Heat input rate (kW)	Energy efficiency (%)	Specific energy consumption (MJ/kg)	Thermal efficiency (%)
Open door (+6C)	Modified	17.41^b ±.01	76.18^b ±.02	74.01^a ±.06	3.24^b ±.04	86.06^b ±.09
	Unmodified	22.49^a ± .10	106.43^a ± .03	52.02^b ±.02	4.61^a ±.06	87.13^a ±.08
Open door (-1 C)	Modified	17.71^b ±.10	11.72^b ±.02	54.51^a ±.10	5.09^a ±.10	81.75^a ±.05
	Unmodified	20.82^a ±.02	12.75^a ±.05	47.24^b ±.04	5.09^a ±.06	54. 40^b ±.03
Niji(+1C)	Modified	18.11^b ±.01	76.18^b ±.08	78.55^a ±.01	3.06^b ±.04	80.31^b ±.05
	Unmodified	21.09^a ±.03	106.43^a ±.03	63.27^b ±.02	3.79^a ±.10	80.49^b ±.03

Figure 1 presents the temperature distributions along the drying ducts of three models of flash dryers. The figure depict that there was high rate of heat transfer between the drying air and the product, thus enhancing the high rate of moisture evaporation during the constant drying period. The same trend is observed for the three dryers.

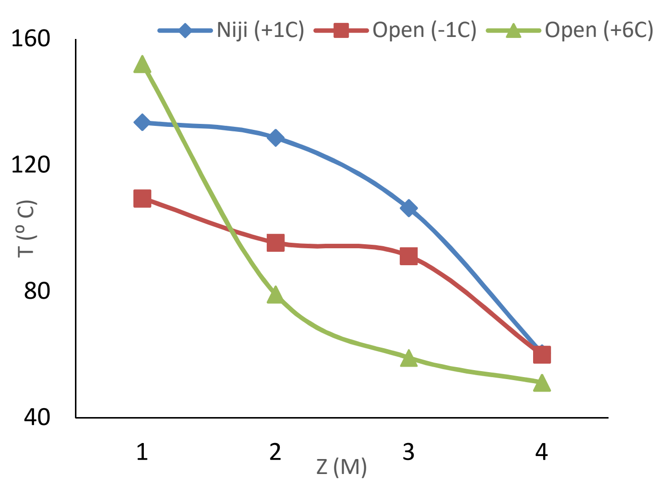

Fig. 1. Thermal Drying Curve

4.0 Conclusion and Recommendation

The three models of pneumatic flash dryers were successfully evaluated. The qualities of the HQCF samples obtained from the model of flash dryers were within the limits set by the relevant Nigerian standards which are an indication that those dryers are suitable for HQCF production. However, some drawbacks observed on the flash dryers evaluated were: absence of insulation on the drying duct which facilitate greater heat loss to the ambient, improper design of the multiple cyclone which affect proper separation of exhaust air and product and absence of heat control system on the burners. These identified drawbacks are resulting to the low energy utilization which is militating against the optimum drying performance of pneumatic flash dryers evaluated. There is an urgent need for new engineering design of a functional and well efficient pneumatic flash dryer for HQCF production, because there is a limit to which modification could be carried out on existing flash drying system. The development of the new efficient pneumatic flash dryer should require the collaborative efforts between Agricultural Engineers and local fabricators.

