PROCEEDINGS OF THE 37th NATIONAL CONFERENCE & ANNUAL GENERAL MEETING

PROCEEDINGS OF THE 37TH NATIONAL CONFERENCE, MINNA 2016

NIGERIAN INSTITUTION OF AGRICULTURAL ENGINEERS (NIAE)
A DIVISION OF THE NIGERIAN SOCIETY OF ENGINEERS

PROCEEDINGS OF THE 37th NATIONAL Conference & ANNUAL GENERAL MEETING

Minna, 2016

Theme:

AGRICULTURAL AND BIORESOURCES ENGINEERING: GATEWAY TO DIVERSIFY NIGERIA OIL-BASED ECONOMY, JOB AND WEALTH CREATION AND ENVIRONMENTAL SUSTAINABILITY.

Date: October 4th - 7th 2016

Venue: Federal University of Technology, Minna, Niger State, Nigeria.

EDITED BY:
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SUB-THEMES

- Agricultural Waste to Wealth for job creation and healthy environment.
- Soil and Water Resources Management for Sustainable Agricultural Production.
- Post-Harvest and Value addition for food security.
- Improved Farm Transportation System for reduction of Post-Harvest losses.
- Renewable Energy for Sustainable Environment.
- Farm Mechanization and Emerging Technologies
- Entrepreneurship in Agricultural Production
- Farm Structures and Electrification for Enhanced Rural Life and Development

Venue: Chemical Engineering Hall, Federal University of Technology, Minna, Niger State, Nigeria
Date: October 4th - 7th 2016

Proc, niae: volume 37, 2016

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PREFACE

We are delighted to welcome you to the 37th National Conference and Annual General Meeting of the Nigerian Institution of Agricultural Engineers tagged "Minna 2016". In keeping the institution, we present you with a program of cutting-edge research in the field of Agricultural Engineering in the form of papers and panel discussion to address the need to diversify the Nigerian economy from its present status to that of Agriculture. As such Agricultural Engineers are role players in this transformation.

The role of this conference is therefore to pool together Agricultural Engineers and other related experts from within and outside Nigeria to deliberate and articulate the various ways in which the goal of this present administration will be achieved. This is also expected to show a healthy mixture of high standards of selectivity coupled with wide participation from farmers, researchers and academic community. For 37th conference of NIAE, papers were called for from core Agricultural Engineers and other professionals through circulation of flyers and a total number of one hundred papers which cover various sub-themes of the conference were received. The articles received were subjected to peer review by seasoned Agricultural Engineers. The book of proceedings is the outcome of the review process. It is our expectation that participants would be professionally enriched by this compilation and indeed all the presentations during the conference. We are also grateful to our colleagues from Federal University of Technology, Minna for offering to host this year's conference and for their invaluable work in providing the necessary infrastructures and support for a successful conference. Finally, without your participation, this conference would not have been possible. We would like to take this opportunity to express our gratitude and appreciation to you all.

Engr. Dr. John Jiya Musa
Chairman, Technical Sub-Committee
Minna 2016

ACKNOWLEDGEMENTS

The Local Organizing Committee (LOC) of "MINNA 2016", on behalf of the National Executive Council (NEC) and the entire members of the Nigerian Institution of Agricultural Engineers (NIAE), wish to acknowledge the sincere support received from all who responded to the invitation to attend this conference and contributed immensely to the overall success of the conference.

In particular, we thank the Special Guests, Keynote Speaker and the Lead Paper presenters for the contributions made through their professional intellectual. We sincerely appreciate your contributions in making the conference a memorable event. The zeal and passion exhibited by the LOC members right from the planning to the execution of the conference is highly appreciated.

Thank you all and God bless

Engr. Prof. Peter Aba Idah
Chairman, LOC
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Minna 2016 NIAE Conference-Highlights ("MINNA 2016")

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KEYNOTE ADDRESS DELIVERED AT THE NIGERIAN INSTITUTION OF AGRICUTURAL ENGINEERS CONFERENCE SCHEDULED TO HOLD AT CHEMICAL ENGINEERING COMPLEX, FED. UNIVERSTY OF TECH. MINNA ON WEDNESDAY 5TH OCTOBER 2016

BY

GAMBO HAMZAT GARBA,

EXECUTIVE SECRETARY,
KADUNA INVESTMENT PROMOTION AGENCY,
GOVERNMENT HOUSE, KADUNA

I wish to sincerely thank the Local Organizing Committee for this opportunity to deliver the Key Note Address of this conference with the theme: Agricultural and Bioresources Engineering: Gateway to Diversify Nigeria Oil-Based Economy, Wealth and Job Creation and Environmental Sustainability.

According to A.A. Jongebreur , Agricultural engineering developed into a really multidisciplinary field of science in the 20th century. Further to traditional mechanical engineering, essential developments in microelectronics, systems and control engineering, chemical engineering and physics have unlocked wide perspectives for agricultural engineering. Bioresource Engineering again is an interdisciplinary program which incorporates engineering, design and the biological sciences. It is such an exceptional profession since it applies engineering principles to the enhancement and sustainability of the world's natural resources, and it the process provide results to difficulties that involve animals, plants and the environment.

Harnessing the various components of these two broad subjects hold the key to our diversification drive. The developed nations of this world only got this aspect right and that was the beginning of their industrial revolution which led them through a very sustainable path to the development they finally achieved. No nation can take the first step towards development without first providing food and nutrition for its citizens. To get the best in terms of physical and mental strength from a populace, the country must be have food security capability. This capability starts with research and ideas which are transformed into actual results by the technology and mechanics driven by invention, innovation and creativity. A further complex use of systems and designs will further accentuate the nation's zeal to go beyond the basics and think of health care using available natural and environmental resources. A healthy nation, or a nation that has developed the ability to be healthy and feed its populace is one which has recognized the quality of life as a necessary condition for inclusive growth. Every other thing will be centred on the science and technology to further develop.

Sadly, over the past decades; Nigeria came to over rely on crude oil for its sustenance. The Dutch disease took effect and other things we relegated or totally ignored because of oil. Nigeria depended on oil for about 90 % of foreign exchange and oil accounted for about 75% of Government revenue. Furthermore, lack of bioresources engineering among others led to Nigeria not having refining capacity to take care of domestic demands for refined petroleum products. As such a huge chunk of our resources is spent on the importation of these products and in the past, large amounts of our annual budgets were fretted on subsidy payments which went on to fuel corruption.

To compound this problem, Nigeria once a major producer and exporter of food became a food import dependent nation. Agriculture which was the main stay of our economy was totally relegated to the background. Currently, Nigeria spends about 11 billion US dollars on food imports. Added to the collapse of our manufacturing and agro allied industries, it was only a matter of time before we would be confronted with serious economic challenges like the current economic crisis.

The theme of this conference and the sub-themes are a sharp reawakening for us as professionals to take front line ownership or if you like first line charge in the economic revival of Nigeria. Agriculture and Bioresources engineering holds the key to diversifying Nigeria's economy which hitherto has come to over depend on oil. The gateway to this diversification which will reduce our dependence on oil or imports for our food, garments, energy sources and also entrench value addition in our subsistence farming will come from how we take the outcome of such conferences serious. There is always a nexus somewhere between agriculture and mechanization, mechanization and manufacturing, manufacturing and technology, technology and infrastructure, infrastructure and sustainable energy, energy and production, production and growth, growth and diversification, diversification and investments, investments and development.

Agriculture not only holds the key to feeding this nation but has the ability to replace oil as the major foreign exchange earner. This is not a mere postulation but based on empirical evidence as witnessed before the first oil boom. Agriculture and bioresources engineering is a fertile ground for breeding entrepreneurship which is badly needed to create jobs. Entrepreneurs innovators and to paraphrase Schumpeters, entrepreneurs helps the system to regenerate.

All professionals gathered here today have a responsibility to challenge the status quo and come up with inventions, innovations or creations to address the myriads of challenges confronting us as a Nation. These challenges present very viable opportunities that will elevate agricultural and bioresources as a gateway to diversify Nigeria's oil based economy, create wealth and job for the people and ensure environmental sustainability

Professionals in agricultural engineering need to keep stride with developments in science and technology, like central developments in biotechnology ,the information and communication technology, materials technology, microelectronics and mechatronics..

In line with these expectation of this conference, the sub themes offer realistic ways of providing solutions on how to diversify the Nigerian economy from oil. I have faith that this conference which is holding at this critical time when our economy is going through shock will produce academic and practical solutions on how to navigate the economy from the current recession not only in the short run, but help to diversify it for good.

I thank you for your audience and wish all professional bodies like NIAE a renewed resolve and visionary engagement in this renewed circle of nation building

HARNESSING RENEWABLE ENERGY FOR SUSTAINABLE AGRICULTURAL PRODUCTION IN NIGERIA

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INTRODUCTION

Agriculture is now appreciated as the 'green economy' and the flagship of the Nigerian economy. The use of available, accessible and acceptable energies on Nigerian smallholder farms is the key to unlocking this economy. There is a food crisis as indicated by the regular and steady increases in prices of food and malnutrition of the population. Agricultural production in Nigeria is beset with high cost of imported machinery, inappropriate machinery mix, low energy utilization and the continued dominance of the hoe-cutlass technology amongst others. Sustainable agricultural production means our ability to steadily maintain an appropriate agricultural production level over a very long period of time or forever, that will guarantee food security and unlock the green economy of Nigeria. The true story of agriculture today is that we have a world with 842 million malnourished and 1.5 billion obese people because consumers in the West spend on average 7% of their incomes on food while people in Asia and Africa spend as much as 60 - 70% (Sirinathsinghji, 2014). There is thus simultaneous malnutrition and obesity.

Renewable energy (RE) is inexhaustible energy that derives from the sun. The common types of RE that have found use in agriculture include solar thermal, solar photovoltaic (PV), wind, biofuels - bio-ethanol, bio-diesel, and biogas. Renewables contributed 18.4% to the global energy mix, out of which bio-energy contributed 14.2% (Fig. 1). The production of energy from renewable sources is increasing. E. g. solar PV is the fastest growing energy sector in the US market recording 67% growth. There is a huge potential for renewables; it is estimated that 0.4% of total land on earth covered by low 10% efficient panels can meet the total worldwide energy demand. The energy from the sun is 385 billion billion MW! The earth receives 95 billion MW of this energy, which is about 95 million typical sized nuclear power plant. Renewables are contributing to reduction in unemployment and increase in revenue. The PV industry generated $93 million in global revenue in 2011 and the solar energy sector is estimated to have generated 1.2 million new employment opportunities since 2011.

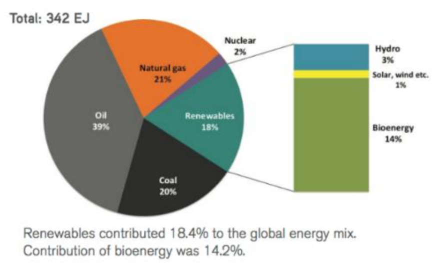

Fig. 1: Global energy consumption in 2012

The justification for the increased use of RE is the narrowing gap between crude oil production and consumption (Fig. 2). At the current production, resources will be depleted in 31 years (Table 1). The use of RE is driven by governments of the world, providing favourable policies to accelerate the dispersal and deployment of renewable energy technologies (RETs). The most successful government policies on RE include feed-in-tariff, tax incentives/rebate, tax relief, RE credits/carbon credits and interest-free loans and financing. The International Solar Energy Society (ISES) white paper (Holm, 2005) identified the following factors as mitigating the dissemination of RE in developing countries: lack of regulations governing market/electric grid access and quotas mandating capacity/generation, lack of financial interventions and incentives. Others are insufficient education and information dissemination, lack of industry standards, planning permits and building regulations (codes) and absence of public ownership and stakeholder involvement.

This paper discusses how RE can be harnessed for sustainable agricultural production in Nigeria.

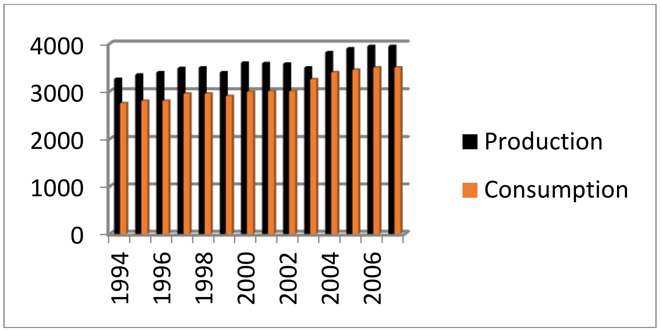

Fig. 2: World fuel production and consumption
(Source: IEA World Energy Statistics, 2007)

Table 1: World fuel reserve

Fuel	Reserve
Coal	200 years
Crude oil	40 years
Natural gas	62 years
Region	Reserve (crude oil)
Western Europe	< 10 years
North America	25 years
Middle East	100 years
Nigeria	40 years

Outlook of world agriculture

Discussing sustainable agriculture without a mention of a mention of agricultural mechanization is meaningless because mechanization is the driver of agricultural production. It is estimated that inappropriate mechanization has over the years caused the collapse of small family farms in developed countries. The failure of agricultural mechanization in developing counties has left about 1.4 billion people undernourished and poor, 70 - 80% living in rural areas, who can no longer afford to buy enough food, even when food is available (Ho, 2013). The Institute of Science in Society report (Ho, 2013) stated that small farms (less than 2 ha) dominate the world today; 800 million hectares of the 1.6 billion hectares of global croplands are smallholder farms cultivated by 99% of the world's 2.6 billion farmers, producing70% of the food consumed. 70% of these famers are women. These small farms are known to be 2 to 10 times as productive as large industrial farms, and much more profitable.
The thinking now is that the inter-related problems of agriculture can be solved by a paradigm shift away from the industrial agriculture and globalized food system to a conglomerate of small, bio-diverse, ecological farms around the world and a localized food system that promotes consumption of regional produce (Ho, 2013). Current production practices must support this thinking.

A snapshot at Nigeria's agriculture

Nigeria is made up of 98.32 million hectares of land and of this available land, 74.036 million hectares (75.3%) may be regarded as arable. Table 2 is employment in crop farming by gender and category of workers in Nigeria as at 2009 (NBS, 2012). There were 16,636,279 farmers in Nigeria of which 3,346,589 (20.2%) of them are women. The farmer population represents about 10.4% of the estimated Nigerian population of 160 million. Therefore, the available land per farmer is about 4.5 hectares. Kaduna state has the highest farmer population of 1,433,702 farmers followed by Jigawa state with a farmer population of 1,024,354. Bayelsa state has the least farmer population of 384,248 while the Federal Capital Territory has the least female farmer population of 1,109.

Table 2: Employment in crop farming by gender and category of workers in Nigeria, 2009

STATE	FARMERS		UNPAID FAMILY		PAID EMPLOYEES	
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE
Abia	176,802	130,347	237,642	275,956	261,820	254,466
Adamawa	386,092	52,659	308,448	204,673	175,255	38,813
Akwa Ibom	223,318	107,434	127,331	171,136	33,448	42,851
Anambra	341,406	282,738	273,941	275,125	257,413	174,002
Bauchi	790,207	4,381	657,081	153,125	392,683	30,049
Bayelsa	72,220	41,134	54,912	59,826	96,708	35,107
Benue	322,025	125,581	499,381	511,520	190,879	236,577
Borno	426,039	11,238	275,376	289,509	207,637	103,995
Cross River	280,025	124,126	363,484	335,175	299,183	276,154
Delta	294,924	145,247	179,021	212,038	237,516	59,482
Ebonyi	395,283	264,962	449,742	436,744	479,463	390,672
Edo	247,599	104,579	191,831	225,347	213,180	46,195
Ekiti	117,791	16,848	57,866	67,106	159,001	17,423
Enugu	203,996	115,628	87,536	139,908	49,754	56,836
Gombe	368,973	88,052	436,431	200,684	461,243	377,090
Imo	511,638	122,647	304,985	526,812	100,357	307,188
Jigawa	1,021,184	2,985	498,425	129,920	278,185	36,873
Kaduna	1,049,454	384,248	949,563	540,881	676,828	343,426
Kano	415,553	234,465	1,223,889	581,939	1,119,608	374,848
Katsina	227,862	131,043	1,030,020	247,927	1,050,565	308,728
Kebbi	205,696	109,183	544,950	213,450	401,147	124,674
Kogi	134,423	352,307	60,242	325,355	127,396	
Kwara	285,961	17,591	191,272	132,841	146,640	34,422
Lagos	456,961	27,250	121,038	125,281	139,127	67,955
Nassarawa	285,594	35,019	223,303	169,599	115,985	50,141
Niger	456,961	3,279	563,022	385,006	360,661	289,363
Ogun	200,226	54,933	181,091	175,636	314,359	26,103
Ondo	237,416	47,806	212,503	239,374	307,488	265,083
Osun	322,331	31,130	189,191	271,585	309,500	205,870
Oyo	338,531	62,534	167,470	287,719	789,131	146,499
Plateau	307,229	35,180	374,203	380,698	1,145,386	132,795
Rivers	284,053	160,190	362,450	460,124	394,052	545,915
Sokoto	467,777	11,785	563,839	150,260	547,071	175,214
Taraba	325,709	15,083	389,355	238,167	243,550	108,895
Yobe	493,462	20,392	542,055	83,035	131,015	38,297
Zamfara	482,270	233,783	454,731	311,129	552,969	599,071
FCT	119,699	1,109	113,568	108,653	123,262	42,542
Nigeria	13,276,690	3,356,589	13,753,253	9,378,150	13,087,424	6,491,010
Source: NBS/CBN Socio- Economic Survey On Nigeria, 2010.						

Table 3 is agricultural machinery, 4 - WD tractors per 100 square km (10,000 ha) of arable land in Nigeria compared to some countries from 2003 to 2006 (World Bank, 2012). Nigeria has an average of 7 tractors for every 100 km^2 of arable land compared to 100, 1900 and 64,000 tractors for Algeria, Ghana and South Africa respectively. In Nigeria where 'tractorization' is misconstrued for mechanization, the table shows that mechanization is, therefore, almost zero. This means that Nigerian agriculture is still dominated by the hoe-cutlass technology.

Table 3: Agricultural machinery, tractors per 100 km^2 of arable land

Country	2003	2004	2005	2006
Nigeria	6.9	7.0	6.6	6.8
Algeria	97,800	97,809	100,128	102,636
Ghana	1,920	1,912	1,803	-
South Africa	65,475	63,200	-	-

Source: World Development Indicators

The Nigerian hoe-cutlass farmer, therefore, deserve our praise (Itodo, 2005):

Our Burden, His Burden
(An ode to the hoe-cutlass farmer)

It is dawn
cockcrow everywhere
I am awaken
darkness still over the world

With my weapon of life
I hold
supported on my left shoulder
I journey
To the forest on tired legs
miles to my field of life
where I own your burden
all the days of my life

Till my end days
I bear pains
of bowed waist
my harvest but not plentiful

It is dusk
I return
to my hut
where peace is peace

In my dream
I see tomorrow
tomorrow like yesterday
I will bear your burden

Nigerian agriculture is characterized by poor mix of machinery and lack of electrical energy to power prime movers on agricultural machines such as rice threshers, maize shellers, grain grinders, etc in remote rural farm locations. The 4 - WD tractor that has supported the partial mechanization of our agriculture, remains the symbol of Nigeria's mechanization efforts. The other machinery that should augment the tractor to enable the attainment of full mechanization are almost non-existent. The Nigeria agricultural system lacks such machinery as cultivators, boom sprayers, land planes, chisel plough and harvesters. Of course, the mechanization of tuber and indigenous crops is zero as there are no known machines for planting, weeding, harvesting and processing of yam and cassava crops.