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OTHER PAPERS

EFFECT OF UNTREATED WASTEWATER REUSE IN AGRICULTURE AND SUSTAINABLE REPROACH FOR MICRO-POLLUTANT REMOVAL USING HYDROCHAR

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Abstract

Scarcity of freshwater resources has prompted millions of smaller farming communities in Nigeria and elsewhere in developing countries to depend on wastewater for agriculture, drinking, bathing and fishing. Continuous reuse of wastewater resources ensures all year-round cultivation of varying crops. Whilst the intent of the Nigerian peasant farmers is to use any available water source for crop irrigation, they seldom care about the associated health risks. Reported studies on wastewater reuse for agriculture in Nigeria have reported varying concentrations of inorganics (heavy metals), reactive dye/methylene blue and pharmaceutical residues (organics) in wastewaters used crop irrigation. Unfortunately, the concentration of these pollutants in wastewater used for crop irrigation and domestic purposes were found to be above World Health Organization (WHO)/Food and Agriculture Organization (FAO) recommended threshold. This inherently becomes a subject of concern particularly as it relates human health. Although, several conventional wastewater treatment technologies exist; their applications are limited by high procurement, operation and maintenance costs. Currently, studies on biomass wastes as low-cost adsorbents for the treatment of industrial wastewater is now gaining momentum. The pilot studies carried out involves the use hydrochar from biomass wastes such as coco-peat, coconut shell, rice husk, lemon peel and eggshell for the removal of heavy metal ions. In this context, batch experiments were carried out in triplicates at 3 different contact times and pH. After 2 h of contact time at pH9, the coco-peat was proven to have Cr removal efficiency of 91.6%; and 95.0% for Pb(II). This suggests that hydrochar provides a cost-effective means for metal removal from industrial wastewaters. Inherently, release of these micro-pollutants into municipal water supply or waterways has become an issue of public interest and particularly of concern amongst researchers due to the pervasive health implications on humans. Although, several conventional wastewater treatment technologies exist; however, their applications are limited by high procurement, operation and maintenance costs, they could also be inefficient at much lower concentrations, their design process are usually complex and very expensive. In this study, effort was made to devise a simple, efficient, affordable and reliable technology for wastewater treatment using low cost adsorbents. The trend in using biomass wastes as adsorbents for wastewater treatment is gaining momentum. From the analysis of the batch II experiments, the adsorption efficiency of HTC-CP is over 90%; HTC-ES was able to remove nearly 100% of Fe (II) and Cu(II) while coconut shell CS proved excellent for decolouration of textile wastewater. In conclusion, applying this innovation to treat wastewater used for crop irrigation in Nigeria and other developing countries with similar environmental apathy.

Keywords: Adsorption, agriculture, freshwater scarcity, hydrothermal carbonization, wastewater reuse

1. Introduction

1.1 Background to the study

The use of wastewater in developing countries has emerged as an important option to augment the perennial scarcity of freshwater resources. Agricultural productivity in developing countries is lower due to scarcity of freshwater resources. This is observed to affect the expansion and quality of crop production. Several studies have established the presence of micro-pollutants (heavy metals and organics) in wastewaters used for crop irrigation in developing countries. Countries where untreated industrial wastewater are commonly used to cultivate a variety of crops among which are perishables include: Nigeria (Akan et al., 2007; Akan et al., 2009; Dan'Azumi and Bichi, 2010), Romania (Lacatusu, 1996), Pakistan (Khan et al., 2013), India (Chhikara and Rana, 2013), Bangladesh (Das et al., 2010; Islam et al., 2013; Sarker et al., 2015) and Turkey (Demirezen and Aksoy, 2006; Halim, 2013). The studies show that the concentrations of micro-pollutants in such wastewaters often exceed the recommended threshold (FAO/WHO, 2006). It is important to note that chemicals have varying industrial applications, so the waste being generated. However, to limit the scope of this study, only wastewater from textile and tannery industries is in focus. Production in textile and tannery industry requires large amount of water; hence, generating corresponding volume of wastewater. Municipal wastewater combined with untreated textile and tannery wastewater are often reported to be indiscriminately discharged into adjoining rivers in Kaduna, Kano and Zaria Cities (See Figure 1 and Figure 2 (a) - (f)) illustrating the kind of wastewater used for crop irrigation along the fringes of river Jakara in Kano State, Nigeria. In reality, Nigeria wastewater infrastructure is either non-existent, inadequate or obsolete. The wastewater often contains both organic and inorganic pollutants. Unlike organic pollutants, which are susceptible to biodegradation, the inorganic pollutants such as heavy metals are non-biodegradable and usually have long decay and mobile half-life in biological tissues. Based on documented evidence, on industrial operations reported that about 75% of the wastewater generated by textile and tannery industries are discharged directly into nearby rivers, streams or lagoons, 15% into surrounding bushes and 10% into drainage and gutter systems without treatment (Ademoroti *et al.,* 1992; Adebayo *et al.,* 2007). The study, further reported that 42% of all the textiles industries in Nigeria are sited in Lagos (Apapa, Illepeju, and Ikeja), while 27% are in Kano (Bompai, Challawa, and Sharada), 20% in Kaduna (Kakuri, Kaduna South) and the remaining 11% are distributed in cities such as Aba, Onitsha, Asaba, and Ado-Ekiti (Ademoroti *et al.,* 1992). On the other hand, the northern parts of Nigeria (Kano, Kaduna, Maiduguri) have the largest tannery industries (NBS, 2010). The effluents from these industries contain reagents such as carboxylic acids, alkalis, dyes, sodium bisulphate, soda ash, hydrogen peroxide, dextrin-starch, gums and resins, waxes, surfactants, dispersing agents, soaps and heavy metals (Holkar *et al.*, 2016). The presence of these pollutants at varying concentration levels, above their recommended threshold has been a subject of concern among researchers due to their pervasive health accumulative and impact both ecological systems and public health (FAO/WHO, 2006; Ensink and Van Der Hoek, 2009; Sorsa *et al.*, 2015).

Figure 1 Pathways through which organics and inorganics pollutants enter biological tissues

Figure 2 (a) and (b) are outlets of raw effluent from textile and tannery industries; (c)and (d) contaminated Challawa River diverted into irrigation field; (e) irrigated spinach, cabbage and carrots; (f) vegetables ready for sale

Regrettably, this type of wastewater is currently being used for crop irrigation in Nigeria (Akan *et al.*, 2009; Dan'Azumi and Bichi, 2010; Bichi *et al.*, 2013). Micro-pollutants in irrigation water, soil and plants are impediments, which hinders safe agricultural practice and farmers' productivity. Notably, documented reports have shown that farmers exposed to prolonged contact with wastewater and the consumers of crops irrigated with untreated wastewater are likely to suffer a wide range of diseases, these include: sclerosis, skin lesion, cancer, cardiovascular disorder, neurological dysfunctions illnesses and shinking of the bones *(itai itai)* (FAO/WHO, 2006). Scholars have also established some epidemiological links between consumption of food crops irrigated with untreated wastewater and individual or communal illnesses (Ensink and Van Der Hoek, 2009). For instance, a study from Romania by Lăcătuşu *et al.* (1996), reported that the typical life expectancy of the inhabitants of Copsa Mica reduced by 9-10 years due to the consumption of crops and vegetables grown with wastewater containing Cu(II), Cd(II), Pb(II) at concentration levels exceeding the recommended thresholds.

To this end, policymaking bodies such as Food and Agriculture organization (FAO), United State Department for Agriculture (USDA) and World Health Organization (WHO) and have been exploring modalities to safeguard humans from excessive exposure to micro-pollutants though wastewater reuse for agriculture. The FAO and WHO have jointly issued some guidelines to regulate the concentration of contaminants in surface water used for crop irrigation, agricultural soils and plants (FAO/WHO, 2006). This is with a view to protect humans and animal health. However, while the implementation of this modalities and guidelines are successful in developed countries; it is hard to achieve practically in Nigeria and many other developing countries (Ensink and Van Der Hoek, 2009). This may be due to any or combination of the following: 1) high cost of procuring and installing modern wastewater treatment facilities (e.g Reverse Osmosis and Nanotechnology); 2) non-compliance or poor enforcement of policy and regulations governing wastewater discharge into surrounding surface waterbodies in Nigeria; 3) organization malpractices which affects infrastructural development and management of wastewater treatment facilities. Hence, this paper stems to proffer an alternative measure for industrial wastewater treatment using low cost carbon-based materials (biomass wastes) to item 1 above, thereby forming the basis for this study.