Renewable energy controversies

The controversies arising from the use of RE derive largely from the production and use of bio-fuels such as bio-ethanol and bio-diesel. Some of the diverse opinions on RE, which are generating controversies are:

4.1 The use of food crops for bio-fuel production is responsible for the world's food and hunger crisis. Bio-fuels are conservatively estimated to have been responsible for at least 30% of the global food price hike in 2008 that pushed 100 million people into poverty and drove some 30 million people into hunger (Action Aid, 2010). If all global bio-fuel targets are met food prices could rise by up to an additional 76% by 2020 and starve an extra 600

million people. FAO estimated that in 2008/09 125 million tons of cereals were diverted into bio-fuel production. In 2010, more cereal (1107 million tons) was diverted into animal feed and industrial use than for feeding people (1013 million tons). Action Aid reports that in 5 African countries, 1.1 million hectares of land have been devoted to the production of bio-fuels for export, while 1.4 million hectares were for food production for export. In Mozambique, farms were destroyed for industrial bio-fuels, conferring hunger on the rural population (Ho, 2010).
4.2 Food and fuel are competing everywhere for land. EU companies require and have requested for at least 5 million ha of land for industrial bio-fuels. To meet EU's 10% target would require 17.5 million ha of land for growing bio-fuel crops in developing countries (Ho, 2010).
4.3 Bio-fuels are not carbon-neutral! It is generally accepted that bio-fuels are carbon-neutral because no net CO_2 is added to the atmosphere. But this is only true if no fossil fuel energy is expended in growing the biomass, producing the fertilizer and the destruction of the natural carbon sinks during land clearing (CAT, 2010).

5.0 World renewable energy outlook

Hydro power is the leading RE followed by wind, solar PV and biomass (Fig. 3). The regional distribution of cumulated installed power capacity at the end of 2013 (Fig. 4) shows that Africa is almost completely dependent on installed hydropower. Asia, Europe, North and Central America have significant capacities of installed wind and solar PV power. Table 4 is worldwide installed power capacity of RET for grid connected generation and estimated annual energy generation in 2013. The table showed a cumulated installed capacity of 1,658 FW from all the RE sources with a growth rate of 21% for cumulated installed capacity. The table also showed that the electricity generation from all RE sources was 4,916.4 - 5,224 TWh/year. It is estimated that over 1.2 million direct and indirect new jobs would be generated if a portion of South Africa total energy needs, including fuels, were sourced with RETs by 2020 (Banks and Schaffter, 2005).

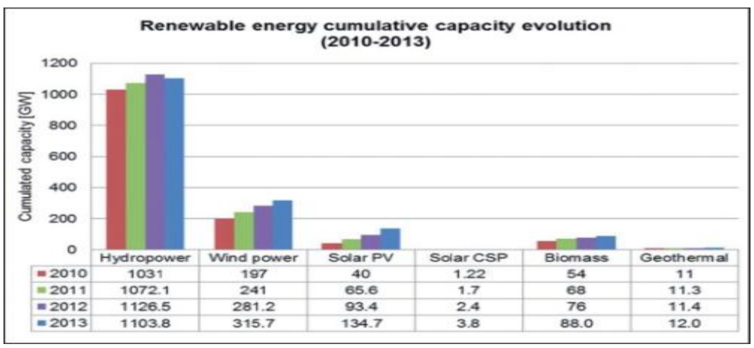

Fig. 3: Worldwide renewable energy cumulative capacity generation (2010 - 2013)

Biogas for energy is a growing trend in about 50 countries of the world especially China, Sweden, Germany and the UK. Several European countries are expanding their total share of power from biomass - Australia (7%), Finland (20%) and Germany (5%). Electricity generation from biogas mainly takes place in industrialized nations. Global players in biogas markets are Germany and UK generating 9 - 10 TWh and 5 - 6 TWh respectively.
Biogas is widely used in Asian countries like India and China where its use has minimized the drudgery of household activities such as hewing firewood from the forest. Biogas is considered as the key to China's rural development. As at 2007, there were about 26.5 million biogas plants with a combined output of 10.5 million m^3 of biogas. The technology is promoted in India by the Khadi and Village Industries Commission and the Gobar Gas Scheme.

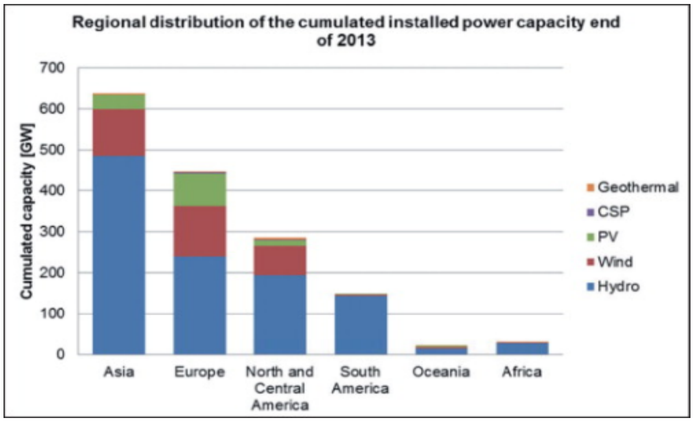

Fig. 4: Regional distribution of cumulated installed power capacity (2013)

Table 4: Worldwide installed power capacity of RET for grid connected generation and estimated annual energy generation in 2013

Renewable energy type	Cumulated installed capacity (GW)	New Installed capacity (GW)	Growth of cumulated installed capacity (%)	Growth rate of newly installed capacity (2012-1013)	Estimated electricity generation (TWh/y)
Hydropower	1,103.8	39.9	5%	35%	3,704.9
Wind power	315.7	35.4	13%	-21%	683.0
Solar PV	134.7	36.3	41%	25%	140.6
Solar CSP	3.8	1.2	56%	63%	6.8
Biomass	88.0	4.3	5.1%	-55%	308-816
Geothermal	12.0	0.5	4%	42%	73.0
World total	**1,658.0**	**117.5**	**21%**	**15%**	**4,916.4 -5,224.4**

Biogas is used in Sub-Saharan African countries like Tanzania, Burundi, Cameroon and Benin Republic and is promoted by the Biogas Extension Programme (BEP) of the GATE, German GTZ. Biogas is the main energy feature of the Songhai Farm Centre, Port Novo, Benin Republic. In Tanzania, the Technology is promoted by the Centre for Agricultural Mechanization and Rural Technology (CAMARTEC).

Fig. 5 is share of bio-fuels production by region from 1993 to 2014. The biofuels production in North America increased from 27.4% in 1993 to 44.1% in 2014. Similarly it increased from 3.3% in 1993 to 10.6% in 2014 for the Asian Pacific region. Africa is not shown in the figure, indicating an insignificant production of bio-fuels (British Statistical Review of World Energy, 2015). Ten countries have made it mandatory to blend bio-ethanol and bio-diesel with fossil gasoline and diesel respectively. They are Paraguay, Brazil, USA, Philippines, Costa Rica, Argentina, India, Jamaica, Canada and China.

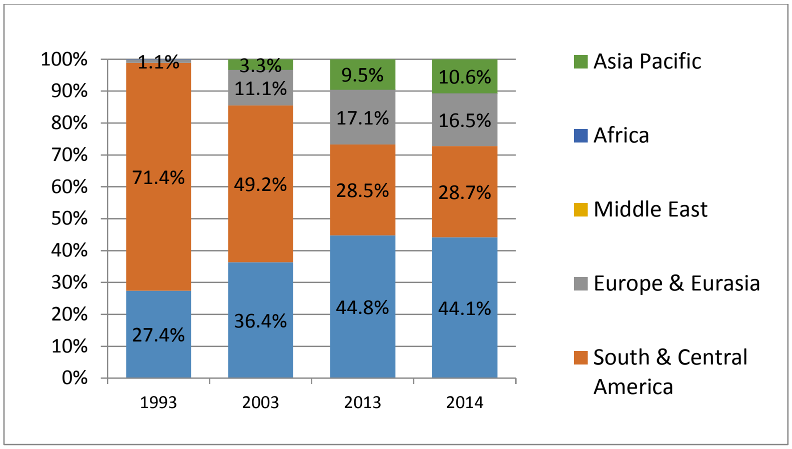

Fig. 5: Share of bio-fuels production by region

The Addex Bioenergy project in Sierra Leone produces 85 million litres of ethanol from sugarcane yearly and employs 3,600 people directly during high season. The project delivers 15 MW of electricity to the national grid and accounts for 20% of the power production in Sierra Leone. The project has also had a positive impact on agriculture and the economic development of the region (www.addaxbioenergy.com).
Ethanol production has been implemented in Zimbabwe, Malawi and Kenya. Zimbabwe produces 40 million litres every year. The Malawi Ethanol Company Limited, the sole producer and distributor of ethanol since 1982 produces 13 million litres annually. The Agro-Chemical and Food Cooperation of Kenya established in 1978 with an average output of 60,000 litres a day produces an average of 45,000 litres in a day (Goldernberg et al, 2004).

Profiles of renewable energy in Nigeria

Table 5 is Nigeria's renewable resources (ECN, 2005), which shows the enormous renewable energy potential of Nigeria. Biomass currently account for 97% of household energy needs of Nigerians. The average annual wind speed of 2.4 m/s limits the use of wind energy because wind energy can most effectively be harnessed in locations with wind speeds of not less than 5.0 m/s. Consequently, the use of wind energy is restricted to few locations such as the coastal areas, the high lands of the plateaus and the windy arid locations of the far north. Of the combined large and small - scale hydropower capacity of 10,734 MW, only 1,000 MW of electricity is currently being generated and utilized from the hydropower stations at Kainji and Shiroro. The livestock population of 289.7 million generates about 61 million tonnes of waste in a year, 50% of which can generate 40 MW of electricity in a year when subjected to biological gasification. This amount of electricity represents 0.2% of Nigeria's electricity needs. By the Energy Commission of Nigeria's projection, biomass will add 3,345 MW of electricity by 2025, although Nigeria presently has no single biomass-fired electricity generating plant despite the abundance of biomass.

Table 5: Nigeria's renewable resources

Energy source	Capacity
Hydropower, large scale	10,000
Hydropower, small scale	734 MW
Fuelwood	13,071,464 ha (forest land 1981)
Animal waste	61 million tonnes/year
Crop residue	83 million tonnes/year
Solar radiation	3.5-7.0 kWh/m^2-day
Wind	2.4 m/s (annual average)

(*Source: ECN, 2005*)

Currently, there are no biofuels - bio-ethanol and bio-diesel producing plants in Nigeria. Bio-fuels are, therefore, not in use. However, the Nigeria National Petroleum Corporation (NNPC) Automotive Biomass Programme is proposing the building of bio-ethanol plants using sugarcane for blending with gasoline as transport fuel. There are two functional biogas plants in Nigeria; a 3 m^3 floating drum plant at the University of Agriculture, Makurdi (Fig. 6) and a fixed dome plant at the Sokoto Energy Research Centre, Usmanu Danfodio University, Sokoto. The use of solar photovoltaic in generating electricity is growing rapidly. Solar PV has found application mostly in the built environment and agriculture for irrigation and the farmsteads. The actual contribution of solar PV to Nigeria's electricity generation and consumption has recently not been appropriately estimated.


(a) Biogas plant


(b) Burning flame from the plant

Fig. 6: Picture of the biogas plant at the University of Agriculture, Makurdi

Critical factors in the production and utilization of RE resources

Biomass

Solid, liquid and gaseous fuels can be obtained from biomass. Solid biomass fuel include fuelwood. The liquid biomass fuels that have gained acceptance are bio-ethanol and bio-diesel. Biogas is the most commonly used gaseous biomass fuel. Fig. 8 are the pathways for producing energy from biomass.

The critical factors in the production and use of bio-ethanol and bio-diesel are:

Bio-ethanol

1. The removal of water from the bio-ethanol during the distillation process in order to attain 100% bio-ethanol (E100) is critical to the quality of the ethanol as engine fuel. At a point in the separation, azeotrope is attained making it impossible to remove the water by simple multiple fractional distillation, thus requiring the use of a reflux column.
2. The blending of bio-ethanol with gasoline should not exceed 10% of pure bio-ethanol (E100) mixed with 95% of gasoline (E10). If otherwise, adjustments will have to be made on the spark ignition engine.

Bio-diesel

1. The free fatty acid (FFA) content of the oil that is transesterified into biodiesel is critical. Oils with high FFA don't transesterify. Excess FFA must first have to be removed from the oil.
2. The purification of the bio-diesel to a water-free specific gravity of 0.88 is also important for its used as engine fuel.
3. The blending of bio-diesel with fossil diesel should not exceed 20% of pure bio-diesel (B100) mixed with 80% fossil diesel (B20), otherwise changes will first have to be undertaken in the engine.

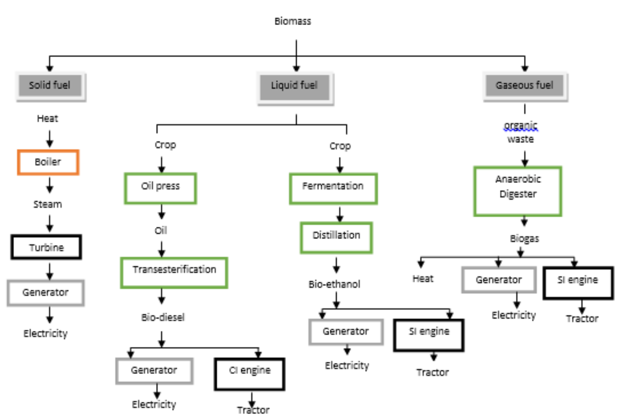

Fig. 8: Pathways for producing energy from biomass

Solar thermal
Solar radiation is the most abundant energy resource on earth. However, its utilization requires a deep knowledge of the solar system, understanding the daily, hourly and monthly position of the sun at a given location. This will enable the appropriate determination of the facing direction and sloping angle of solar collectors at any given location (latitude).

Solar photovoltaic

1. In utilizing solar for electricity generation, it is important to ensure that most of the solar radiation is incident upon module during the solar window; only then can the maximum output of the module be achieved because the modules respond linearly to the amount of solar flux incident upon it. Therefore, the facing direction, sloping and azimuth agngles of the modules must be carefully selected.
2. The design of solar - powered PV systems must take into account at least two days of presumed cloudiness, which assumes that there will be no sunshine for two dys and therefore, the battery storage capacity must be higher to prevent system failure if this incidentally happens.
3. Also, battery storage capacity of solar PV systems must take into account the efficiency and depth of discharge of the batteries selected for use.
4. Similarly, the efficiency of inverters employed in converting d.c electricity from solar powered systems to a.c electricity for various applications must be considered in designing the system.

Harnessing renewable energy in Nigerian agriculture

The justification for applying renewable energy in agriculture is that industrial agricultural systems are responsible for 44 - 47% of all greenhouse gas emissions. The issue on the agenda now is how to produce food without adding more greenhouse gases to the atmosphere. It is generally recognized that emissions from land use change and deforestation are due to agriculture and food-related transport, processing, storage and consumption (Ho, 2013). Indeed, it is now believed that agriculture is the problem and solution to climate change.
There are many benefits of using RE in Nigerian agriculture. The application of RETs in Nigerian agriculture promotes rural development by improving rural infrastructure. It creates employment, facilitates technology transfer and enhances international collaboration. Also, energy security and independence is improved because of the decentralization of electricity generation.RE will boost agricultural production, which will stimulate more cottage industries resulting in improved rural livelihood and increased economic activities in the villages. Fig. 9 is the picture of a tractor-drawn solar powered rice thresher developed at the University of Agriculture, Makurdi. Table 6 is the application of RE in Nigerian agriculture for sustained production.

Fig. 9: Picture of solar- powered rice threshing machine at the University of Agriculture, Makurdi

The current status, limitation and application of the various RE sources in Nigerian agriculture are shown in table 6. Fig. 10 is picture of a biogas-powered tractor at the International Biomass Conference Expo 2016 at the Convention Centre, Charlotte, North Carolina, USA. This shows the growing application of RE in agriculture worldwide.

Table 6: Application of RETs in Nigerian agriculture

RE type	Limitation	Application	Current status in Nigerian agriculture
Bio-ethanol	1. Limited by the use of food crops 2. Higher pump price	Blended with gasoline in SI engines used on machines	Application is currently zero
Bio-diesel	1. Limited by the use of food crops 2. Higher pump price	Blended with diesel in CI engines used on machines	Application is currently zero
Biogas	1. Low pressure system requiring boosting before use in many applications. 2. Gas requires purification for some uses	• Crop heating and drying • Cooking • Production of organic fertilizer • Management of agricultural wastes • Production of animal feed • Electricity generation for lighting of livestock houses and farmsteads	• Application is very low • Existing biogas plants are largely for demonstration.
Solar-thermal	No known limitation	• Crop drying • Desalination of saline water • Provision of hot water in livestock houses • Provision of hot water for processing of crops, e.g. parboiling of rice	Use is very high for open air sun drying and zero for other applications
Solar PV	High cost of solar modules and batteries	• Power agricultural machines like threshers • Power irrigation gadgets • Lighting of livestock houses • Heating of livestock houses • Lighting of farmsteads • Refrigeration of agricultural products	Application is presently low but is increasing
Wind	High investment costs, thus unaffordable to the smallholder farmers	• Crop processing such as powering electric motors that can be used in threshing etc. • Refrigeration of agricultural products • Heating of livestock houses • Power irrigation gadgets • Lighting of livestock houses • Lighting of farmsteads • Providing hot water for processing of crops	Application is zero

Fig. 10: Biogas-powered farm machinery at the Expo

The role of the Nigerian Institution of Agricultural Engineers in sustainable agricultural development in Nigeria

The Agricultural Engineer remains the main agent of agricultural production, be it the arable crop or livestock enterprise, supporting the farmer (crop and/or livestock farmer) achieve his initiative and production plan. Our discussion at this year annual conference should dwell on our roles in delivering sustainable agriculture in Nigeria. The NIAE should invite the policy, researcher, on-the-farm, legislature and businessman Agricultural Engineers to put together a document on sustainable agricultural production in Nigeria. The proposed document must address the availability, accessibility and acceptability of the various forms of energy on our smallholder farms, appropriate machinery mix, development of tuber crop machines and appropriate postharvest gadgets. The document should also consider pilot plants for food processing, preferential use of the 2-WD motorized farm machinery, smallholder irrigation, livestock housings and agricultural waste management.

This document should be considered as a proposal from a learned society to the government. The document should assign roles to the NIAE, NCAM, Departments of Agricultural Engineering in the universities and polytechnics, the International Institute for Tropical Agriculture (IITA) and other learned societies such as the Solar Energy Society of Nigeria, Nigerian Institution of Mechanical Engineers, Nigerian Institute of Food Science and Technology, Nigerian Institute of Animal Production, etc. These roles may include review of the agricultural engineering curriculum, re-prioritizing research focus of the profession and appropriate policy interventions. This may not be a once-for-all document. It becomes the ideological and practical green book of the profession, and is subject to periodic review to ensure delivery.