To achieve this research goal, a cost-effective thermochemical process known as hydrothermal carbonization (HTC) is used to convert the biomass wastes into carbon-rich, coal-like derivative commonly called '*raw biomass waste*' at saturated pressure, thereby releasing CO_2 and other volatiles (Funke and Ziegler, 2010). HTC involves dehydration and decarboxylation of biomass in order to raise the carbon content which increases its energy value (Libra *et al.*, 2011). During hydrothermal carbonisation of biomass, decomposition of carbohydrate takes place though hydrolysis, resulting in an exothermic reaction, which breaks down the biomass to form glucose, fructose and other by-products (Holgate *et. al.,* 1995). Hydrothermal carbonisation of biomass wastes has many advantages compared to other biochemical and thermochemical (conventional methods) processes for char production. HTC can take from a few minutes to hours, against days or even months as required by other conventional methods (Titirici *et al.*, 2007; Libra *et al.*, 2011).The sorption potentials of the raw biomass wastes sourced from different biomass wastes: eggshell (ES), rice husk (RH), coconut peat (CP) and coconut shell (CS) and lemon peel (LP), were exploited via pilot studies based on functionality tests. The objective of the research are(1)tudy the sorption mechanism of the hydrochars (2)Evaluate the % adsorption of the interacting metal ions of each hydrochar (3)Determine the residual concentration of interacting metal ions in the filtrate (4)job creation (turning waste-to-wealth)

2. Materials and Methods

2.1 Reagents and synthetic wastewater preparation

All reagents used in this study were of analytical grade, supplied by Fisher Scientific Equipment Laboratories Ltd., Loughborough, United Kingdom. The standard ICP solution was prepared in nitric acid with concentration of 10,000 mg/L for $CuSO_4$ and $Pb(NO_3)_2$, and 1000 mg/L for K_2CrO_4 and $FeSO_4$. Procedure for the synthetic wastewater preparation was based on the method outlined in Standard Methods for the Examination of Water and Wastewater (APHA, 2012). To prepare the required 5 mg/L of the standard solution needed for the adsorption studies, approximately 0.5 ml of $Pb(NO_3)_2$ and $CuSO_4$ were withdrawn and poured into an empty 1000 ml (1 L) volumetric flask, followed by addition of 5.0 ml of K_2CrO_4 and $FeSO_4$. Purite water was added to the flask to make up to 1 L. The stock solutions of the aqueous solution and interacting ions are to contain a mixture of Cr(VI), Cu(II), Fe(II) and Pb(II) at six different concentrations for instance 0.5, 1.0, 2.0, 3.0, 4.0 and 5.0 mg/L. The mixture was poured into separate volumetric flasks and labelled according to the concentrations. To produce a fair representation of typical textile and tannery wastewater, 2 g/kg of corn starch, 6.13 g/kg of anhydrous sodium sulphate (Na_2SO_4) and 0.09466 g/kg of reactive blue dye was added to the undiluted constituents in each volumetric flask before purite water was then added to make 1 L (See Figure 3). The dosages of corn starch, salt and methylene blue stated above were chosen and used based on the recommendations of Awomeso *et al.* (2010).

Figure 3 Contaminated textile and tannery wastewater

2.2 Sources of adsorbents and preparation for adsorption

The biomass used in this study originates from plants and poultry waste. The plant wastes include coco-peat (CP), coconut shell (CS), rice husk (RH) and lemon peel (LP); while, egg shell (ES) is from poultry. These wastes are readily available in large quantities and can be sourced locally in Nigeria. The technique used in converting the raw biomass into raw biomass waste is though HTC. The raw biomass wastes were ground in a blender and sieved to aperture size of 0.850 mm and 0.600 mm. The raw biomass wastes were then thoroughly washed with tap-water and further rinsed with purite water before being air-dried in an incubator oven set at 40 ^{o}C for 24 h. The incubator temperature was set in order maintain the surface characteristics of each raw biomass without being de-natured before conversion into raw biomass waste. This was done in order to retain the surface functionality groups on each adsorbent. The air-dried raw biomass wastes were subjected to carbonisation though HTC. The carbonisation for each biomass waste was carried out under the same conditions; these is to include a temperature of 200 $^{\circ}$C, under an autogenous pressure of 20 bar for 1200 min (20 h) as the reaction time. One hour is a recommended time to heat up the process and raise the temperature to 200 $^{\circ}$C (Danso-Boateng *et al.*, 2015). The process involves weighing a known mass of biomass waste and mixing it with purite water in specified ratio, this is based on the procedure described by Titirici et al. (2007). The authors suggest that for a solids concentration of 7-33.3%, a total volume of 200 mL of water is required for effective carbonisation. Based on that suggestion, the present study has considered using a mass of solids within the specified range in relation to water mix ratio for each material. Specifically, for the CP, the percentage of solids was 7%, for the RH and LP 20% and for the ES and the CS was 33.3 %. The sample of raw biomass waste mixed with water were then transferred into a non-stirred 195 ML durable polytetrafluoroethylene (PTFE) Teflon vessel with 40 mm inner diameter and 158.7 mm inner height. The PTFE was then inserted into a core stainless steel SS 316TI (Berghof high-pressure reactor, BR-200, Germany) with 44 mm internal diameter and 166.7 mm inner height. After carbonisation, the reactor was allowed to cool down to room temperature (25 ± 2) $^{\circ}$C before uncapping the lid to vent CO_2 (gas) produced during the process as described in Figure 4. The raw biomass wastes produced were then washed in methanol to remove available organic residues before being thoroughly rinsed with purite water. Then, the carbonised materials were dewatered from the liquid phase using Whatman filter Paper No.42 (2.5μm pore size) to obtain the desired raw biomass wastes. The raw biomass wastes were further oven-dried at 105 ^{o}C for 24 h. The oven-dry (raw biomass waste) were poured into an air-tight container ready for adsorption. Note: all the sorbents were dried on the basis of constant weight. During which there is no further reduction in weight of the sorbent and then the final sample weight is taken and considered completely dried.

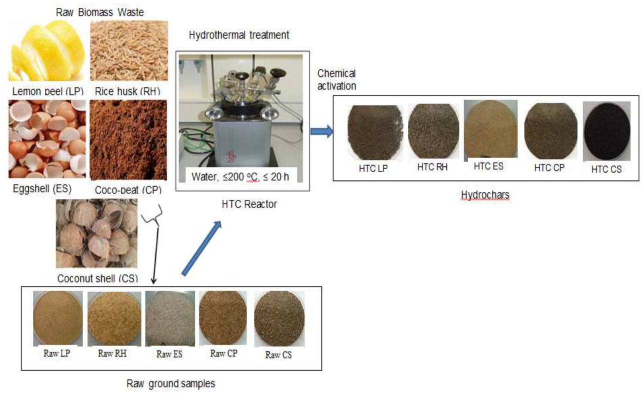


Figure 4 Graphical illustration of the hydrothermal carbonisation process

2.3 Batch experiment and adsorbent dosage

All glassware needed to carry out the batch experiments were washed with detergent, followed by addition of 10% HNO_3 and then thoroughly rinsed with purite water and dried before use. The batch adsorption tests were carried out using 1.5 g of each raw biomass waste in a conical flask before adding 50 mL of ordinary purite water. The purpose for this is to determine a baseline concentration of each inherent analyte of interest and pH in the aqueous samples. The conical flasks were then placed on a pH meter incorporated with magnetic stirrer (pH-8+ DHS Benchtop meter, Czech Republic) and various sample pH taken. Then the conical flasks were transferred to a mechanical shaker (Gallenkamp Orbital Incubator-cooled Shaker, INR-200 INR-250, Netherlands) for thorough mixing. The incubator was pre-set at room temperature (25 ± 2 ºC) and speed of 150 rpm. At each time lap (10, 20, 30, 40, 50, 60, 120, 240 and 360) mins, a corresponding flask was withdrawn from the shaker, filtered using Whatman paper No. 42 (2.5 μm) membrane filter to separate treated water from the solid sorbents. The filtrates were analysed for the baseline concentrations of Cr(VI), Cu(II), Fe(II) and Pb(II). The baseline concentrations served as the controls for the experiments and were deducted from the sample analysed using wastewater. Similarly, the procedure was followed using the same adsorbent dosage, operating conditions and volume of wastewater.

2.4 Batch adsorption and pH adjustment

The experiments were conducted in three batches with each carried out in triplicates. Another three separate control tests were carried out (adsorbents mixed with just purite water) according to the chosen pH value (natural/acidic, 9 and 11). For each batch test, a fixed amount of 1.5 g adsorbent was weighed and placed in separate conical flask, and 50 ml of the standard aqueous solution with concentration strength of 5 mg/L was added. The mixture was then stirred using a magnetic stirrer (a polygon F371220040 spin bar was dropped into each volumetric flask containing ordinary water different adsorbent to examine the effect of solution pH on adsorption) which is attached to Mettler