CONCLUSION

It is concluded that:

1. The application of RETs in Nigerian agriculture is inevitable for sustained production, increased output, reduced drudgery and glamourisation our agriculture. Currently, the application of RE in Nigerian agriculture is very low except for the open air sun drying of crops and the increasing use of solar PV for electricity generation. However, there is a high prospect for use of RE in Nigerian agriculture in the coming years.
2. The use of RET on Nigerian smallholder farms will result in value chain addition, improved food security, reduction in youth/graduate unemployment, simulation of cottage industries and development of infrastructures in the rural communities.
3. The NIAE should through its appropriate committees ensure that RE is integrated into our agriculture by proposing a review of the agricultural engineering curriculum, instituting prizes for novel indigenous developed RE-powered machines, developing a practical sustainable agricultural production policy and practice document for adoption by government and effective liaison with other busy-bodies in Nigerian agriculture.

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AGRICULTURAL PRODUCT PROCESSING, VALUE ADDITION FOR FOOD SECURITY AND JOB CREATION

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INTRODUCTION

For an economy but in particular for a developing economy, agriculture is a very important sector. Besides ensuring food security, employment and the supply of raw materials to industries, agriculture is the base for the development of other sectors of the economy.

The ultimate aim of agricultural production is to get agricultural products to the consumers in the form that will be useful to them. Food items including meat, fish, milk and products, eggs and products, fruits, vegetables, cereals, legumes, roots and tubers are some of the common agricultural products.

Nigeria has a highly diversified agro ecological condition which makes possible the production of a wide range of agricultural products. Agriculture has therefore always been an important activity in the Nigerian economy, providing gainful employment and livelihood for the populace.

Though Agriculture is the leading contributor to Nigeria's GDP with 35.75% in 2015, it has continued to underperform other sectors of the economy, falling from 42% of the GDP in 2009. This trend is projected to continue till 2017 with agriculture forecast to contribute 33.86% in 2017 (First Securities Discount House Limited (FSDH) Research on Nigerian Economic Outlook 2013-2017)

Given the influence of agriculture on the Nigerian economy – value addition and employment, it is inconceivable that the country can continue to grow without a significant improvement to agriculture.

AGRICULTURAL PRODUCT PROCESSING

Agricultural processing takes place after the crops are produced. Agricultural processing is simply transforming the primary agricultural products into other useful products. The ultimate aim of processing is to preserve or improve the quality of agricultural products and thereby minimizing losses. Processing of agricultural products leads to storage or consumption of it. Moreover processing agricultural produce adds more value to the produce, increases its shelf life, enhances its qualities, increases its versatility and most importantly increases the selling price.

Processing Common Nigerian Crops

For the purpose of processing, agricultural produce are grouped into cereals and legumes, tuber and root crops, fruits and vegetables and cash crops. The common Nigerian crops include rice, cassava, yam, maize, oil palm, guinea corn, and groundnut as well fruits and vegetables such as plantain, banana, oranges, mangoes, pawpaw, cashew, carrot, and amaranth. Some are more in certain areas than others. The processing and storage of these crops can be a source of income as they can also create job for the unemployed. It is worthy of note that different methods are used in processing these crops. Each of the unit operations involved in the processing of these crops may be carried manually or through the use of machines. The major fruits produced in Nigeria include mango, pineapple, plantain/banana, citrus, guava, pawpaw, while vegetables include onion, tomato, okra, pepper, amaranthus, carrot, melon, Corchorus olitorus (ewedu), Hibiscus sabdariffa (sobo), Adansonia digtata (baobab leaves) etc. Nigeria is the largest producer of pineapples in Africa, producing 903,000 metric tones, Nigeria is also the largest producer of mangoes in Africa with 620,000 metric tones. Tomatoes has domestic demand of 2.3 million tonnes annually, national production is estimated at 1.8 million tonnes, with wastage of over 750,300 tonnes, According to FAO estimates, Nigeria currently produces over 100,000 metric tonnes of Kola nut, which finds use in the manufacture of beverages, liquor, and confectionaries. Yet, local processing units are rare and exports are largely limited to fresh and dry nuts with little value addition.

Processing of Livestock

Nigeria is endowed with an estimated 19.5 million cattle, 72.5 million goats, 41.3 million sheep, 7.1 million pigs, 28,000 camels, 145 million chickens, 11.6 million ducks, 1.2 million turkeys and 974, 499 donkeys which had made Nigeria number one in livestock in Africa. (Federal Ministry of Agriculture, 2016, National Agricultural Sample Survey 2011). Data from the CBN, and FAO indicates that from cattle, less than 2kg of beef is available to an average Nigerian per year and just mere 4kg of eggs per annum is available to each Nigerian. In fact, milk production has been nose diving or at best has remained constant since 2000.

Meat processing
Livestock produced include cattle, goat, sheep and pig. Cattles are produced in large quantities by the Fulani cattle rearers, livestock share of agricultural GDP declined from 24 percent in 1980 to 6 percent in 2010; (CBN, 2010). They are common in the northern part of Nigeria. Cattles are produced for the meat and dairy. The skins of the cattle are further processed into hide and skin for the leather and shoe industries. Meats are locally prepared at abattoirs (badly managed). The unit operations include slaughtering, washing and cutting before storage or sales.

Poultry Production and Processing
Poultry are raised for the meat and egg. Poultry meat is processed by slaughtering, de-feathering, cutting before storage. Poultry industry is one of the fastest growing segments of the agric sub-sector in Nigeria. It accounts for 9-10% of the agricultural GDP with net worth value of over 250 million USD. Poultry population is 140 million sub-divided into Commercial (25%), Semi-Commercial (15%) and Rural/Backyard (60%).Poultry farming is an integral component of livelihood for both rural and urban middle income earners providing a source of income and nutrition. The estimated one billion table eggs and 500,000 metric tonnes of poultry meat are produced annually

Fish Production and Processing
Fish can be processed by drying, smoking or cold storage. This is a money spinning venture now. Most efforts to increase production are focused on meeting domestic demand. There is currently little use of processing by products, such as fish meals and oils, which are generally discarded. There is potential for growth in the aquaculture industry, which the government has supported since the 1960s (FAO, 2008). Currently, most operations are small and private, but some larger companies are attempting to develop economies of scale

Milk Processing
Milk, in its fresh and natural form, is just a simple product and raw material. Although fresh milk can be consumed directly by humans, not very many people can enjoy the privilege. Some of the most popular dairy (milk-based) products that sell huge volumes in Africa include:

- ***Powdered milk*** (or milk powder) is produced by removing water from milk. It is the most common type of milk in African markets and is preferred because it is compact and long lasting.
- ***Pasteurized milk*** – usually available in liquid form as ordinary (non-sweetened), evaporated or condensed (sweetened) milk.
- ***Ice cream*** – this frozen dessert is very popular especially in Africa's urban areas. There's a wide variety of ice cream on the market made from several different ingredients and flavours.
- ***Yoghurt*** – Is definitely the most popular dessert in Africa after ice cream. It is a fermented milk product produced by the bacterial fermentation of milk.
- ***Infant formula*** (baby food) – Another major product produced from dried milk powder with specific additives for feeding human infants.
- ***Cheese*** – is one of the world's most popular milk products. There are over 100 types of cheese in a wide range of flavors, textures, and forms.

Milk processors tend to make more money than producers because they add value to 'ordinary' milk, and transform it into products that are more attractive to consumers in a variety of ways. Over 100 variants from raw milk as against 25 from oil.
However, processing milk (depending on the size of the business and end product) may require a significant investment in machinery and labour.

Agricultural Products and Food Security
The 1996 World Food Summit adopted a more complex definition: "Food security is a situation that exists 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 preferences for an active and healthy life" (FAO). "Food security, at the individual, household, national, regional and global levels [is achieved] when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life".
To increase food security, the world needs farmers at every level of production to be successful. First, smallholder farmers need training in agricultural best practices and access to inputs, credit, storage and technology to increase their productivity in a sustainable way, which raises their own living standards and produces surpluses to help nourish others. Second, farmers need some form of revenue certainty. Smallholder farmers often are forced to sell at harvest

when they are cash flow destitute and have limited access to real credit. Selling at depressed prices creates a cycle of discouraging further production in future years. Farmers in developing countries need reliable markets into which to sell their crops each season and an adequate price to compensate them for their efforts and provide incentive to continue production the following year. Third, farmers need access to crop insurance and other risk management tools so they can rebound from crop failures or other growing season fluctuations. And fourth, farmers must be able to own their land and pledge it as collateral if they are expected to reinvest and raise their productivity over time.

Value Chain in Agricultural Product Processing

Agriculture in Nigeria often is characterized by dual value chains operating in parallel for the same product: one informal or traditional, and the other formal or modern. Small holders are frequently involved in informal chains that deliver products to local middlemen and then to small local stores. Formal value chains can deliver the same product, usually in better or more uniform quality, from larger farms or more organized groups of small farmers to more commercial wholesalers and from there to supermarkets or exporters. This duality has been accentuated by the explosive growth of supermarkets in developing countries. It can limit many small producers to markets characterized by low-quality products, and low prices and low returns for them — hence a frequent concern is to find ways to integrate small producers into more modern value chains, both domestic and export-oriented; the need for out grower scheme solves this problem.

Agricultural Products Processing and Job Creation

Fruits and vegetables generate more jobs per hectare, on-farm and off-farm, than staple based agricultural enterprises. This benefits farmers and landless laborers in both rural and urban areas. Value addition to fruits and vegetables generates further employment in the associated agri-businesses and further down the commodity chain from the producer to the consumer. Fruits and vegetables can generate higher profits than staple crops, especially when land is relatively scarce and labor is abundant. The value of fruits and vegetables per unit area is significantly higher than the value of the cereal crops. Although the costs of inputs such as labor can be higher, the profits are higher and the income thus generated can be used for many different purposes in terms of eradication of hunger and affording access to education and health care.

Below is an illustration of processing agricultural products with its value addition, food security and job creation

Tomato (Boosting Production and Creating Domestic Paste Processing Capacity)

Opportunity Description

- Nigeria is a major consumer of tomato paste; although 20%-30% of paste consumed in Nigeria is "produced" domestically, ~25%-50% of the inputs for this domestic paste is double-concentrated paste imported from China.
- Many domestic players are already involved in the latter half of this equation (re-processing, packaging, and marketing double concentrate combined with other inputs); however, the market for domestically produced double concentrate remains underserved.
- At industrial-scale production levels and with enforcement of existing import tariffs, Nigerian double concentrate sold to domestic or West African processors / re-packagers can be price-competitive with Chinese imports.
- The investment could be used as a platform on which to expand into further value-added processing activities (i.e., re-packaging, marketing) following several years of successful operation.

Market Size

- The size of the Nigerian market for tomato paste is approximately 200,000 tonnes per annum, with proximity to a broader West African market of 300,000-400,000 tonnes per annum.

Competitive Intensity

- Imports of double concentrate from China make up 55,000tonnes of the domestic tomato paste market.
- Currently the only domestic producer of double concentrate within Nigeria is Ciao

Target Customers

- Nigerian tomato paste processors / re-packagers including Vital, Gino, Tastitone, Derica, Olam, Chi, Dangote and Erisco.

Investment Return Potential & Start-Up Costs

- With a start-up cost of about $3.9m, a 75,000tonnes tomato processing project has a projected IRR of 20% and a payback period of 4 years.

Policy Issues, Entry Barriers and Key Risks

- Insufficient certified seeds available to farmers, hence supply chain inefficient from inception.
- Entry barriers incl. ensuring supply from smallholder / commercial farming, intra- and inter-state transport infrastructure, and ensuring demand from end-users; risks include import duties, competitor growth, and crop viability (*Sources; Nigeria Incentive Based Risk Sharing for Agricultural Lending NIRSAL, CBN*).

Cattle (Boosting Production to Milk and Meat)

Opportunity Description

- The Total Milk produce in Nigeria is less than 10% of the total milk required. (room for improvement).
- The total meat produce in Nigeria is less than 50% of the total meat required (room for improvement)

Market Size

- The Nigerian market size of Meat is N 1.1trillion.
- The Nigerian Market Size of Milk is N 3.1 billion supplies mostly of West Africa

Target Customers

- Nigerian populace, West African (*Sources: NAPRI, Zaria*).

CONCLUSION AND RECOMMENDATIONS

The Agricultural product plays a fundamental role in the creation of income and employment opportunities. The agro-processing sector is by far the most significant component in the agric industry and covers a broad area of postharvest activities, packaged agricultural raw materials, industrial and technology intensive processing of intermediate goods and the fabrication of final products derived from agriculture. Almost all farm produce can be processed into another product which leaves us with an enormous amount of choice plus the demand for processed product is far greater than that of the raw material used in making the product. To increase food security, the world needs farmers at every level of production to be successful. This paper therefore recommends;

1) Establishment of agricultural fund to finance and facilitate medium/large scale agricultural production, credit should be granted to farmers who are ready and willing to embark on medium/large scale farming to enhance employment, production for local consumption and for export in order to generate foreign exchange revenue for the Nigeria. The essence of the Fund is to address the most basic constraints facing agriculture, which is funding; and the disbursement of such funds should be through banks, which would do normal credit appraisal and rating.
2) Harmonization of agricultural research institutions, it is widely accepted that research and technology are the vehicles on which agricultural development move forward. A thorough analysis of the objectives, roles and activities of each institute should be made with a view to streamlining their operations for better and effective performance. The focus of the institutions should be to enhance yield in agricultural production through continuous research that would bring in new seedlings etc. Also, there is the need to commercialize research findings, government should set up Research Grants to assist research institutes execute research projects. The results can thereafter be sold to venture capitalists, commercial enterprises, or even purchased by the government itself.

MANAGEMENT OF LIMITED WATER AND LAND RESOURCES FOR IMPROVED AGRICULTURAL PRODUCTION IN NIGERIA.

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INTRODUCTION

As water and land resources around the world are threatened by scarcity, degradation and overuse, and food demands are projected to increase, it is important to manage the limited land and water resources for improved agricultural productivity. The demands of a burgeoning population, economic development and global markets has been met by unprecedented land-use change and water quality modification and hence there is need for the management of land and water resources for improved agricultural production needed to meet the food demand of the growing population. Unsustainable land and water use is driving both land and water degradation. Land degradation ranks with climate change and loss of biodiversity. Water degradation causes pollution, leads to loss of aquatic lives, poses a threat both to humans and the entire ecosystem.

Harmful and persistent pollutants, such as heavy metals and organic chemicals are still being released to the land and water from mining, manufacturing, sewage, energy and transport emissions; from the use of agrochemicals and from leaking stockpiles of absolute chemicals.

This paper highlights better management strategies for sustainable agricultural production through the effective management of land and water resources. Sustainable land management practices combines technologies, policies and activities aimed at integrating socioeconomic principles with environmental concerns, whereas Agricultural water resource management covers a wide range of agricultural systems and climatic conditions, drawing on varying water sources, including: surface water; groundwater; rainwater harvesting; recycled wastewater; and desalinated water.

Agricultural production in Nigeria currently faces big challenges arising from climate change and insurgency. In the past, most of the staples (grains) and vegetables were produced in northern part of the country. With insurgency, the land available for agricultural production is limited due to fear of abduction and land mines. On the other hand, climate change is not helping matters. Drought condition is on the increase and rainfall variability makes it difficult to predict the trend. The assessment of the dynamics and regime of a particular hydrological phenomenon in imperative; especially the time-based characteristics. Time-based characteristics of hydrological data are of great significance in planning, designing and operation of water resource system. This significance is informed more largely due to the variability and oscillatory behavior of hydrological sequences.

Rainfall which is the main source of water on the earth's surface, (especially in the tropics), is a complex atmospheric process which is space and time dependent and basically not easily predictable (Ramana et al., 2013).

In Nigeria, a study by Ahaneku and Otache (2014) on monthly rainfall time series of Ilorin, north central Nigeria using 43 years rainfall data attest to this fact. Results of analysis of the stochastic characteristics revealed that monthly rainfall time series does not show any discernible presence of long- term trend though there was a seeming inter-decadal annual variation.

In most areas, rain storms increase in both frequency and intensity giving rise to high runoff and less infiltration into the soil and consequent low aquifer recharge. Under these circumstances, a way out is to adopt soil and water conservation measures that favours infiltration and soil moisture storage, and minimize water evapouration from the soil surface.

In low rainfall areas especially, irrigation will in no small way help improve agricultural production. In this wise, sprinkler or micro-irrigation systems coupled with irrigation schedules to save water should be adapted. Deficit Irrigation or water productivity (maximum productivity per unit of water consumed) may also be adopted, provided the capacity of the farmers is developed to master the technologies/techniques involved through extension agents.

There is consensus that climate change over the next 20 years will affect farm production, with many regional differences in impacts. Changes may increase water requirements of crops, and increasing rainfall variability may exacerbate water scarcity in dry lands (Burke et al., 2006). Quantifying the current biological production for human consumption requires better estimates of global productivity of agricultural, grazed and human-occupied lands (Rojstaczer et al., 2001). In the face of current uncertainty, it would be prudent to conserve and manage the available land and water resources.

According to the World Resources Institute (Robert et al., 2013), the four most promising improved land and water management practices that are particularly relevant to the drylands of Sub-Saharan Africa are:

1. Agroforestry—the deliberate integration of woody perennial plants—trees and shrubs—with crops or livestock on the same tract of land.
2. Conservation agriculture—a combination of reduced tillage, retention of crop residues or maintenance of cover crops, and crop rotation or diversification.
3. Rainwater harvesting—low-cost practices—such as planting pits, stone bunds, and earthen trenches along slopes—that capture and collect rainfall before it runs off farm fields.
4. Integrated soil fertility management—the combined use of judicious amounts of mineral fertilizers and soil amendments such as manure, crop residues, compost, leaf litter, lime, or phosphate rock.

LAND RESOURCES MANAGEMENT PRACTICES

Land provides an environment for agricultural production, but it also is an essential condition for improved environmental management, including source/sink functions for greenhouse gases, recycling of nutrients, amelioration and filtering of pollutants, and transmission and purification of water as part of the hydrologic cycle.

Sustainable Land management practices combines technologies, policies and activities aimed at integrating socioeconomic principles with environmental concerns, so as to simultaneously:

- Maintain and enhance production (Productivity)
- Reduce the level of production risk, and enhance soil capacity to buffer against degradation processes (stability/resilience)
- Protect the potential of natural resources and prevent degradation of soil and water quality (protection)
- Be economically viable (viability)
- Be socially acceptable, and assure access to the benefits from improved land management (acceptability and equity)

More ecologically balanced land management can achieve both economic and environmental benefits, and this must be the foundation for further rural interventions. Without good land management, other investments in the agricultural sector may yield little. Water quality, Forest land quality, Rangeland quality and Land contamination/pollution are the biophysical components of sustainable land management.

DEGRADATION OF LAND RESOURCES

Anticipated human population increases and continued economic growth are likely to further increase exploitation of land resources over the next decades. The most dynamic changes in land use have been in forest cover and composition, expansion and intensification of cropland, and the growth of urban areas. Unsustainable land use drives land degradation through contamination and pollution, soil erosion and nutrient depletion. In some areas, there is an excess of nutrients causing eutrophication, and there can be water scarcity and salinity. Beneath land degradation lies disturbance of the biological cycles on which life depends, as well as social and development issues. Desertification and drought conditions most of the time are human-induced land degradation. Land degradation in the form of soil erosion, nutrient depletion, water scarcity, salinity and disruption of biological cycles is a fundamental and pertinent problem (Ahmad et al., 2007). Land degradation diminishes productivity biodiversity and other ecosystem services, and contributes to climate change.