Delta 340 pH Meter to measure the respective pH values before and after adsorption based on the given contact time (2, 4, and 6) h. While the magnetic stirrer is switched ON, the mixture begins to stir, and the initial pH taken. and that was repeated after adjustment with 1M NaOH. Based on typical scenarios as documented in several literature, textile and tannery wastewaters are known to be alkaline in nature with pH values ranging from 9 to 11. Hence, this justifies the choice of pH9 and pH11 for alkalinity medium used in this study. Whereas, the pH of solutions that contain hydrochar in natural state ranges from 4 to 6, which is relatively acidic. However, in order to adjust the acidic pH to alkalinity, 1M of sodium hydroxide (NaOH) was gradually added to the solution until the desired pH for each mixture was attained. All conical flasks were then placed in a mechanical shaker (Adjustable GALLENKAMP Orbital Incubator-cooled Shaker) which was pre-set to a temperature of 25 ± 2^{o}C and a speed of 150 rpm. Each sample was removed from the shaker at the end of each contact time and was filtered using a Whatman paper No. 42 to separate the filtrate from the solids. The concentrations of Cr, Cu, Fe and Pb in the wastewater following adsorption were analysed using Inductively Couple Plasma Atomic Spectrometry (ICP-AES-9000, Shimadzu Scientific Instruments, Japan).

2.5 Heavy metal removal efficiency

To determine the percentage adsorption of heavy metals by the adsorbents, the following equation as described by (Chen and Wang, 2008) is applied.

$$R\,\% = \left[\frac{C_i - C_f}{C_i}\right] \times 100 \qquad (1)$$

Where: C_i is initial metal concentration (mg/L) and C_f is the final metal concentration (mg/L).

2.6 Characterisation of adsorbents using BET, SEM/EDS and FTIR techniques

2.6.1 Determination of surface area using BET technique

The precise specific surface area, pore size and pore volume of each hydrochar was measured as a function of relative pressure using automated BET (Brunauer–Emmett–Teller) analyser (Micrometrics, TriStar 3000, Micromeritics Instrument Corporation, Norcross, GA, USA). To carry out the tests, the empty sample handler was initially weighed, followed by addition of the adsorbate and re-weighing. The sample handler usually is expected to occupy an area of about 10–20 square metres before placing the handler into a heating mantle for degassing and dewatering which takes about 1 - 2 h at very high temperature set at 200 ^{o}C.

2.6.2 SEM/EDS technique

Characterisation of the hydrochar were carried out using scanning electron microscopy (SEM), energy dispersive spectrometry (EDS). The surface morphology of each adsorbent was examined using SEM at different magnifications (100x, 250x, 1000x and 5000x). The magnification that produce clearer image is then selected for interpretation. The EDS on the other hand, was employed to quantify the elemental composition in each hydochar (adsorbent).

2.8 FTIR technique

The Fourier Transformed Infrared-Ray Spectrometry (FTIR) for all hydrochar (HTC-ES, HTC-CP, HTC-RH, HTC-LP and HTC-CS) are very essential, because it would enable the functional groups in each adsorbent to be determined.

3. Results

3.1 Surface Characterisation of hydrochars

The hydrochars, were produced through a thermochemical process referred to as HTC at 200 ^{o}C for 20 h. Samples of each raw biomass waste and its corresponding hydrochar were characterised using SEM, EDS, BET and FTIR to determine surface morphology, elemental composition, surface area/pore size/pore volume and functional groups respectively. Changes from fibrous and cellular appearance to hollow and stack type appearance as shown on the SEM images were due to thermal application that resulted from denaturing of biomass structures. The HTC process was observed to alter the functional groups of the biomass tested. Details on the characterisation of each hydrochar used in this study can be found via the following link *https://doi.org/10.1007/s42452-021-04273-5*

3.2 Effect of pH on metal adsorption by hydrochar

The effect of pH on adsorption of Cr(VI), Cu(II), Fe(II) and Pb(II) ions by hydrochar of ES (HTC-ES were investigated. The preliminary results of the batch test that were carried out using hydrochar of raw biomass wastes are presented in Figure 5 (b), (c) and (e) has shown very low uptake of Cr ions by hydrochar of eggshell (HTC-ES and turn the samples colourless. This implies that the surface chemistry of the hydrochar ES, shows poor sorption affinity for the Cr ion at all pH level but progressive increase in Cu(II), Fe(II) and Pb(II) adsorption of 95%, 98% and 97% respectively. While some adsorbents attained optimum adsorption in weak acidic conditions, others were achieved at slight alkaline phase.