The land needs to be conserved because it is the material medium for plant growth. On the land depends agriculture, shelter and profitable crop production hinges upon achieving a conducive soil environment capable of retaining adequate soil nutrient and water for sustained seed development and growth (Ahaneku, 2010). Considering the role the land plays in sustaining plant and animal life and the economy of the people, our very existence depends on the conservation of this all important natural resource base.

WATER MANAGEMENT PRACTICES

World-wide there is an enormous challenge to produce more food for the teeming population. Sequel to this enormous demand, there is need for increased agricultural production which can only be achieved by rightful management of the land and water resources. Consequently, it will be important in future that farmers face the right signals to increase water use efficiency and improve water management, especially as agriculture is the major user of water, accounting for about 70-80% of the world's freshwater withdrawals, mainly for irrigation (Ahmad et al., 2007). The scope of sustainable management of water resources in agriculture concerns the responsibility of water managers and users to ensure that water resources are allocated efficiently and equitably and used to achieve socially, environmentally and economically beneficial outcomes. It includes: irrigation to smooth water supply across the production seasons; water management in rain-fed agriculture; management of floods, droughts, and drainage; and conservation of ecosystems and associated cultural and recreational values. The goal of USAID (2015) water and development strategy is to save lives and advance development through improvements in water, sanitation and hygiene programs and through the

sound management and use of water for food security. Accordingly, agricultural water resource management covers a wide range of agricultural systems and climatic conditions, drawing on varying water sources, including: surface water; groundwater; rainwater harvesting; recycled wastewater; and desalinated water. It also operates in a highly diverse set of political, cultural, legal and institutional contexts, encompassing a range of areas of public policy: agriculture, water, environment, energy, fiscal, economic, social and regional. Future policies to address the sustainable management of water resources in agriculture will be greatly influenced by climate change and climate variability, including seasonality problems, such as changes in the timing of annual rainfall patterns. In some regions, projections suggest that crop yields could improve. For some localities, climate change will lead to increased stress on already scarce water resources, while other areas are expected to see the growing incidence and severity of flood and drought events, imposing greater economic costs on farming and the wider economy. Irrigated agriculture, which accounts for most water used by agriculture, will continue to play a key role in agricultural production growth.
According to Mollinga et al. (2007) there are high expectations globally for the potential of improved water management to drive agricultural growth and poverty reduction. These expectations are understandable especially in region where there are high level of poverty and stunting characterized by soil nutrient depletetion and land degredation which include major farming systems in south Asia and Sub-Saharan Africa (Leakey et al., 2009).

HOW CAN WE COPE WITH LIIMITED WATER RESOURCE?

This can be achieved through productive water use as follows:

- Implement better storage of soil water through conservative tillage, mulching, use of cover crops and rainwater harvesting techniques. Water storage helps the poor cope with climate variability.
- Provide supplementary irrigation to make-up for erratic rainfall supplies. Supplemental irrigation during dry spells could double agricultural and water productivity.
- Proper attention should be given to under-preformation of irrigation systems as well as in rainfed system. To minimize avoidable losses of water that could have contributed higher productivity.
- Utilize wastewater or effluent from industries (especially agro-allied industries) as resource for agriculture. Treated wastewater provides both water and nutrients to the crop.
- Wet lands should be used wisely. They filter and clean polluted water and are a good source of water for agriculture especially during the dry season.
- Improve irrigation infrastructure and management.

As researchers in the area of Soil and Water Resources Engineering, it is incumbent on us to ensure that research output has impact. One of the banes of research output from Research Institution (including the Universities) is basing the research output quality "on high science citation scores" in journals with high impact factor. According to Chartres (2008), while high science citation give recognition to the quality of our work, there is the need to know the number of people benefiting from our research. In this regard, the International Water Management Institute (IWMI) based in Sri-Lanka has introduced impact pathways for its research projects, to describe how research outputs which are developed can be used by those outside the projects to achieve developmental outcomes and impact. For example, at Chanchaga Irrigation Scheme, here in Minna, we should be able to determine the number of farmers who may be impacted by specific water interventions.

CONCLUSIONS

Agriculture is critical to development – the majority of the world's poorest and hungry people depend on it for their livelihoods. Agriculture in turn depends on basic natural resources: biodiversity, soil, and water. Good stewardship of natural resources is central to sustainable development: agriculture's long-term viability is a function of how well we – individuals and communities – fulfill our roles as stewards. Best-fit agricultural water management practices are environmentally, socially, and economically sustainable; increase food security; improve livelihoods; and increase resilience to climate change and variability.
The available land and water resources in Nigeria are threatened. These resources need to be managed to ensure optimal use for the greatest agricultural productivity. Improved land and water resources management is a pre-requisite for sustainable agriculture, especially in the quest to meet the increasingly demanding world population. This is also a necessary condition for economic growth, poverty reduction and environmental sustainability in Nigeria. Land and water resources are very important in agricultural production and hence a better management of these natural resources will lead to an improved productivity.
Education and training on management of these resources remains the best way to increase the adoption rate of technologies. This highlights the importance of agricultural extension agencies in the country. As earlier advocated (Ahaneku., 2010), better land use planning and proper soil management using modern technologies like Geographic

Information System (GIS) can improve soil conservation. The issue of land rights and ownership should equally be addressed so that farmer's access to land can be guaranteed.

To effectively utilize the nations' water resources potentials, there is the need to develop agricultural strategies that comprises of both rainfed and irrigated agriculture. In this regard, information on our water resources (surface and ground water) is urgently needed to facilitate irrigation planning. This issue requires very serious attention because it is one single factor that can revolutionize Nigerian agriculture. It should however, be emphasized that irrigation is not an exclusive feature of Savanah agriculture (Northern Nigeria). This is because even in the rain forest zones of Southern Nigeria, water is a limiting factor to crop production. Accordingly, correct irrigation scheduling have to be worked out by researchers in Soil and Water Engineering for different soil types, crops and ecologies in Nigeria.

Finally, sustainable agricultural development calls for careful planning for the utilization and management of land and water resources. The ultimate objective of this plan is to empower the farmers with the necessary tools and requisite know-how to conserve their land and water resources. This is because, it is they who suffer when land loses its productivity and water its quality.

There is no doubt that access to and management of land and water resources need to improve markedly. Projected demands for food and agriculture production have to be met, malnutrition and rural poverty still have to be addressed, and competing demands for land and water must be reconciled with concerns over rapid degradation of natural systems. This calls for improved management of land and water resources and a closer integration of policies, combined with increased and more strategic investment targeting food security and poverty reduction.

RECOMMENDATIONS

The productivity of degraded water and land resources can be restored and crop yields boosted if tens of millions of smallholder farmers are motivated to invest their labor and their limited financial resources in these proven land and water management practices. This working paper proposes seven pathways to accelerate scale-up of these improved practices (Howe et al., 2011):

1. Strengthen knowledge management systems and access to information.
2. Increase communication and outreach in ways that amplify the voices of champions and leverage direct engagement with farmers.
3. Support institutional and policy reforms, particularly for strengthening property rights.
4. Support capacity building, particularly in community-based management of natural resources.
5. Increase support for integrated landscape management.
6. Reinforce economic incentives and private sector engagement.
7. Mainstream investments in improved land and water management to catalyze adoption of these practices as a strategic component of food security and climate change adaptation programs.

While smallholder farmers are the key actors, many other entities and organizations have a role to play in implementing these strategies. National governments should create enabling agricultural development policies— as well as land tenure and forestry legislation—that secure farmers' rights to their land and recognize their ownership of on-farm trees. Governments also should create enabling conditions for the private sector to invest in market-based approaches to strengthening agroforestry value chains. The public and private sector—working with local communities, international partners and development assistance organizations—can take these improved practices to scale by investing in knowledge management, communication, and outreach, which will help restore agricultural productivity, enhance rural livelihoods, and contribute to a sustainable food future.

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INCREASING FOOD PRODUCTION THROUGH MECHANIZATION AND PRECISION FARMING: THE ROLE OF AGRICULTURAL ENGINEERS

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ABSTRACT.

With dwindling resources from oil which has been the main source of foreign exchange earnings and the emerging recession, government seems to be laying more emphasis on increased agricultural production. Agriculture must be mechanized to be able to meet the demand for food by the ever increasing population of Nigeria. Because mechanization is about application of technology and engineering to agriculture, agricultural engineers must play a critical role in efforts made towards increase in food production. This paper looks at agricultural mechanization as it has evolved till date and considers precision agriculture as a stage in mechanization. Mechanization is both a labour and land productivity enhancing technology and it is expected to continue evolve. Local production of key mechanization inputs is advocated. It has also been stressed that mechanization has to be private sector centred with government only providing enabling environment.

Keywords: *agriculture, mechanization, precision agriculture, GPS*

INTRODUCTION

Nigeria is a West African country covering an area of about 93,700 km^2. Her population of roughly 170 million makes her the most populous country in Africa. Nigeria's population continues to increase rapidly necessitating the need for increased food production. As a result, more emphases are laid on higher productivity which demands for greater inputs generally and mechanization specifically. There has been considerable investment on mechanization in the century. However, this is not matched with corresponding substantial increase in food production. Increased production can be achieved through the use of improved techniques, cropping of high yielding varieties and cultivation of larger areas. These in turn could be achieved through a well-conceived mechanization strategy.

A wide variety of crops are produced in Nigeria. These include cereals like maize, rice, millet, wheat, sorghum etc. and tuber crops like yam, cassava, cocoyam, potatoes etc. others are legumes namely soya beans, cowpea, groundnuts, melon etc. and fruits like oranges, pineapples, paw-paw, water melon, mango, coconuts, guava etc. similarly, cocoa, palm tree, timber and rubber are produced in Nigeria. The distribution of these crops across the country is dictated by the type of soil, vegetation, climate and culture.

In the past, agricultural mechanization in developing countries has been much criticized because it often failed to be effective and was blamed for exacerbating rural unemployment and causing other adverse social effects. This was largely the result from experiences during the 1960s until the early 1980s when large quantities of tractors were supplied to developing countries as a gift from donors or very advantageous loan terms. In particular projects which were designed to provide tractor services through government agencies have a miserable report. These proved not sustainable because of the intrinsic inefficiencies of government run businesses.

An overvalued foreign exchange rate and low real interest rates made agricultural machinery artificially cheap as compared to labour and draft animals. These experiences, often combined with very narrow perception and lack of knowledge about mechanization, namely the one sided promotion of tractors and other capital-intensive mechanical power-technology, has caused the aid community to largely turn its back on mechanization. At the same time there are many examples where mechanization has been successful, contributing to increased food production, productivity and advancement of rural economies. For example privately owned shallow tube wells for irrigation in south asia, axial flow threshers in southeast asia, single-axle flow tractors in Thailand and various forms of farm mechanization in many parts of China (Rijk,2000) and Nigeria (Yisa, 2008, Yisa, 2009).

Definitions

Agricultural Mechanization.

Defining Agricultural mechanization is not as straight forward as it may seem this is why different authors give different definitions to it. In general, by agricultural mechanization we should understand the replacement of strenuous and low efficiency work with the work of equipment and machinery which will reduce drudgery and allow for increased efficiency. It deals with design and development, testing and manufacturing, marketing, operation, maintenance, and repair of all agricultural tools, implements, machinery and equipment. A segment of the so understood agricultural mechanization is the idea of agricultural motorization, which covers the replacement of human and animal power with mechanical power (Yisa, 1997; Yisa 1999).

Agricultural Mechanization embraces the use of tools, implements and machines for agricultural land development crop production, harvesting, preparation for storage, storage and on-farm processing. It includes three main power sources: human, animal and mechanical.

The manufacture, distribution, repair, maintenance, management and utilization of agricultural tools, implements and machines is covered under this discipline with regard to supply of mechanization inputs to the farmer in efficient and effective matter (Rijk, 2014).

Taking mechanization to be the application of technology, four levels of mechanization can be identified, namely, human power, draught animal, engine power and mechatronics technologies.

Human power technology: This is the simplest (lowest) and most basic level of mechanization involving the use of tools and implements using human muscle as the primary source of power. These tools include hoes, cutlasses, matchetes, diggers, axes, spades, shovels, rakes, forks etc.

Draught animal Technology: This refers to all forms of implements, equipment and processes in which animal power is used as the source of power. In Nigeria, animals like donkeys, horses' oxens, camels, and buffalos are used for this purpose. The application of this technology is confined to the Sahel and Sudan Savannah ecological regions due to reasons of environmental conditions and animal health and safety.

Mechanical power technology: This technology embraces all machinery which obtain power from other sources other than muscular. The technology includes all sizes of tractors used for both mobile and stationary operations, engines or motors used to power machines such as threshers, mills, grinders, pumps, aircraft and self-propelled machines for production, harvesting, processing, storage, and a wide variety of handling operations.

Mechatronics technology: Under this technology, strong introduction of electronics components is witnessed in mechanical power technology. Computer chips gradually become part of agricultural machinery. A further extension of this technology is the introduction of artificial intelligence (AI), Global Positioning System (GPS), image sensors, Geographic Information System GIS) on agricultural machines and equipment.

The highest level of mechanization in terms of sophistication of technologies used is probably the use of unmanned aerial vehicles (UAVs) and unmanned land vehicles (ULVs) – driverless tractors or autonomous tractors.

Precision Agriculture (PA): Four decades of remarkable progress in Agriculture has more than doubled agriculture production while reducing labour input three folds (Addiscott *et al*., 1991; Upadhyaya, 1992). Although hybrid seeds played an important role in increasing production, this impressive production would have been impossible without the use of chemical fertilizers and other agro-chemicals. In recent years concerns have been raised about the sustainability of this type of agriculture. One major factor at the center of this concern is the nitrate problem.

A better understanding of soil and crop conditions variability within fields brought the notion, in the early 1980s that variable management within fields by zones rather than whole fields (Site-Specific Crop Management, SSCM) would increase profitability by doing the right thing at the right place in the right way at the right time (4Rs). This innovative and futuristic concept of SSCM is often referred to by several other buzz words such as "Farming by Soils", "Prescription Farming", "Farming by the Foot", "Farming by Soils, not Fields", "Environmental Friendly Production", and recently, "Precision Agriculture, PA". At the same time, microcomputers became available and made possible the acquisition, processing, and use of spatial field data as well as the development of a new kind of machinery with computerized controllers and sensors.

Agricultural Mechanization

Purpose of agricultural mechanization

Principal objectives;

a) Decrease in the cost of production: Introduction of a machines may lower production costs or offset increased costs of draft animals or labour.
b) Increase in labor productivity: Introduction of machinery to substitute for labour (labour saving) is a common phenomenon associated with the release of labour for employment in other sectors of the economy or to facilitate cultivation of larger area with the same labour force.
c) Increase in land productivity: One of the key objectives of mechanization is to produce more from the same piece of land (i.e. from the existing land). This is achieved through timeliness of operations, through the introduction of irrigation pumps and appropriate (optimum) application of inputs, like fertilizers, herbicides etc.

It must be noted that whatever the strategy of mechanization, it is not uncommon to see the above three objectives achieved in various degrees. Furthermore, with mechanization comes reduction in drudgery of farm work, greater leisure-farming is made more attractive and a considerable reduction of risk. These are subjective benefits which are not easy to quantify.
There are also few disadvantages to mechanization because it reduces the social interactions usually associated with farm work. Also, it can have negative health implications and may increase an individual workload.

Stages of Agricultural mechanization
Yisa (1997) presented four distinct stages of mechanization. These stages although presented by different authors in different forms, similarities are visible within the stages. Specifically, the first stage of mechanization is the use of hand tools alone. This is followed by the introduction of work animals to agriculture where animal drawn implements played a major role in expansion of fields, staged II. With the advent of internal combustion engines and the development of the agricultural tractor, the use of mechanical power became apparent, stage III. At this stage most of the farm work is done by machines operated by humans. The fourth stage is automation where man's role is reduced drastically to control.
Elsewhere, Rijk(1989) having defined agricultural mechanization as a labour productivity enhancing stratrgy distinguished nine stages of mechanization of agriculture namely 1. Application of improved hand tool technology; 2. Draught animal power application; 3. Stationary power substitution; 4. Motive power substitution; 5. Human control substitution; 6. Adaptation of cropping practices; 7. Farming system adaptation; Plant adaptation; 8. Plant adaptation; and 9. Automation of Agricultural production.
3.3 Development of Agricultural Mechanization in Nigeria
In the review of agricultural mechanization in Nigeria, the role of governments during the different eras of development cannot be overlooked. Nigeria has undergone 56 years of independences under different leaders with each of them coming up with one programme or another aimed at promoting increased food production through mechanization of agriculture. These programmes include Farm Settlement Schemes(FSS), National Accelerated Food Production Programme (NAFPP), Grow More Food Programme (GMFP), River Basin Development Authorities (RBDA), Tractor and Equipment Hiring Units (TEHU), Agro Service Centres (ASE), Tractor and Equipment Subsidy Schemes, Tractor Assembly Plants (TAP), Operation Feed the Nation (OFN), Green Revolution (GR), National Centre for Agricultural Mechanization (NCAM), World Bank Assisted Agricultural Development Programmes, National Directorate of Employment (NDE), Directorate of Food Roads and Rural Infrastracture (DFFRI), National Agricultural Land Development Authority (NALDA), Rural Agro-Industrial Development Scheme (RAIDS), Agricultural Mechanics and Machinery Operators Training Centre (AMMOTRAC), and Family Economic Advancement Programme (FEAP), (Onwualu *et al.*, 2006).
Others are FADAMA I, FADAMA II, FADAMA III, National Programme for Agriculture and Food Security (NPAFS), National Programme for Food Security (NPFS), Root and Tuber Expansion Programme (RTEB), Commercial Agriculture Credit Scheme (CACS), Agricultural Transformation Agenda (ATA), Growth Enhancement Scheme (GES), Out-growers Demand Driven Scheme (ODDS), and Anchor Borrowers Programme (ABP).
From the above, we note that with all these programmes, mechanization of our agriculture ought to have passed the level it is today where human power technology is still the dominant source of technology with hoe and cutlass still serving as the main tools.

Problems of agricultural mechanization in Nigeria
A number of factors affect the low level of agricultural mechanization in Nigeria. These factors include system of land ownership, high cost of tractors and other machinery brought about by over dependence on importation, lack of appropriate machinery for some operations, some imported machines are not suitable for our environment, prevailing agronomic practices, inadequate after sales services, lack of support for local design and manufacturing of machines and tools, poor financial environment (poor credit facilities), inconsistency of government policies

Strategy for agricultural mechanization
In the preceeding paragraphs, we have highlighted some of the problems associated with agricultural mechanization in Nigeria and stated reasons why we are still where we are in terms of agricultural production in spite of numerous government efforts. It follows that whatever strategies we have had in the past, they have not worked effectively well and therefore, they must either be changed outrightly or amended. When planning new strategies for mechanization, it must be kept in mind that

- Mechanization is driven by change in relative prices, in particular cost of labour versus cost of capital
- Essentially, the reasons for mechanization are economical, the farmers drive to maintain or increase net profit

- Mechanization is also demand driven. It is the farmer who decides what machine to buy, from whom to buy and how to use it
- Unlike in the past, mechanization must be left to the private sector as much as possible. Government should not actively get involved in the manufacture, distribution and repair of agricultural machinery and its operation, but rather provide incentives for the private sector (Rijk, 1989).

Any mechanization Strategy must reflect that there are three principal actors actively participating in the process of mechanization. These are the demand side that is, the end user (usually the farmer). Machinery hiring establishments are also considered on the demand side.