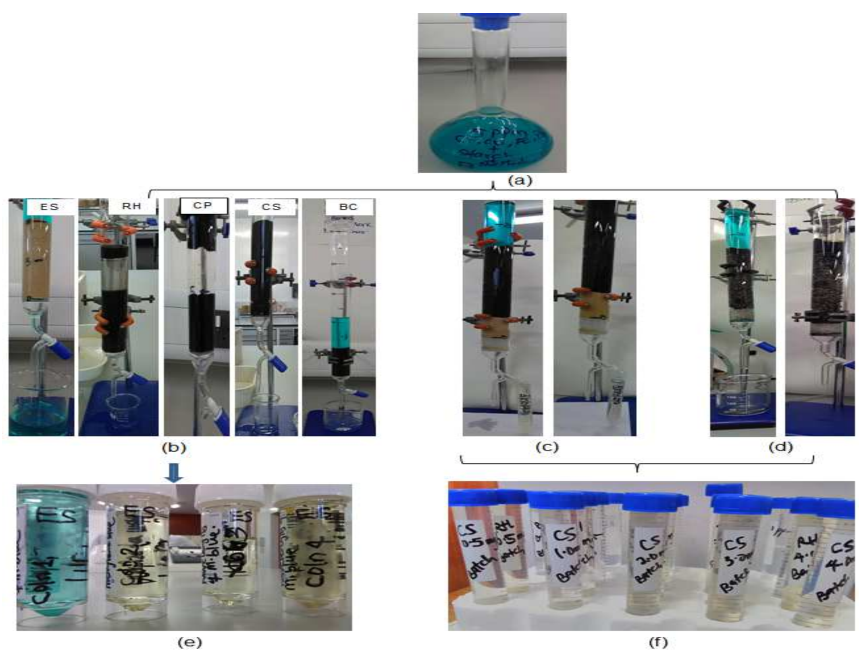


Figure 5 (a) Wastewater, (b) stand-alone (c) Layer (d) mixed/composite (e) filtrates from b, (f) colourless treated water

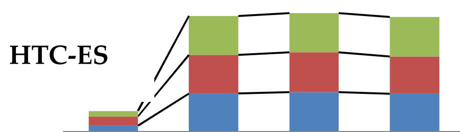
3.2 Effect of contact time on metal adsorption by hydrochar

The batch II studies was carried out using hydrochar to investigate the effect of adsorption parameters such as varying contact time on adsorption at pH9, 1.5 g dosage per weight of each adsorbent. The amount of metal uptake per adsorbent is observed to increase with time to a point where it reaches a constant value where no more metal ion can be removed from the solution. At this stage, the amount of metal ions being adsorbed per adsorbent was in a state of equilibrium and the time required to reach this point is called equilibrium time.

4. Discussion

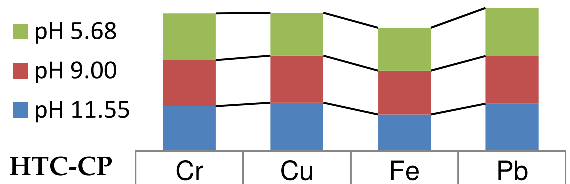
The quantity of metal adsorbed at equilibrium time reflects the maximum adsorption capacity of each of the adsorbent under specific operating conditions. Figures 6 – 10 illustrate rapid metal adsorption within the first 10 minutes followed by a gradual increase up to 20 minutes and remained almost constant. There is a trend in almost all the adsorbents whereby the results showed that the adsorption of metal ion increases with time up to 2 h. Figure 7 shows rapid removal of Cr(VI) by HTC-CP HTC-LP and HTC-CS. However, HTC-ES did not perform well. The poor performance of ES may be due to the complex electrostatic cooperating effects and the bonding interactions to construct a stable linkage between the ES with the Cr(VI) ions. The hydrochar of LP has demonstrated its ability to remove Cr ions compared to when it was used in batch II for the same experiments. This confirms that the presence organics in LP affects its sorption ability. Figure 8 shows all hydrochars can effectively compete with BC in removing Cu(II) ions. Surprisingly, Figure 9 shows that 100% of Fe(II) ions were completely adsorbed by HTC-ES after 120 mins to reach equilibrium. The removal of Pb(II) follow a similar pattern for all the hydrochars as shown in Figure 10

Generally, the increase in adsorption at the initial stage may be due to availability of large active sites for binding, which becomes saturated with time and subsequently reducing in decreasing efficiency with time. In conclusion, findings from this study is in agreement with those reported by Azouaou *et al.*(2010), Han *et al.* (2017) and Mihajlovići1 *et al.*, (2016).



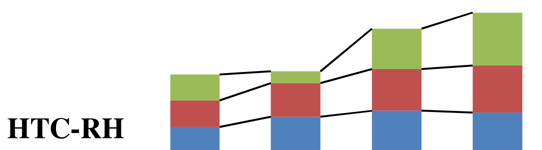
	Cr	Cu	Fe	Pb
pH 7.98	13.86	95.65	96.72	97.79
pH 9.00	22.65	95.57	98.34	92.20
pH 11.25	15.74	95.33	98.82	94.36

Figure 6 Amount of heavy metal ions adsorbed (%) by HTC-ES as a function of pH



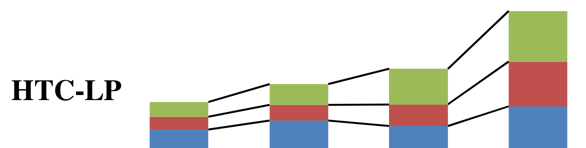
	Cr	Cu	Fe	Pb
pH 5.68	92.59	84.96	84.82	95.23
pH 9.00	91.55	93.57	87.46	94.96
pH 11.55	89.86	96.76	73.20	94.82

Figure 7 Amount of heavy metal ions adsorbed (%) by HTC-CP as a function of pH



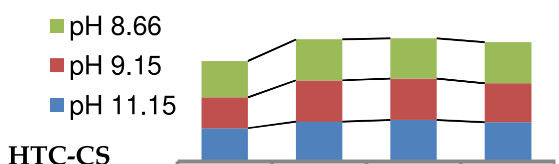
	Cr	Cu	Fe	Pb
pH 5.87	40.51	18.46	62.61	82.55
pH 9.44	41.43	52.23	65.11	73.53
pH 11.73	39.73	55.65	64.84	61.99

Figure 8 Amount of heavy metal ions adsorbed (%) by HTC-RH as a function of pH



	Cr	Cu	Fe	Pb
pH 4.61	24.76	34.04	58.67	83.67
pH 9.09	20.88	26.26	35.91	73.80
pH 11.25	35.90	50.79	41.61	74.13

Figure 9 Amount of heavy metal ions adsorbed (%) by HTC-LP as a function of pH



	Cr	Cu	Fe	Pb
pH 8.66	87.04	98.02	95.77	98.49
pH 9.15	73.22	98.01	98.91	91.76
pH 11.15	79.53	95.32	98.91	94.14

Figure 10 Amount of heavy metal ions adsorbed (%) by HTC-CS as a function of pH

4. Conclusions

The potential of using hydrochar as low-cost adsorbent for the removal of heavy metal ions from textile and tannery wastewater was investigated. The work presented in this research has set a roadmap for the development of a simple, affordable and effective wastewater purification process. This research has successfully explored the potentials of using hydrochars produced from various biomass wastes to adsorb heavy metal ions and decolourise textile and tannery wastewater (See Figure 4.1). It has also set a pace for the treatment of industrial wastewater used for crop irrigation not only in Nigeria but in many other developing countries around the world. If this technique is adopted, implemented and efficiently utilised; it can significantly reduce humans' exposure to high concentrations of heavy metals and other organics tenable through food chain. The farmers need to be adequately informed about the dangers of using contaminated wastewater for irrigation and soils in the name of manure to raise their crops. The refuse dumpsites contain all manner of wastes, which have long decay life when found through food chain. Government should work out modalities to reduce the use of contaminated soil for raising our crops.

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