The supply side which involves importers, distributors, dealers, local manufacturers and repair services. They are in the business of providing goods and services for the sole objective of making profit. In the past, the supply side has been found wanting due to an unfavourable institutional and policy environment. This was the reason for government to take over suppliers' job rather than analysing the reasons why suppliers fail and instituting a policy that will check the problems.

The government is considered as a facilitator, to eliminate market failure and to ensure that supply meets the demand in an efficient and satisfactory manner. To achieve this, government can provide extension, training credit, subsidies and incentives. Government can stimulate mechanization by creating and implementing favourable policy environment, e.g. Policies related to import duties, taxes, subsidies, financing terms and conditions etc.

Mechanization should not be expected to flourish if any of these three factors fails to fully meet its role and responsibilities.

Precision Agriculture

The goal of precision agriculture research and development is to define a decision support system (DSS) for whole farm management system with the aim of optimizing returns on inputs while preserving resources.

Among these many approaches is a phytogeomorphological approach which ties multi-year crop growth stability characteristics to topological terrain attributes. The interest in the phytogeomorphological approach stems from the fact that geomorphology component typically dictates the hydrology of the farm field.

The practice of precision agriculture has been enabled by the advent of GPS and GNSS. The farmer's and/or researchers ability to locate their precise position in a field allows for the creation of maps of spatial variability of as many variables as can be measured (e.g. crop yield, terrain features/topography, organic matter content, moisture levels, nitrogen levels, pH, EC, Mg, K etc.).

Precision agriculture has also been enabled by technologies including crop yield monitors, mounted on GPS equipped harvesting machines, the development of variable rate technology (VRT) like seeders, sprayers, fertilizer distributors etc., the development of array of real-time vehicle mounted sensors that measure everything from chlorophyll levels to plant-water status, multi- and hyper-spectral aerial and satellite imagery, from which products like (NDVI) maps can be made.

Precision agriculture aims to optimize field-level management with regard to:

- Crop science: By matching farming practices more closely to crop needs (e.g. fertilizer inputs).
- Environmental protection: By reducing environmental risks and footprint of farming (e.g. limiting leaching of nitrogen.
- Economics: By boosting competitiveness through more efficient practices (e.g. improved management of fertilizer usage and other inputs.

PA also provides farmers with a wealth of information to:

- Build up a record of their farm.
- Improve decision making.
- Foster greater traceability.
- Enhance marketing of arm products
- Improve lease arrangements and relationship with landlords.
- Enhance the inherent quality of farm products (e.g. protein level in wheat bread flour).

A Geographic Information System (GIS) or a Field Information System (FIS) can be used to map the variability within a field. This map along with a Global Positioning System (GPS) can be used to apply an appropriate amount of chemical or some other input in real-time. Most of this technology is already available. A differential GPS with a

precision of an inch is currently available for less than $2,000. Sensors to determine soil-organic matter on-the-go and grain meters to map yield have been successfully developed.
Much research and development are in progress in Universities, government agencies and industries across the world, but Nigeria. There are still important needs in engineering technology, management, understanding of natural condition variability, profitability, environmental protection, technology transfer.
Most frequent research needs are classified and ranked as;

1. Development of real-time sensors for soil and plant characterization
2. Remote sensing techniques for soil and crop condition detection, and management
3. Quantification of PA impacts on the environment
4. Development of protocols for sampling procedures
5. Economics of PA
6. Quantification of spatial and temporal natural resources variability
7. Development of practical crop models for PA management
8. Development of improved spatial data analysis methods
9. Methodologies for developing soil and crop site-specific prescriptions
10. Development of educational programmes

Tools
Precision agriculture is usually done as a four-stage process to observe special variability.
Data collection: This starts with geolocating a field through using an in-vehicle GPS.

- Precision agriculture drones.
- Precision agriculture software.

Fuse-agco-connecting your farms.

I. Enterprise planning.
II. Tillage and field preparation planting.
III. Growing.
IV. Grain drying, monitoring and control.
V. Mobile.
VI. Dealer/decision support.

FUSE connecting your farm enterprise like never before. Fuse is AGCO's approach to PA, delivered through technology products and services. This approach ensures grower's operation are always running and optimized, all assets are in the right place at the right time and each phase of the crop cycle is seamlessly connected through farm total data management. Fuse enables more informed business decisions, reduced input costs and improved yields and profitability.
FUSE TECHNOLOGIES: In the foundation of optimized farm. Tools including guidance, telematics and advanced sensors create smart, connected machines, five-tuned for each application that can communicate with farm managers, 3rd party service providers and each other.
FUSE CONNECTED SERVICES: Combines the right machines, technology, parts, services and support for customers. This complete solution optimizes the customer's operation and maximizes uptime through preventive maintenance, machine condition monitoring and year-round consultation.
The following facts set fuse tech apart from other technologies.

- Connecting the mixed fleet.
- Respecting your data choices.
- Mobile function ability and logistics.
- Pioneering open approach.

Convergence of Agriculture Mechanization and Precision Agriculture
From the foregoing analysis, we have seen that both Agricultural Mechanization and Precision Agriculture have the same or similar objectives. These objectives put together are geared towards increasing food production profitably, sustainably, wholesomely without adverse effect environmental degradation. In this regard, Precision Agriculture can be seen as the latest level (stage) of mechanization.

CONCLUSION
The underlying issues concerning agricultural mechanization and precision agriculture have been presented in this paper. Precision agriculture is considered as the latest level of agricultural mechanization. To increase food production with the view of providing daily requirement for the teaming population of Nigeria, and provide raw materials for our

industries, mechanization must be accorded a priority place in the scheme of things and particularly in any developmental plan. Government must drive the process through creating an enabling environment for private sector participation and local manufacturing of agricultural production inputs including tractors and other machinery. Efforts must be made to take advantage of the opportunities provided by new technologies being developed under precision agriculture. Government and indeed the country as a whole must use the agricultural engineers to apply the required knowledge to agriculture.

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POST-HARVEST TECHNOLOGY

EFFECT OF PROCESSING TECHNIQUES ON THE QUALITY OF INSTANT POUNDED YAM FLOUR.

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ABSTRACT
This study was undertaken to evaluate the effect of processing methods on the quality of Instant pounded yam flour (IPYF). Five methods were used to produce IPYF. The methods investigated were different size reduction and drying methods. Also, effect of unpeeled yam before steaming was also investigated.The yield, chemical and physical properties of the flours were determined. The yield of the IPYF ranged from 18.94-20.56%. Significant differences ($p<0.05$) were observed in the proximate composition of the samples. The processing methods significantly affected the swelling index and water absorption capacity of the IPYF flour. AFHP sample showed the highest value in swelling index and water absorption capacity. The processing methods positively affected the colour as samples have high degree of whiteness which is one of the quality parameters for IPYF with ACHP being the whitest. Processing methods significantly affected the pasting properties of the IPYF with ASHP the least through viscosity while Setback viscosity of samples ACKU and ACHP (1371 RVU) are equal and the highest

Key words: Pounded yam, Flash drying, IPYF, Yam and Flour

INTRODUCTION:
Yam, (*discorea spp*) is an important staple food that is grown extensively in Nigeria. Yam is grown majorly for food and income; it can be processed in diverse ways such as boiling, roasting, frying, pounding and making into flour for Elubo (yam flour) and instant pounded yam. Pounded yam is a special and delicious delicacy in Nigeria (Olaoye and Oyewole, 2012). Traditional method of producing pounded yam involves making pieces into dough after boiling by pounding with a mortar and pestle (Ferede *et al.,* 2010); the drudgery involved in making pounded yam led to the development of instant pounded yam flour (FIIRO, 2005).

There are indications that yam has great prospect of contributing to closing the projected food deficit in Africa in the 21st century, if efforts are made to identify and overcome the constraints to its production. Processing of yam increases its shelf life, adds value to the tuber (from where it is processed) before being exported to enhance its economic value, reduce waste and cut down the cost of transporting the product to longer distances compared with the heavy wet tubers that are unprocessed. The fact that yam can be preserved by processing helps to stabilize prices during off harvest season.Instant Pounded Yam Flour (IPYF) is a value-added product derived from white yam (FIIRO, 2005; Asiru *et al.,* 2013). The recent acceptability and popularization of IPYF is fuelled by consuming elites and socialites both home and abroad (Komolafe and Akinoso, 2005; Akinoso and Olatoye; 2013). This is because all that is required in the preparation of IPYF is by dissolving a measured mass of the flour in a specified volume of boiled water and carefully stirring the mixture over heat until dough with smooth consistency similar to pounded yam is obtained.

According to FIIRO (2005), the process technology for the production of IPYF consists of simple operations whose unit operations are: yam selection and weighing, washing, peeling and slicing, sulphiting, parboiling, drying, milling and packaging. Generally, drying as a unit operation is an energy consuming process which accounted for higher percentage of energy consumption/utilization in any food industry (Singh, 1986; Ramirez *et al*., 2006; Akinoso and Olatoye, 2013); and it remains critical unit operation in food processing which determines the quality characteristics of the final products (Krokida *et al*., 1998). Due to the present need for reduction in production cost, the need to conserve energy through the reduction of the drying time utilized in food processing is very necessary (Aiyedun *et al*., 2008; Wang, 2009); and among those factors that affect the efficiency of drying operation is the thickness as well as the surface area of the product to be dried (Mohammed, 2009).

This study focused on production of instant pounded yam flour (IPYF) using two drying methods namely: ; considering the effect of varying sizes and size reduction methods such as slicing, chipping and chunking on quality of IPYF and the effect of peeling and unpeeling of the skin on quality parameters.

MATERIALS AND METHODS

Source of sample

Discorea rotundata variety (Abuja type) was obtained from a local market called Ile-Epo market at Abule Egba, Lagos. The yams were bought relatively wholesome, void of sprouting and mechanical damage.

Preparation

IPYF was produced using FIIRO (2005) and Asiru *et al.* (2013) modified methods. About 36kg of yam tubers each was used to produce instant pounded yam flour using five different processing methods.

Method I

This is a conventional method used in FIIRO for IPYF production. Thirty six kilogram (36 kg) of the tubers were washed with cold tap water and manually peeled with stainless steel knives. The peeled tubers were thinly sliced (0.5mm thickness), treated with sodium meta-bisulphitethen steamed for 30mins in a parboiler, cooled and hot air dried in a cabinet dryer at 75^{0}C, milled after drying then cooled, packaged and labelled ASHP.

Method II

Another Thirty six kilogram (36 kg) of the tubers was washed with cold tap water and manually peeled with stainless steel knives. The peeled tubers were cut in to chunks (50mm thick), pre-treated with sodium meta-bisulphitethen steamed till cooked for 45mins in a parboiler, cooled at room temperature then hot air dried in a cabinet dryer at 75^{0}C, milled with an hammer mill, cooled, packaged and labelled ACKP (Asiru *et al*., 2013).

Method III

Thirty six kilogram (36 kg) of yam tubers was washed with cold tap water. The unpeeled tubers were cut into chunks (50mm thick), pre-treated with sulphite then steamed till cooked for 45mins in a parboiler, cooled at room temperature, then peeled before hot air dried in a cabinet dryer at 75^{0}C. It was then milled with a hammer mill, cooled, packaged and labelled ACKU (Asiru *et al*., 2013)

Method IV

36 kg of the tubers was washed with cold tap water and manually peeled with stainless steel knives. The peeled tubers were chipped (0.36 mm thickness) using an adaptable FIIRO designed cassava chipping machine,and pre-treated with sodium meta-bisulphite for about 30mins then boiled for 15mins in a parboiler, cooled and hot air dried in a cabinet drier at 75^{0}C, milled after drying, then cooled, packaged and labelled ACHP.

Method V

Thirty-six kilogram (36 kg) of the tubers were washed with cold tap water and manually peeled with stainless steel knives. The peeled tubers were cut into chunks (50mm thick) and pre-treated with sodium meta-bisulphite for about 30mins, steamed for 30mins in a lagged double walled parboiler, then cooled at room temperature. After cooling, it was granulated with a grater and dried in a flash drier at 165^{0}C, milled with a hammer mill, packaged and then labelled AFHP (Asiru *et al*., 2013).

Determination of yield of IPYF

This was determined using the expression

$$Yield(\%) = \frac{Weight\ of\ instant\ pounded\ yam\ flour}{Weight\ of\ unpeeled\ yam\ tuber}$$

Determination of chemical properties of IPYF

Moisture content, ash, crude fibre, crude fat, crude protein and carbohydrate were determined by the method of AOAC (1990), carbohydrate was estimated by the difference method (% carbohydrate = 100% - sum of percentage of moisture, ash, fat, crude fibre and crude protein contents)

Determination of physical properties

Bulk density of IPYF was determined by the method described by Chau and Cheung (1997). For loose bulk density, an empty calibrated centrifuge was weighed. The tube was then filled with a sample to 5 ml. The weight of the tube and its contents was taken and recorded. The weight of the sample alone was then determined by difference.

For pack bulk density, the tube was filled with a sample to 5 ml and the tube was constantly tapped until there was no further change in volume. The weight of the tube and its contents were taken and recorded. The weight of the sample alone was then determined by difference.
Densities were calculated from the values obtained as follows:

$$Density = \frac{Weight\ of\ sample}{Volume\ occupied}$$

Determination of Water Absorption Capacity (WAC):
Water absorption capacity (WAC) of the IPYF samples was determined by the modified method of Phillips *et al.* (1988).
WAC was calculated as follows:

$$WAC = \frac{W_2 - (W_0 + W_1)}{W_0} \times 100$$

Determination of Oil Absorption Capacity (OAC):
Oil absorption capacity (OAC) of the IPYF samples was determined by the modified method of Phillips *et al.* (1988).
OAC was calculated as follows:

$$OAC = \frac{W_2 - (W_0 + W_1)}{W_0} \times 100$$

Determination of swelling power:
Swelling power of the IPYF samples was determined by the procedure described by Takashi and Seib (1988).

$$Swelling\ power = \frac{Weight\ of\ wet\ mash\ of\ sediments}{Weight\ of\ dry\ matter\ in\ the\ geeeel}$$

Determination of Dispersibility:
Dispersibility of the IPYF samples was determined by the method described by Kulkarni *et al.* (1991)

Colour Determination
The colour of the IPYF samples was measured with a Minolta CR-310 (Minolta camera Co. Ltd, Osaka, Japan) tristimulus colorimeter, recording L*, a* and b* values. L* represented lightness (with 0= darkness/ blackness to 100= perfect/brightness); a* corresponds to the extent of green colour (in the range from negative= green to positive = redness); b* represents blue in the range from negative=blue to positive=yellow.

Determination of Pasting Properties
Pasting characteristics of the IPYF samples was determined with a Rapid Visco Analyser (RVA) as described by Adebowale *et al. (*2008).

Statistical Design and Analysis
All data obtained were subjected to analysis of variance (ANOVA) using SPSS version 17.0 software package.The significance of treatment of means was tested at $P < 0.05$ probability level using Duncan's New Multiple Range Test (DNMRT) (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

The results of the experiments and effect of processing methods on physical, chemical and yield of IPYF are presented in Figures 1-5 and Tables 1-4.
Figure 1 showed the yield of IPYF from the five methods of production used. The yield of IPYF samples ranged from 18.94% to 20.56%. ACKU sample had the highest yield of 20.56%.This is likely due to the breakdown of cementing material between the peel and fleshy portion thereby making peeling easy and reducing the loss during peeling (Ekwu *et al.,* 2014). The low yield of AFHP can be attributed to losses during the peeling of the chunks in addition to loss during granulation.

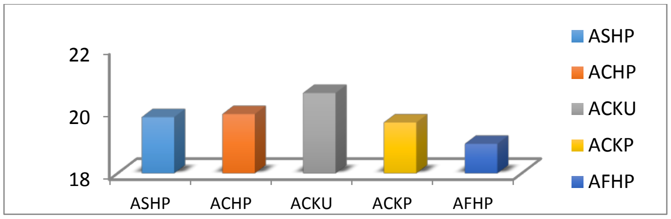

Figure 1: Effect of Processing Methods on the Yield of IPYF Samples

The sensory properties of IPYF samples (Table 1) from different methods of production showed a significant difference ($P<0.05$) only in the attributes of colour and aftertaste while all the other attributes do not differ significantly. This implies that any of the production methods could be adopted for the production of Instant Pounded Yam Flour that would meet the sensory specification of the consumers.

The proximate composition of the IPYF samples is as presented in Table 1. There are significant differences ($p<0.05$) between the moisture content of samples which can be attributed to the different processing methods, especially drying. The moisture content of the IPYF samples ranged from 6.97 to 8.77 g/100g. The minimum and maximum moisture content of samples ACKU and ACKP can be attributed to the thickness of the slices. However, the moisture content of all the samples are below 10% recommended by FIIRO (FIIRO, 2005), the low moisture content are advantageous as the samples will store well if kept in air tight packages.

Table 1. Result of Proximate Analysis of IPYF

Proximate Composition	ASHP	ACKP	ACKU	ACHP	AFHP
		2(1)	2(2)		
Moisture Content (%)	7.50^{bc} ± 0.30	7.37^{c} ± 0.17	6.97^{d} ± 0.15	7.80^{b} ± 0.20	8.77^{a} ± 0.18
Crude Protein (%)	7.51^{a} ± 0.19	5.38^{c} ± 0.21	4.85^{d} ± 0.11	4.43^{e} ± 0.28	6.11^{b} ± 0.27
Crude Fat (%)	0.17^{bc} ± 0.02	0.18^{b} ± 0.03	0.15^{bc} ± 0.03	0.27^{a} ± 0.04	0.12^{c} ± 0.02
Total Ash (%)	2.04^{c} ± 0.04	2.20^{b} ± 0.05	2.01^{c} ± 0.05	1.92^{d} ± 0.03	2.37^{a} ± 0.03
Crude Fibre (%)	1.50^{d} ± 0.04	1.36^{e} ± 0.02	1.69^{c} ± 0.04	1.79^{b} ± 0.03	2.20^{a} ± 0.05
Carbohydrate (%)	81.10 ± 0.60	83.51^{c} ± 0.38	84.33^{b} ± 0.41	83.78^{bc} ± 0.09	80.43^{d} ± 0.41

Values in the same rows with different superscripts are significantly different ($p<0.05$).

The protein content of all the IPYF samples ranged from 4.31 – 7.51%. The protein content of samples ACKP, ACKU, ACHP and AFHP were lower than the control (ASHP) produced with the FIIRO conventional method.However, the protein contents are in agreement with findings of Abara *et al*. (2003) and Abara (2011) that reported values of 2.31%, 5.75% and 6.35% in the wet and dry tissue of *Discorea bibifera.* There are significant differences in protein content ($p<0.05$) of samples and this may be due to the different processing methods used.

Fat content of samples range of 0.12 to 0.27% were significantly ($p<0.05$) lower than values gotten for instant flours by Oladeji *et al*. (2013).This indicates that parboiling reduces the fat content of yam and the low fat content will enhance the storability as rancidity would be reduced (Ekwu *et al.,* 2014).

Ash content of the samples ranged from 1.92 to 2.37%, these values have a significant difference ($p<0.05$). The difference can be attributed to the different processing methods. The values of the IPYF samples are higher than those reported by Oladeji *et al.* (2013) this is probably due to leaching of organic matter more than mineral during boiling thereby resulting in high concentration of mineral in the samples (Ekwu *et al*., 2014).

The crude fibre content ranged from 1.36 – 2.20% and is significant ($p<0.05$) between samples. The values are significantly higher than Oladeji *et al.* (2013) reported values. The high crude fibre in IPYF samples suggests that the samples can help in contributing to healthy conditions of the intestine when consumed.The AFHP sample has the highest value of fibre. This may be due to the age of the tubers (Njoku and Banigo, 2006)

The results of some physico-chemical characteristics of Instant Pounded Yam Flour produced using different production methods differs significantly ($P<0.05$) in all the characteristics investigated (Table 2). The loose and pack bulk densities ranged from 0.805 to 0.855 and 0.888 to 0.970 respectively.

These densities are important for determining package requirement, material handling and applications in wet processing in the food industry.The bulk densities are greater than the result of instant yam flour reported by Oladeji *et al.* 2013 this means the particle size are smaller. The small particle size of the IPYF samples makes it a potential food for allergic infants and persons with gastro intestinal disorder as reported by Opara (2007) for taro flour.

Water absorption capacity (WAC) ranged from 222.55 to 513.59. WAC describes flour – water association ability under limited water supply and this could be attributed to the presence of greater amount of hydrophilic constituents like soluble fibre and lower amount of fat content as shown in Table 2.

Oil absorption capacity (OAC) of the samples ranged from 77.67 to 90.29 with IPYF sample from ACHP having the highest mean value. The highest OAC could suggest the presence of a large proportion of hydrophobic groups as compared with the hydrophilic groups on the surface of protein molecules (Subagio, 2006). The oil absorption can also be influenced by the lipophilicity of protein (Kinsella, 1976).

Water binding capacity ranged from 243.00 to 552.88. AFHP have the highest mean score and significantly differs from other samples. According to Mayaki *et al*. (2003) this could be due to high fibre content and high content of un-degraded starch granules in the flour. As reported by Soni *et al*., (1985) and Ekwu *et al*. (2014) Not listed high water binding capacity of AFHP implies good functionality when used as composite flour.

The swelling power measures the hydration capacity of flour sample as it is a weight measure of swollen starch granules and their occluded water. The values ranged from 484.16 to 935.92 with AFHP having the highest swelling power while ACKUsample had the least mean value. The result follows the same trend reported by Eriksson *et al.* (2014) on cassava and wheat flour composite; they reported that the swelling capacity of flours is associated with bonding forces in their starch granules.

Table 2: Effect of Processing Methods on the Physical Characteristics of IPYF

Physico-Chemical Characteristics	ASHP	ACKP 2(1)	ACKU 2(2)	ACHP	AFHP
Loose Bulk	0.820 ^{cd}	0.830^{bc}	0.845^{ab}	0.805^{d}	0.855^{a}
Density (g/ml)	± 0.002	± 0.002	± 0.003	± 0.025	± 0.005
Pack Bulk	0.888^{de}	0.900 ^{cd}	0.875^{e}	0.945^{b}	0.970^{a}
Density (g/ml)	± 0.002	± 0.004	± 0.003	± 0.017	± 0.004
Water Absorption	222.55^{d} ±	295.10^{b}	254.46^{c}	229.41^{d}	513.59^{a}
Capacity	3.71	± 2.64	± 3.08	± 4.73	± 3.92
Oil Absorption	78.64^{b}	70.59^{c}	86.00^{a}	90.29^{a}	77.67^{b}
Capacity	± 1.82	± 2.93	± 2.46	± 3.75	± 2.09
Water Binding	249.00^{d}	274.51^{b}	258.00^{c}	243.00^{e}	552.88^{a}
Capacity	± 2.14	± 2.86	± 2.50	± 3.00	± 3.94

Values are means of triplicate determinations. ± SD value

Mean values with different superscript within the same row are significantly different ($P<0.05$).

The colour parameters of IPYF samples ranged from 89.26 to 92.35 for L* value, -0.99 to -1.43 for b* value, and 13.14to 17.71 for a* value respectively (Table 3.). The result revealed that all the samples have high lightness values which indicate a high degree of whiteness which is one of the quality parameters for IPYF. However, sample AFHP has the highest mean value for yellowness index.

Table 3: Effect of Processing Methods on Colour Parameters of IPYF

COLOUR PARAMETERS	ASHP	ACKP 2(1)	ACKU 2(2)	ACHP	AFHP
L*	89.98^{d} ± 0.04	89.26^{e} ± 0.02	91.81^{b} ± 0.14	92.35^{a} ± 0.06	90.57^{c} ± 0.06
a*	-1.08^{b} ± 0.02	-0.99^{a} ± 0.01	-1.00^{a} ± 0.01	-1.09^{b} ± 0.00	-1.43^{c} ± 0.02
b*	15.96^{b} ± 0.01	14.65^{d} ± 0.01	15.76^{c} ± 0.02	13.14^{e} ± 0.12	17.71^{a} ± 0.02

Values are means of triplicate determinations. ± SD value
Mean values with different superscript within the same row are significantly different (P<0.05)
Note: L (black/white), a* (red/green) and b* (yellow/blue)*

The pasting characteristics of Instant Pounded Yam Flour produced showed that AFHP has the highest value for most of the pasting characteristics with the exception of setback viscosity and pasting temperature (Table 4)

The pasting temperature ranged from 61.85-86.35 with AFHP having the least Pasting temperature. A higher pasting temperature according to Numfor *et al*. (1996) indicates a higher gelatinization time. This lower swelling property of starch, the breakdown viscosity of AFHP indicates that it has the strongest starch structure (Svanberg, 1987). ASHP had the lowest breakdown viscosity which implies a weak cross linking within granules (Oduro *et al*., 2005). Peak viscosity of AFHP significantly differs from other samples, this indicates high elasticity and gel strength, and this is an indication according to Osungbaro (1990) that it has the highest starch content. Setback viscosity of samples ACKU and ACHP (1371 RVU) are equal and the highest, this indicates high potential for retrogradation of the samples (Otegbayo *et al*. 2006); other samples set back viscosity vary significantly and this determines their gel stability in food products.

The trough viscosity of the samples ranged from 1542 to 3397 RVU. ASHP had the least trough viscosity which implies the sample would be more prone to rupture during pasting and its cooked paste will not be as stable as other samples (Adebowale *et al*., 2008).

Table 4: Effect of Processing Methods on the Pasting Properties of IPYF

Pasting Characteristics	ASHP	ACKP 1	ACKU 2	ACHP	AFHP
Peak Viscosity	1693	2489	2551	2818	3785
Trough Viscosity	1542	2129	2167	2628	3397
Breakdown Viscosity	151	360	384	190	388
Final Viscosity	2403	3275	3191	3999	4008
Setback Viscosity	861	1146	1371	1371	611
Peak Time	6.53	5.80	5.87	7.00	5.87
Pasting Temperature	86.35	79.00	80.60	82.40	61.85

CONCLUSION

From the results obtained from this study, the processing method using un-peeled yam increases yield and gives high carbohydrate product, and also, the functional and pasting qualities such as water binding capacity. Swelling property of flash dried product surpasses cabinet dried products. This implies high fibre which would be advantageous to health associated with low fibre intake. Products made from ACHP and ACKU will be more stable than those made from other methods especially ASHP that will more readily suffer retro-gradation.

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EFFECT OF MOISTURE CONTENT ON PROPERTIES OF JATROPHA SEED OIL

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ABSTRACT:

Jatropha curcas seed oil was extracted employing solvent extraction technique at five moisture content levels. The properties of the extracted oil were analysed. The parameters analysed were yield of oil, acid value, moisture content, peroxide value, saponification value and specific gravity. Results obtained showed that there was an inverse relationship in the yield of oil and moisture content of the seed with the lowest value of 32.3% at 25.85 % w.b seed moisture content to 38.5% at 5.85% w.b. seed moisture content. Moisture content of the oil also increased from 16.3% to 32.5%. The acid value increased from 5.8 to 12.5. Saponification value increased from 175 to 182 as the seed moisture content also increased from 5.85% to 25.85% w.b. Specific gravity of oil witnessed a slight rise from 0.9632 to 0.9660 as the seed moisture content also increased from 5.85% to 25.85% w.b.

Keywords: *Solvent extraction, saponification value, peroxide value, specific gravity.*

INTRODUCTION.

Jatropha from the *Euphorbiaceae* family has over a genus of over 170 plants, indigenous to the Central America but usually planted and exploited across majority of tropical and subtropical countries of the world. It produces four times yields of soybean per hectare and ten times yields of corn per hectares (Nobrega and Sinha, 2008). Out of many varieties of Jatropha, *Jatropha curcas* has a broad sphere of applications and assures different important advantages to man and industry. The concoction from this variety has been reported to possess anti-tumor property (Lin et al., 2003); the leaves can be utilized as treatment for malaria and high fever (Gübitz et al., 1999; Henning, 1997) the seeds can be employed as medication for constipation and the sap has been known to be potent for speeding up wound healing operation (Gübitz et al., 1999). Furthermore, the plant is used for ornamental purposes, dye and pesticides raw material, soil manure/fertility enrichment and more essentially as a promising feedstock for biodiesel production (Tiwari et al., 2007; Vasudevan and Briggs, 2008). Diesel is the principal fuel consumed in the transport sector particularly for vehicles such as trains and trucks. There is an increasing charge for fuel in transportation sectors of majority of countries with the demonstration of the prevailing world energy dilemma. Hence, it is necessary to probe into the workability of having a substitute to diesel fuel which could be produced on an industrial proportion for commercial usage. The *Jatropha curcas* oil which happens to be non-edible assures an economically feasible substitute to diesel because it possess desirable physiochemical properties and performance qualities proportionate to diesel to expedite steady operation devoid of major alterations in the engine design.

Solid liquid extraction is a typical and dynamic method of oil extraction for production of biodiesel (Forson et al., 2004). Solid liquid extraction, otherwise known as leaching, includes conveyance of a dissolvable portion (the solute or leachant) from a solid substance to a liquid solvent. The dissolvable fraction disperses from the solid towards the encircling solvent. Usually, solid liquid extraction relies on the nature of the solvent and oil, reaction time between solvent and materials, temperature of the process, particle size of the material and the ratio of solvent to the material.

There is a wide changeability in diverse affirmations of *Jatropha curcas* from different agro climatic zones (Kaushik et al., 2007). Augustus et al. (2002) reported that oil content of *Jatropha curcas* seeds is about 20-40%. According to the report, the oil fraction contains 14.1% palmitic acid, 6.7% stearic acid and saturated fatty acid, 47% oleic acid and 31.6 of linoleic acid and unsaturated fatty acid. In the recent past, Martinez-Herrera et al. (2006) disclosed that the leading fatty acids present in the *jatropha curcas* oil samples were oleic (41.5-48.8%), linoleic (34.6-44.4%), palmitic (10.5- 13.0%), and stearic (2.3-2.8%) acids. Considering the compelling challenge of utilization of vegetable oil to meet human demand and as raw material for soap factory, it is therefore necessary that other alternative sources of production of non-edible vegetable oil are investigated. *Jatropha curcas* oil falls into this category of non-edible vegetable oil.

Oil extraction includes diverse preceeding processes which involves dehulling, cleansing, drying and milling; although the entire quantity of oil extracted rely solely on the temperature, extraction time, particle size and moisture content of the oil-bearing substance (Gutiérrez et al., 2008). Shankar et al. (1997) reported that the enzymatic hydrolysis of oil seeds precedent to extraction improves the extractability and recoverability of oil in oil seeds. There are majorly two methods of oil extraction from oil seeds. One method is mechanical expression employing a machine to apply pressure on the oil seeds so as to extract the oil. A second technique for oil extraction is solvent extraction method, where a solvent is combined with pre-crushed seeds which aid the oil to dissolve (Ng et al., 2014). The oil is then retrieved from the solvent. For the extraction in an industrial capacity, the two methods (mechanical expression and solvent extraction) are usually employed to achieve the highest yields. In mechanical expression, oil recovery is between 90-95% of the oil contained in the seeds (Okoye et al., 2008), meanwhile solvent extraction method can achieve up to 99% oil recovery; though solvent extraction method is an intricate, industrial-scale solution requiring hazardous chemicals. The objective of the present study was to determine the effect of moisture content on the properties of the extracted *jatropha curcas* oil.

MATERIALS AND METHODS

Material and sample selection

For this study, dried *Jatropha curcas* seeds were collected at Moniya in Ibadan, Oyo State of Nigeria. The climatic condition of the seed’s origin is typified by 2000–2400 mm annual rainfall and 28–35 °C of temperature. The seeds were manually cleansed to discard all foreign objects like chaff, dirt, dust and stones in addition to broken and immature seeds. The seeds’ initial moisture content was measured through oven drying at 105±1ºC for 24 h (Özarslan, 2002) and it was 5.85% w.b. To obtain the preferred sample moisture contents, the seeds were reconditioned to the various moisture content levels using the procedure described by Sacilik et al. (2003) as stated below:

$$Q = \frac{W_i(M_f - M_i)}{(100 - M_f)} \quad (1)$$

Where:

W_i, is the seed sample initial mass in kg; M_i, is seed sample initial moisture content in % w.b.; and M_f, is seed sample final moisture content in % w.b. The extraction of the oil was done at these five moisture levels which are 5.85, 10.85, 15.85, 20.85 and 25.85 % w.b.

Oil extraction

Dried *Jatropha curcas* seeds were crushed in a Moulinex Model SeB PREP'LINE 850 (M oulin cafe). For solvent extraction, 50 g of crushed seeds were arranged into a cellulose paper cone and extracted using light petroleum ether (b.p 40-60 °C) in a 5l Soxhlet extractor for 8 h as described by (Peña et al., 1992). Oil recovery was done by evaporating off the solvent using rotary evaporator model N-1 (Eyela, Tokyo Rikakikal Co., Ltd., Japan) and residual solvent was eliminated by drying in an oven at 60 °C for 1 h and flushing with 99.9% Nitrogen.

Analysis of the Oil

Oil Content.

The mass of oil extracted from 10 g of seeds powders was used to quantify the oil content in the seed. The result was presented as the percentage of oil in the dry matter of seed powders.

Acid value, % FFA.

Acid value of the oil was measured in accordance to AOCS official method Ca 5a-40 (AOCS, 1997). Percentage free fatty acids (FFAs) was determined using oleic acid as a factor (Akbar et al., 2009).

Iodine value

Iodine value of seed oil was measured in accordance to AOCS Official Method 993.20 (AOCS, 1997).

Saponification value

The saponification value was measured in accordance to AOCS Official Method Aa 4–38 (AOCS, 1997).

Peroxide value

The peroxide value was measured in accordance to AOCS Official Method 965.33 (AOCS, 1997)

RESULT AND DISCUSSION

Yield of Oil.

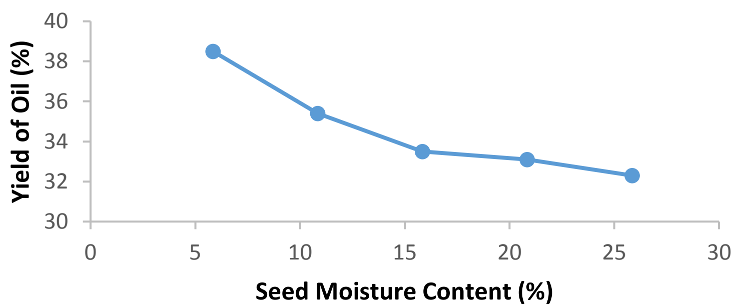

Figure 1: Yield of Oil with Moisture Content.

Figure 1 shows the variation of yield of oil with moisture content, there is a decrease in yield of oil with increase in moisture content. The relationship between yields of oil with moisture content is expressed by this equation:

$$Oil_{yield} = 39.22 + 0.294M \;\; (R^2 = 0.8787) \qquad (2)$$

Acid Value

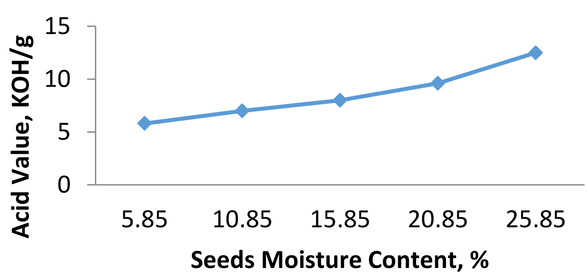

Figure 2: Acid Value with moisture content

Figure 2 shows an increase in acid value with increase in the seed moisture content. This result is similar to that reported for caper seed (Dursun and Dursun, 2005). A high acid value indicates high Free Fatty Acid (FFA). The relationship between acid values with moisture content is expressed by this equation:

$$A_{value} = 0.320M + 3.508, \;\; (R^2 = 0.949) \qquad (3)$$

Moisture Content in Oil

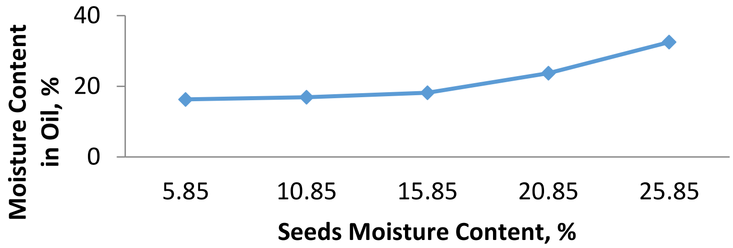

Figure 3: Moisture Content in oil with moisture content of seed.

Figure 3 shows an increase in the moisture content in oil with increase in the seeds moisture content from 16.3 at 5.85 to 32.5 at 25.85%. This trend was similar to what was reported for caper and barbunia bean seeds (Cetin, 2007; Dursun and Dursun, 2005). The relationship between moisture content in oil with seeds moisture content is expressed by this equation:

$$M_{oil} = 0.784M + 9.094, \ (R^2 = 0.831) \quad (4)$$

Peroxide Value of Oil.

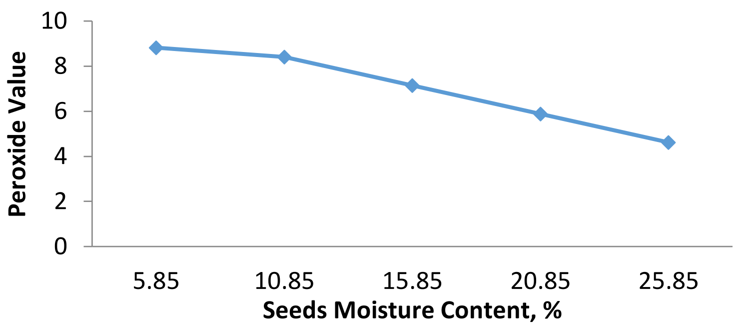

Figure 4: Peroxide Value with Seeds Moisture Content.

Figure 4 shows a decrease in peroxide value with rise in the seeds moisture content. The relationship between the peroxide value and moisture content is expressed by this equation:

$$P_{value} = -0.218M + 10.434, \ (R^2 = 0.977) \quad (5)$$

Saponification Value of Oil.

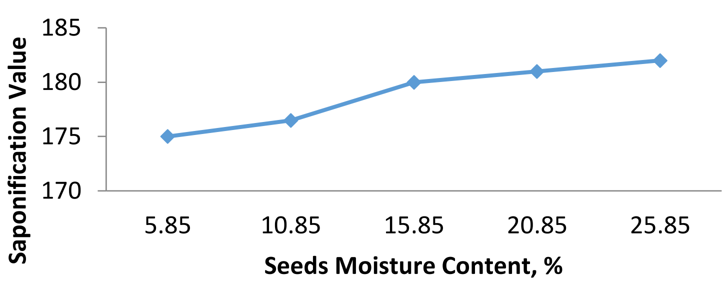

Figure 5: Saponification Value with Seeds Moisture Content.

Figure 5 shows a linear increase in the saponification value with increase in the seeds moisture content. The relationship between saponification value and seeds moisture content is expressed by this equation:

$$S_{value} = 0.370M + 173.036, \ (R^2 = 0.945) \quad (6)$$

Specific Gravity of Oil

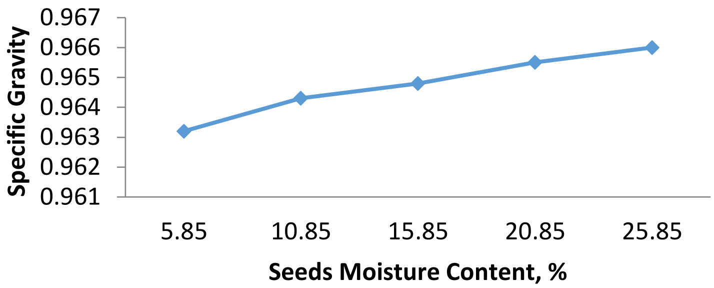

Figure 6: Specific Gravity with Seeds Moisture Content.

Figure 6 shows an increase in the specific gravity of the extracted oil with increase in the seeds moisture content. The relationship between specific gravity and seeds moisture content is expressed by this equation:

$$S_G = 0.00014M + 0.963 \ (R^2 = 0.977) \qquad (7)$$

CONCLUSION

The result obtained from this study implied that the relationships between moisture content and chemical properties followed the linear model. For effective extraction of oil from oilseeds, there is a need to know the relationship between chemical properties and moisture content which this study has provided. It was observed that some of the chemical properties such as oil content, acid value, peroxide value, iodine value are all affected by moisture content. To improve oil extraction efficiency it is important to consider the moisture content of the seed.

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PHYSICAL PROPERTIES OF BAOBAB LEAF POWDER AS INFLUENCED BY MOISTURE CONDITION

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ABSTRACT

The influence of moisture content on physical properties of baobab leaf powder was determined. The properties measured were particle size distribution, geometric mean diameter, geometric standard deviation, estimated surface area of and number of particles in a gram of charge, loose-filled bulk density and, tapped bulk density. Particle size distribution was predicted using log-normal and Gates-Gaudin-Schuhmann distribution functions. Moisture content had a significant effect on the physical characteristics of the powder. About 78% of the particle size ranged from 150 to 500 µm and the estimated maximum particle size were 290, 304, 349 µm for samples at 11.4%, 12.8% and 14.2% (db) moisture content respectively. The geometric mean diameter and geometric standard deviation increased as moisture content increased. The estimated total surface area of and number of particles per gram decreased as moisture content increased. Loose-fill bulk density and tapped density had highest values of 380 and 470 kg/m^3 followed by 360 and 460 kg/m^3 and 350 and 460 kg/m^3 for samples at 14.2%, 12.8% and 11.4% (db) moisture content respectively.

Keywords: Baobab leaf powder, particle size distribution, physical properties, moisture content

INTRODUCTION

Baobab leaf powder is a final product obtained after grinding dried baobab leaf. This baobab product is widely used in Northern Nigeria for soup preparation popularly known as 'miyan kuka' and an important traditional medicine for treating Diarrhoea, fever and inflammation in most African countries (Kamatou *et al*. 2011; Bamalli *et al*. 2014). The production of baobab leaf powder in milling industries is increasing partly due to the problems associated with traditional means of production. However, for baobab leaf powder to be efficiently handled at industrial level, knowledge of its physical properties is important to the efficient design of milling, handling, packaging and storage systems, and unit operations such as mixing, rehydration of powders, settling of particles and flow in hoppers.

Particle size is one of the physical properties that play an important role in unit operations such as milling, mixing, hydrating, extruding and pneumatic handling (Barbosa-Ca´novas and Yan, 2003). Geometric mean diameter and geometric standard deviation are parameters of particle size that represent the fineness of powder and are used to determine number of particles and total surface area of a unit mass of flour (ASABE 2006). During fluidize rehydration and pneumatic conveying of powders, number of particles and total surface areas can influence the performance of the process significantly. Particle size distribution is useful in quality control or system property description and together with particle size they influence properties of food powder such as bulk density, compression and flowability (Barbosa-Ca´novas and Yan, 2003). Another important physical property of flour is bulk density. The bulk density of powdered material increases significantly due to vibration and tapping during handling and transportation or due to normal load during storage (Barbosa-Ca´novas and Yan, 2003; Emami and Tabil, 2008). Moisture content is an important variable component of food material that influences physical properties and is critical in selecting proper process condition (Tumuluru *et al*., 2010).

Researchers have used different types of models to simulate experimental data in order to fully understand the characteristics of powdered materials. Yang *et al*. (1996) reported that log-normal distribution function has the best prediction capability out of the 19 distribution functions used to characterize the particle size distribution of alfalfa grind. Yan and Barbosa-Ca´novas (1997) comparatively simulated selected food powders with five particle size distribution models and reported that Gaudin–Meloy and Rosin–Rammler models have the best simulation power.

The physical properties of several food powders have been investigated experimentally and the results are analyzed using these models. The physical properties of corn and soybean meal, coconut flours, modified potato starch, and native starches of maize, wheat and potato have been reported by Molenda *et al*. (2002), Manikantan *et al*. (2015), Stasiak *et al*. (2014) and Stasiak *et al*. (2013) respectively. However, no research work has been reported on the physical properties of baobab leaf powder. Thus, the objectives of this research work were: to determine the effect of moisture content on geometric mean diameter and geometric standard deviation by mass, number of particles and total surface area per unit weight, loose-fill bulk density and tapped bulk density and to used particle size distribution functions to simulate the experimental data.

MATERIALS AND METHODS

Sample Preparation

About 10 kg of dried baobab leaves were procured from Gambaru market, Maiduguri, Borno State. After sorting out damage ones, the remaining bulk sample was further dried under ambient condition for 7 days. Locally made hammer mill with 2 mm screen size was used to ground the dried leaves. Three replicates of 10 g of the powder were collected and their average moisture content was determined to be 11.4% (db) using oven dried method. The whole sample was then divided into three portions and two portions were then conditioned into different moisture contents, sealed in polyethene bag and kept in refrigerator at 5°C for 5 days for the moisture to reach equilibrium within the sample. The amount of water that was added to further condition the sample was calculated using equation 1:

$$Q = \frac{W_i(m_f - m_i)}{(100 - m_f)} \quad (1)$$

where Q is the quantity of water in g, w_i is the weight of sample at initial moisture content, m_i, and m_f is the final moisture content. The actual moisture contents of the conditioned samples were determined to be 12.8% and 14.2% (db), using oven dried method.

Experimental Tests and Design

The sieving test was carried out using the ASABE standard (2006) method. The sieves have same frame diameters of 200 mm and sieve wire-cloth openings that range from 150 to 2000 µm. The sieve shaker held the set of 8 sieves and a pan arranged in descending order of opening. A charge of 100 g at specific moisture content was initially placed on the top sieve and a small rubber ball. The entire setup was then allowed to shake for 15 minutes to reach the end-point of the sieving process. After shaking, each sieve unit was weigh to record the amount of material in grams left on it.
The loose-filled bulk density was measured using the USP (2011) standard method. This involved passing 100 g through a sieve of 2 mm into a dry graduated 250 ± 2 ml cylinder placed 2 cm below the sieve and carefully leveling the flour without tapping or compacting. The unsettled apparent volume (V_o) was read to the nearest graduated unit. The tapping test was carried out by securing the filled cylinder in the holder of a tapping apparatus capable of dropping from a height of 10 mm. The tapped volumes after 10, 250, 500, 750, 1000 and 1250 taps on the same sample were recorded. A gas pycnometer was employed to determine particle density by measuring the volume of particle in a sample and dividing the mass of the sample by its solid volume.
Completely randomized design was used in all the tests as the experimental design. Samples at all moisture contents were randomly assigned to the sequence of test runs during a test. Each test at particular moisture content was replicated three times.

Data Analysis and Simulation

The size of particles was expressed in terms of geometric mean diameter and geometric standard deviation based on the assumption that particle sizes of powdered materials are logarithmic-normally distributed (ASABE, 2006). The geometric mean diameter and geometric standard deviation were determined using equations 2 and 3 respectively (ASABE, 2006; Wang *et al*. 1995):

$$d_{gw} = \log^{-1}\left[\frac{\sum_{i=1}^{n}(W_i \times \log d_i}{\sum_{i=1}^{n} W_i}\right] \quad (2)$$

$$S_{gw} = \log^{-1}\left[\frac{\sum_{i=1}^{n} W_i(\log d_i - \log d_{gw})^2}{\sum_{i=1}^{n} W_i}\right]^{\frac{1}{2}} \quad (3)$$

where d_{gw} and S_{gw} are geometric mean diameter and geometric standard deviation by mass (µm) respectively, w_i is mass of powder on i^{th} sieve (kg), and d_i is geometric mean diameter on the i^{th} sieve. The particle size distribution of the powder was represented by plotting its cumulative percentage frequency against sieve opening size. Particle size distribution data was simulated using log-normal and Gates-Gaudin-Schuhmann distribution (GGS) functions respectively (Eqns. 4-5):

$$P_r = a * \exp^{-0.5\left[\frac{ln(\frac{x}{x_0})}{b}\right]^2} \quad (4)$$

$$Y = \left(\frac{x}{k}\right)^m \quad (5)$$

where P_r is percentage weight retained on sieve size x; a and b are constants; x_o is the maximum particle size; Y is the cumulative weight fraction finer than size x in %, k is Schuhmann size modulus, m is measurement of the distribution spread. The estimated total surface area and number of particles in a charge were calculated using equations 6 and 7 (Yang *et al*. 1996) respectively:

$$A_{st} = \frac{\beta_s \times W_t}{\beta_v \times \rho \times d_{gw}} e^{[0.5\times(ln S_{gw})^2]} \quad (6)$$

$$N_t = \frac{W_t}{\beta_v \times \rho \times d_{gw}^3} e^{[4.5\times(ln S_{gw})^2]} \quad (7)$$

where A_{st} is the estimated total surface area of a charge in m^2/g, βs and βv are shape factors for surface area and volume of particle respectively, lnS_{gw} is geometric standard deviation in natural logarithm. The loose bulk density and tapped density were calculated by dividing the mass of the flour in the graduated cylinder by the uncompressed volume of the flour and tapped volume respectively. The index of the ability of the flour to flow was calculated using the compressibility index and Hausner ratio.

Simple descriptive statistical analysis was used to report averages and standard deviations of experimental data. Data obtained were subjected to ANOVA to determine the levels at which the effects of moisture content were significantly different. Microsoft Excel software was used to plot graphs and carryout the statistical analysis.

RESULTS AND DISCUSSIONS

Particle Size and Particle Size Distribution

Table 1 presents the results of some particle size related parameters of baobab leave grind at different moisture content levels and the statistical significance of the variations. The geometric mean diameter by mass increased as moisture content increased from 11.4 to 14.2% (db). The geometric standard deviation by mass also increased with increasing moisture content. The variation in moisture content of baobab leaf powder significantly influenced both the geometric mean diameter and geometric standard deviation by mass. The increase in geometric mean diameter as moisture content increased to could be due to expansion of particles when they absorb moisture. The increase in moisture content of a gram of baobab leaf powder significantly decreased the estimated surface area. The number of particles per gram of baobab leaf powder was significantly decreased as the moisture content increased. The decrease in estimated surface area and number of particle with moisture content increase could be due to a significant contribution that weight of moisture has on the sample total weight.

The distributions of the percent weight retained on each test sieve samples for the samples different moisture content levels are presented in Figure 1. The plots in Figure 1 show skewness similar to those reported for alfalfa grind (Yang *et al*., 1996). Most particles, 78%, were in the range of 150 to 500 μm for the samples. Figure 2 presents the distributions of particle size plotted on log scaled abscissa and log-normal distribution function plots fitted to the experimental data. The R^2 value of log-normal distribution function (0.7619 to 0.8740) indicated a good fit to the experimental data. Equations 8 to 10 present the log-normal estimate of percent weight retained. The estimated maximum particle size increased from 290.6 to 349.8 μm with increase in moisture content. The plots of GGS distribution function fitted into cumulative undersize distribution of the samples are shown in Figure 3. The GGS distribution function showed good fit (R^2 from 0.7754 to 0.8935). The estimated measure of the distribution spread, m, increased from 0.5643 to 0.6348 with increased in moisture content from 11.4 to 14.2% (db). The values of m were observed to be similar to the constant 'b' of log-normal distribution.

$$P_{r11.4} = 23.32 * \exp^{-0.5\left[\frac{ln(\frac{x}{290.61})}{0.5565}\right]^2} \quad (8)$$

$$P_{r12.8} = 23.2 * \exp^{-0.5\left[\frac{ln(\frac{x}{304.99})}{0.5514}\right]^2} \quad (9)$$

$$P_{r14.2} = 21.71 * \exp^{-0.5\left[\frac{ln(\frac{x}{349.88})}{0.6394}\right]^2} \quad (10)$$

$$Y_{11.4} = \left[\frac{x}{1500.1}\right]^{0.5643} \quad (11)$$

$$Y_{12.8} = \left[\frac{x}{1546.9}\right]^{0.5927} \quad (12)$$

$$Y_{14.2} = \left[\frac{x}{1596.4}\right]^{0.6348} \quad (13)$$

Bulk densities

The variation of loose-filled bulk density was significantly influenced by change in moisture content of baobab grind (Table 2). It can be observed from Table 2 that the loose-filled bulk density increased as the moisture content increased. Ghorbani *et al*. (2012) reported similar trend for bulk density of alfalfa grind as their moisture content increased. This could be attributed to poor particle expansion as moisture content increases. A significant relationship similar to loose-filled bulk density was not observed between tapped bulk density and moisture content (Table 2). The measures of the flour to be compressed by tapping and interparticulate interaction were significantly influenced by moisture content (Table 2). It can be seen from Table 2 that both the Hausner ratio and compression index of the particles decreased as moisture content increased.

CONCLUSION

The influence of moisture content on the physical properties of baobab leaf grind was investigated in this study. The following conclusions can be drawn from the study:

1. Moisture content had a significant effect on the selected physical properties.
2. About 78% of the particle size ranged from 150 to 500 µm and the estimated maximum particle size were 290, 304, 349 µm for samples at 11.4%, 12.8% and 14.2% moisture content respectively.
3. The geometric mean diameter, geometric standard deviation, loose-filled bulk density and tapped density increased as moisture content increased from 11.4% to 14.2% (db).
4. Estimated surface area of and number of particles in 100 g decreased as moisture content increased from 11.4% to 14.2% (db).

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Table 1. Geometric mean diameter, geometric standard deviation, estimated surface area of and number of particles in 100 g for baobab leaf grind at moisture content range between 11.4% and 14.2% (db)

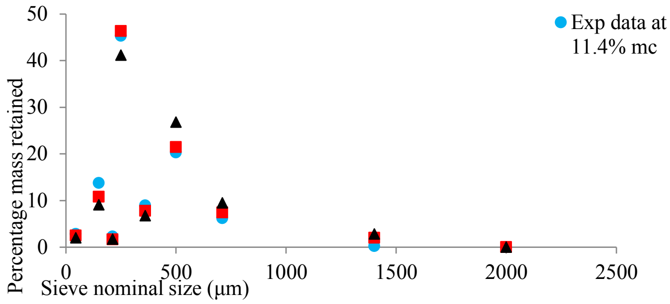
Parameter	11.4% (db) mc	12.8% (db) mc	14.2% (db) mc	F-value	P-value
Geometric mean diameter of particle by mass, d_{gw} (µm)	343.2 (16.5)	368.3 (15.3)	404.8 (57.6)	7.235	0.0251
Geometric standard deviation of particle diameter by mass, S_{gw} (µm)	188.6 (13.3)	215.6 (37.4)	253.2 (34.5)	5.9701	0.0421
Estimated surface area per gram, A_{st} (m^2/g)	0.0438 (0.0019)	0.0409 (0.0011)	0.0386 (0.058)	6.932	0.0196
Number of particles per gram, N_t	357,133 (36,765)	336,203 (81,355)	329,599 (65,637)	7.981	0.03055

Numbers in parentheses are standard deviations

Table 2. Loose-filled bulk density, tapped bulk density, compressibility index, and Hausner ratio for baobab leaf grind at moisture content range between 11.4% and 14.2%

Physical properties	mc =11.4%(d.b)	mc=12.8%(d.b)	mc=14.2%(d,b)	F	P-value
Bulk density(b_d)	350(0.010)	360(0.010)	380(0.00)	9.92	0.0029
Tapped density	460(0.012)	460(0.00)	470(0.006)	0.67	0.55
Hausner ratio(H_r)	1.30	1.27	1.21		
Compressibility index(C_I)	23.11	21.50	21.40		

Numbers in parenthesis are standard deviation.



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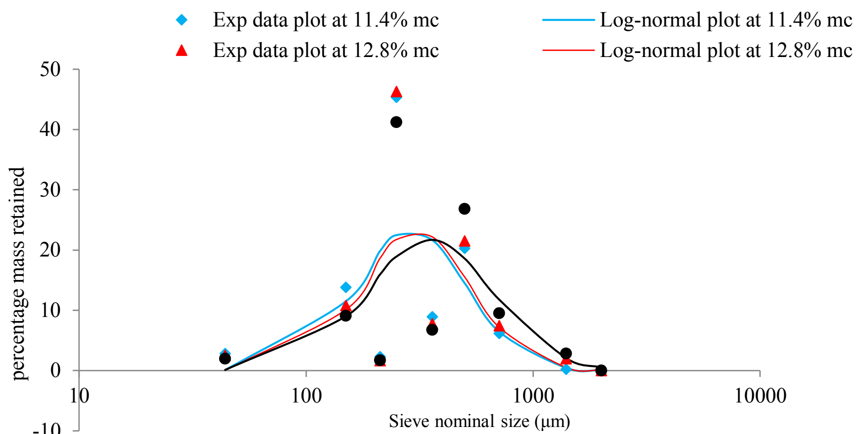

Figure 2. Experimental data and log-normal distribution function plots of baobab leaf grind

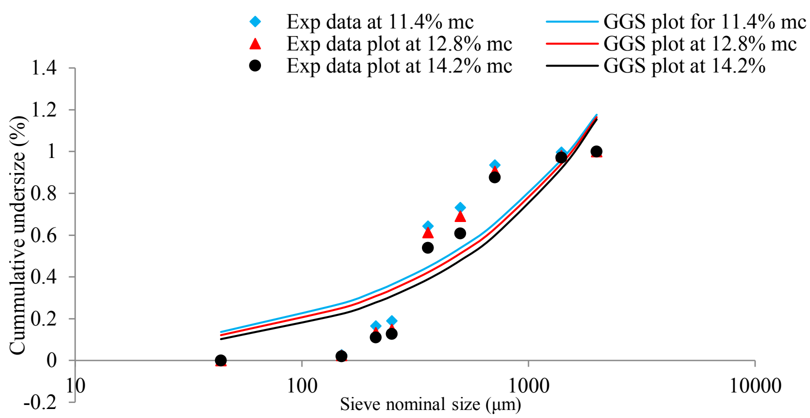

Figure 3. Experimental data and Gates-Gaudin-Schuhmann distribution function plots of baobab leaf grind

EFFECT OF TEMPERATURE AND MOISTURE SORPTION HYSTERESIS ON MONOLAYER MOISTURE CONTENT OF SELECTED CROPS DETERMINED USING BET AND GAB MODELS

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ABSTRACT
Monolayer moisture content is usually considered the minimum value at which food and agricultural product storage stability can be assured. Deterioration reactions occurring below this moisture content disproves the generally accepted view that product stability increased as moisture content decreased, hence the need for accurate determination of monolayer moisture content. Moisture sorption data (adsorption and desorption) in the water activity and temperature ranges of 0.02 – 0.90 and 5°C – 70°C, respectively, were used to determine the monolayer moisture contents (M_m) of four selected food products namely pumpkin seed and kernel, canola seed and potato desiree, and investigate the effect of hysteresis on its value. The M_ms were calculated using Brunauer-Emmett-Teller (BET) and Guggenheim-Anderson-de Boer (GAB) moisture sorption isotherm models. Results showed that M_m decreased with increase in temperature, with the GAB giving higher values than the BET. Energy constants of BET were higher than those of GAB, and desorption M_ms were higher than the corresponding adsorption values. However, analysis of variance (ANOVA) showed that there was no significant pairwise differences among desorption and adsorption M_m means ($P \leq 0.05$), implying that hysteresis did not significantly influence the M_ms of the crops studied. The BET and GAB M_m decreased linearly with temperature for each of the crops.

Keywords: *Monolayer moisture content (M_m), moisture sorption hysteresis, potatoes desiree, canola gulle, pumpkin seed and kernel, BET, GAB*

INTRODUCTION
Pumpkin plant (*Cucurbita pepo*) belongs to the *Cucurbitaceae* family of vegetables and is an annual plant with leafy green vegetation. It has a climbing stem of up to 12m long and a squash-like gourd shaped fruit with fibrous flesh. Figure 1a shows the pumpkin seeds which contain a kernel each that is edible and from which oil can be extracted (Akritidis *et al.*, 1988). Pumpkin has received considerable attention in recent years because of the nutritional and health values of the seeds. The seed has pharmacological potential of serving anti-diabetic, antifungal, antibacterial and anti-inflammation functions and as antioxidant (Abd El-Aziz and Abd El-Kalek, 2011). They serve as a rich source of edible oil that is high in unsaturated fatty acids and vitamin E. The seeds are also consumed directly as snack food in many cultures throughout the world.

Canola (*Brassica napus L.*) is a specific edible type of rapeseed and it is an important oil crop grown mainly in Canada, India, China, Europe and other regions of the world. It is one of the most important source of vegetable oil in Europe and the second most important oilseed crops in the world after soybean (Gazor 2010). The seeds of modern varieties (Figure 1b) typically contain 40 to 45% oil, and that enables the crop to serve also as raw material for the production of biodiesel, industrial lubricants and hydraulic oils. The term **"**Canola**"** is a registered name for the crop by the Western Canadian oilseed crushers association. Canola oil is considered one of the highest quality edible oils available (Kandel and Berglurd, 2011). For prevention of rancidity and to ensure good quality, canola must be harvested and dried in a short period. Drying has very important role in canola storage. In this step, moisture of kernels is reduced to about 7 % d.b., which would result in suitable condition for storage (Pagano *et al.,* 1999; Ward *et al.,* 1985).

The desiree is a red-skinned root potatoes (Figure 1c) mostly grown in Netherlands and some parts of Nigeria. It has reddish yellow flesh with a distinctive flavor and is fairly resistant to diseases. It is firm and holds its shape during cooking. The inherent high moisture content of potatoes desiree make biological deterioration by microbial activities inevitable in its natural state. Reduction in moisture content to a safe level results in decrease in metabolic activities of micro-organism and inherent temperature during storage (Wang and Brennan, 1991).

a b c

Figure 1: a: Pumpkin seeds, b: canola seeds and c: potato desiree

Moisture content is an important factor which affects seed longevity in storage. When seeds are exposed to air of a certain relative humidity, the seed's moisture content tends to equilibrates in relation to the relative humidity of the air surrounding it (Moravec *et al.*, 2008). As the relative humidity of the storage environment increases, the moisture content of the seed also increases, and this in turn, decreases seed longevity as increase in moisture content encourages the development and growth of microorganisms.

Monolayer moisture content (M_m) is an important parameter in food storage and deterioration of dry products. It can be obtained using the BET (Brunauer-Emmett-Teller) and GAB (Guggenheim-Anderson-De Boer) moisture sorption isotherm models (Chung and Pfost, 1967).The value of the monolayer moisture content is of particular interest since it indicates the amount of water that is strongly adsorbed to specific sites at the food surface. It is considered as the minimum value to which food material can be dried to ensure storage stability. Deterioration reactions occurring below this moisture content differ from those that occur above its value. At moisture contents below the monolayer, deterioration that is characterized as autoxidation occurs and results in the development of rancid flavour and odour. This observation opposes the generally accepted view that product stability increased as moisture content decreased. For most dry foods, the rate of quality loss due to chemical reactions is negligible at the monolayer value (Sudathip *et al.*, 2009). Hysteresis is a phenomenon by which at a given level of water activity and temperature, an adsorbent holds a smaller amount of moisture during an adsorption process than during a subsequent desorption process.

The BET and the GAB moisture sorption isotherms models are closely related as they follow from the same statistical model. The GAB model appears represent a refinement of the BET model and shares with it two constants (monolayer moisture content, M_m and energy constant, C) and owes its major versatility to the introduction of a third constant, k (Timmermann, 2003).

Investigators who computed the monolayer moisture content of different crops using the BET include Kumar and Balasubrahmanyam (1986), Aviara and Ajibola (2002), Ajibola *et al.* (2003) and Aviara *et al.* (2004), on mushrooms, flours, different grains and seeds at single temperature, melon seed and cassava in desorption, cowpea in desorption, and soya bean in desorption, respectively. Others are Ajibola *et al*. (2005), Igathinathane *et al*. (2007), Menkov *et al.* (2009), Zomorodian *et al.* (2011) and Rajamanickam *et al.*, (2013), who studied palm kernel in desorption, corn stover fractions, buckwheat grains, canola seeds only in adsorption, and caraway seed, respectively. The GAB was applied by Kiranoudis *et al.* (1993) on fruits and vegetables, Oluwamukomi (2009) on soy-melon-enriched and unenriched gari and Eim *et al.* (2011) on carrot in desotption. Both models were utilized by Siripatrawan and Jantawat (2006) on Jasmine rice crackers in adsorption, Fadeyibi *et al.* (2012) on rubber seed in desorption, Maleki Majd *et al.* (2014) on grape seed in adsorption, and Ogbenjuwa (2014) on sorghum malt in adsorption and desorption. The investigators showed that the GAB monolayer moisture content is usually higher than the BET value and that it varied with crops and decreased with increase in temperature. However, the effect of moisture sorption hysteresis on the temperature dependence of monolayer moisture content of several tropical crops appears not to have been investigated. This has been an obstacle to efforts made to establish the conditions for the storage stability of the products. To provide this needed data and overcome the existing obstacle, there is a need to determine the monolayer moisture content of the crops, its variation with temperature and the influence of moisture sorption hysteresis on its values.

The objectives of this study were therefore, to (1) determine the monolayer moisture content of pumpkin seeds and kernels, canola gulle seeds and potatoes desiree tubers from their moisture sorption data at different temperatures, using the BET and GAB moisture sorption isotherm models, (2) investigate the variation of monolayer moisture content with temperature and (3) determine the extent to which moisture sorption hysteresis has effect on the monolayer moisture content these products.

MATERIALS AND METHOD

Materials

Sample preparation and initial moisture content determination procedures for the seeds and tubers subjected to moisture adsorption and desorption processes were as presented by Akritidis *et al.* (1988) for pumpkin seeds and kernels, Otten *et al.* (1990) for canola gulle seeds and Wang and Brennan (1991) for potatoes desiree tubers.

Methods

Static gravimetric method involving the use of saturated salt solutions was used to obtain the adsorption and desorption equilibrium moisture content-water activity data of the products investigated in this study. Data were obtained in the temperature and water activity ranges of 40-70ºC and 0.058-0.884 for potatoes desiree tubers (Wang and Brennan 1991), 5-35 ºC and 0.02-0.9 for canola gulle seeds (Otten *et al.,* 1990), 10-60 ºC and 0.05-0.75 for pumpkin seeds and kernels (Akritidis *et al.,* 1988). The adsorption and desorption equilibrium moisture content-water activity data at different temperatures are presented in Tables 1, 2, 3 and 4 for potatoes desiree tubers, canola gulle seeds and pumpkin seeds and kernels, respectively.

Table 1. Adsorption (Ads) and desorption (Des) equilibrium moisture contents (EMC %, db) of potatoes desiree tubers at four temperatures and different water activities (a_w)

40ºC	Ads	a_w	0.058	0.125	0.197	0.292	0.377	0.532	0.753	0.884
		EMC	2.4	3.2	4.0	5.1	7.1	8.9	13.3	18.7
	Des	a_w	0.058	0.126	0.198	0.29	0.373	0.53	0.751	0.882
		EMC	2.2	2.9	3.5	5.0	6.3	8.5	12.9	18.4
50ºC	Ads	a_w	0.062	0.133	0.206	0.304	0.387	0.543	0.762	0.888
		EMC	2.1	3.1	3.7	4.9	6.4	8.1	12.1	16.6
	Des	a_w	0.062	0.13	0.205	0.297	0.383	0.541	0.762	0.886
		EMC	2.1	2.8	3.3	4.5	6.0	8.2	12.8	17.1
60⁰C	Ads	a_w	0.07	0.142	0.221	0.312	0.398	0.561	0.762	0.888
		EMC	2.0	2.7	3.4	4.4	5.4	6.5	9.9	14.7
	Des	a_w	0.07	0.144	0.22	0.309	0.393	0.559	0.763	0.888
		EMC	1.8	2.4	3.1	4.2	5.3	7.6	11.8	16.3
70⁰C	Ads	a_w	0.074	0.152	0.23	0.323	0.405	0.579	0.768	0.887
		EMC	1.8	2.2	2.3	3.4	4.2	6.0	8.4	13.6
	Des	a_w	0.075	0.154	0.228	0.319	0.4	0.576	0.766	0.887
		EMC	1.5	2.0	2.4	3.1	4.8	7.2	11.0	14.7

Source: Wang and Brennan, (1991)

Table 2. Adsorption (Ads) and desorption (Des) equilibrium moisture contents (EMC %, db) of canola gulle seeds at four temperatures and different water activities (a_w)

5 ºC		a_w	0.20	0.30	0.40	0.40	0.60	0.70	0.80	0.90
	Ads	EMC	3.5	4.4	5.3	6.2	7.3	8.8	11.9	17.2
	Des	EMC	3.8	4.7	5.6	6.5	7.4	9.2	12.2	17.9
15 ºC		a_w	0.20	0.30	0.40	0.40	0.60	0.70	0.80	0.90
	Ads	EMC	3.4	4.3	5.0	5.9	7.0	8.6	11.5	16.7
	Des	EMC	3.5	4.4	5.3	6.2	7.3	8.8	11.9	17.2
25 ºC		a_w	0.20	0.30	0.40	0.40	0.60	0.70	0.80	0.90
	Ads	EMC	3.2	4.0	4.8	5.7	6.7	8.3	11.4	16.4
	Des	EMC	3.4	4.3	5.0	5.9	7.0	8.6	11.5	16.7
35 ºC		a_w	0.20	0.30	0.40	0.40	0.60	0.70	0.80	0.90
	Ads	EMC	3.2	4.2	4.6	5.5	6.6	8.1	11.2	16.4
	Des	EMC	3.2	4.0	4.8	5.7	6.7	8.3	11.4	16.4

Source: Otten *et al.* (1990)

Table 3. Adsorption (Ads) and desorption (Des) equilibrium moisture contents (EMC %, db) of pumpkin seeds at six temperatures and different water activities (a_w)

10 ºC		a_w	0.05	0.15	0.250	0.35	0.45	0.55	0.65	0.75
	Ads	EMC	4.2	6.1	6.6	7.6	8.0	8.8	10.4	11.7
	Des	EMC	4.8	6.1	7.1	8.2	8.9	9.8	11.3	13.3
20 ºC		a_w	0.05	0.15	0.250	0.35	0.45	0.55	0.65	0.75
	Ads	EMC	3.9	5.3	6.6	7.4	7.9	8.7	10.2	11.4
	Des	EMC	4.3	5.9	6.6	7.8	8.6	9.2	10.8	12.3
30 ºC		a_w	0.05	0.15	0.250	0.35	0.45	0.55	0.65	0.75
	Ads	EMC	3.5	5.0	6.2	7.1	7.5	8.4	10.1	11.2
	Des	EMC	3.6	5.0	6.0	6.9	7.9	8.7	10.3	12.3
40 ºC		a_w	0.05	0.15	0.250	0.35	0.45	0.55	0.65	0.75
	Ads	EMC	3.1	4.5	5.0	6.9	7.2	8.1	10.1	10.7
	Des	EMC	3.3	4.5	5.2	6.3	7.3	8.2	10.3	13.9
50 ºC		a_w	0.05	0.15	0.250	0.35	0.45	0.55	0.65	0.75
	Ads	EMC	2.6	3.9	5.1	6.1	6.8	8.0	8.4	10.6
	Des	EMC	3.1	4.5	4.7	5.8	6.7	7.5	9.7	11.6
60 ºC		a_w	0.05	0.15	0.250	0.35	0.45	0.55	0.65	0.75
	Ads	EMC	2.0	3.8	4.3	4.7	6.1	7.0	7.2	9.9
	Des	EMC	2.5	3.4	4.2	4.9	5.7	6.8	8.4	10.4

Source: Akritidis et al. (1988)

Table 4. Adsorption (Ads) and desorption (Des) equilibrium moisture contents (EMC %, db) of pumpkin seed kernels at six temperatures and different water activities (a_w)

10⁰C		aw	0.05	0.15	0.25	0.35	0.45	0.55	0.65	
	Ads	EMC	4.5	5.6	5.8	6.6	6.9	8.0	8.6	10.5
	Des	EMC	4.5	5.6	6.3	7.3	7.7	8.2	9.6	11.2
20⁰C		aw	0.05	0.15	0.25	0.35	0.45	0.55	0.65	
	Ads	EMC	3.7	5.0	5.9	6.4	6.7	7.6	8.4	9.8
	Des	EMC	4.0	5.4	6.0	6.9	7.5	8.0	8.9	
30⁰C		aw	0.05	0.15	0.25	0.35	0.45	0.55	0.65	
	Ads	EMC	3.3	4.4	5.4	6.2	6.7	7.6	8.3	10.5
	Des	EMC	3.5	4.8	5.5	6.0	6.7	7.3	8.7	10.3
40⁰C		aw	0.05	0.15	0.25	0.35	0.45	0.55	0.65	
	Ads	EMC	3.0	4.2	4.6	6.0	6.3	7.2	8.5	8.5
	Des	EMC	3.2	4.1	4.8	5.6	6.4	7.0	8.4	
50⁰C		aw	0.05	0.15	0.25	0.35	0.45	0.55	0.65	
	Ads	EMC	2.5	3.3	4.5	5.4	5.8	6.9	6.7	7.7
	Des	EMC	2.9	3.9	4.6	5.2	5.6	6.5	7.8	9.1
60⁰C		aw	0.05	0.15	0.25	0.35	0.45	0.55	0.65	
	Ads	EMC	2.1	3.0	4.1	4.3	4.8	6.1	5.3	7.1
	Des	EMC	2.5	3.2	3.9	4.3	5.1	6.2	7.1	7.6

Source: Akritidis et al. (1988)

Monolayer moisture content (M_m) determination

The monolayer moisture content (M_m) of potato desiree tubers, canola gulle seeds and pumpkin seeds and seed kernels was evaluated at each temperature for the adsorption and desorption arms of their isotherms by applying the two parameter BET (Brunaeur-Emmett-Teller) and three parameter GAB (Guggenheim-Anderson-De Boer) equations to the isotherm data as follows:

Brunauer-Emmett-Teller (BET)

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 the form of Equation (1).

$$M = \frac{M_m C a_w}{(1-a_w)[1+(C-1)a_w]} \quad (1)$$

where: **M** is equilibrium moisture content (% db), **M_m** is monolayer moisture content (%, db), **a_w** is water activity in the range 0.05-0.45 and **C** is energy constant related to net heat of sorption.

The algebraic manipulation of equation (1) yields the linear form as follows:

$$\frac{a_W}{(1-a_w)M} = \frac{1}{M_m C} + \frac{a_w(C-1)}{M_m C} \quad (2)$$

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 yields a straight line with the slope as $\frac{C-1}{M_m C}$ and intercept on the y-axis as $\frac{1}{M_m C}$. From the slopes of the plots from equation (2) at different temperatures, the BET monolayer moisture content, M_m and energy constant, C of the products in adsorption and desorption processes, were obtained. The values of adsorption and desorption BET M_m were plotted and regressed against temperature.

Guggenheim-Anderson-De Boer (GAB)

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 expressed as

$$M = \frac{CkM_m a_w}{(a-ka_w)(1-ka_w+Cka_w)} \quad (3)$$

where: C and k are sorption constant of the GAB model.

Equation (3) was transformed into a polynomial of the second order (Equation 4) and used to determine the GAB constants and monolayer moisture content.

$$\frac{a_w}{M} = \propto a_w^2 + \beta a_w + \gamma \quad (4)$$

where: $\propto = \frac{K}{M_m}\left(\frac{1}{C} - 1\right)$

$\beta = \frac{1}{M_m}\left(1 - \frac{2}{C}\right)$, and

$$\gamma = \frac{1}{M_m CK}$$

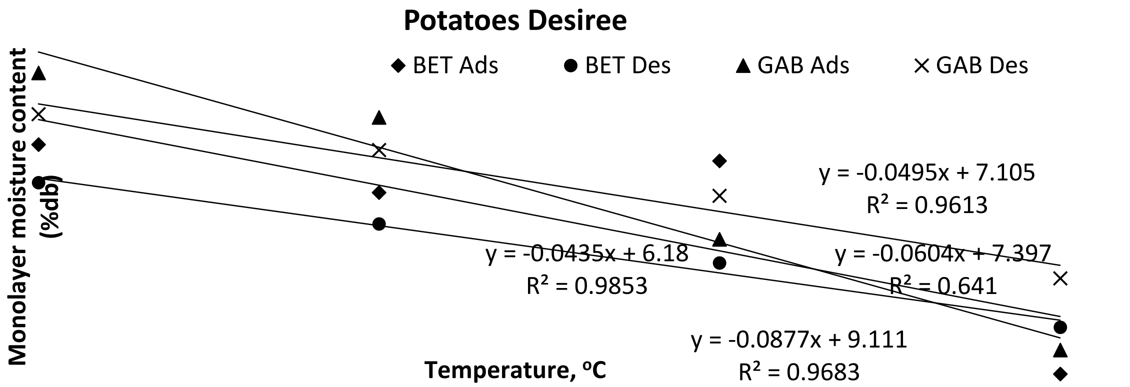
Equation (4) was solved by plotting a_w/M versus a_w at each temperature and fitting the plot with a second order polynomial using Microsoft Excel (2007) in order to determine the values of the coefficient of the quadratic term ∝, the linear term coefficient β and the constant γ. The values of adsorption and desorption GAB M_m obtained were then plotted and regressed against temperature.

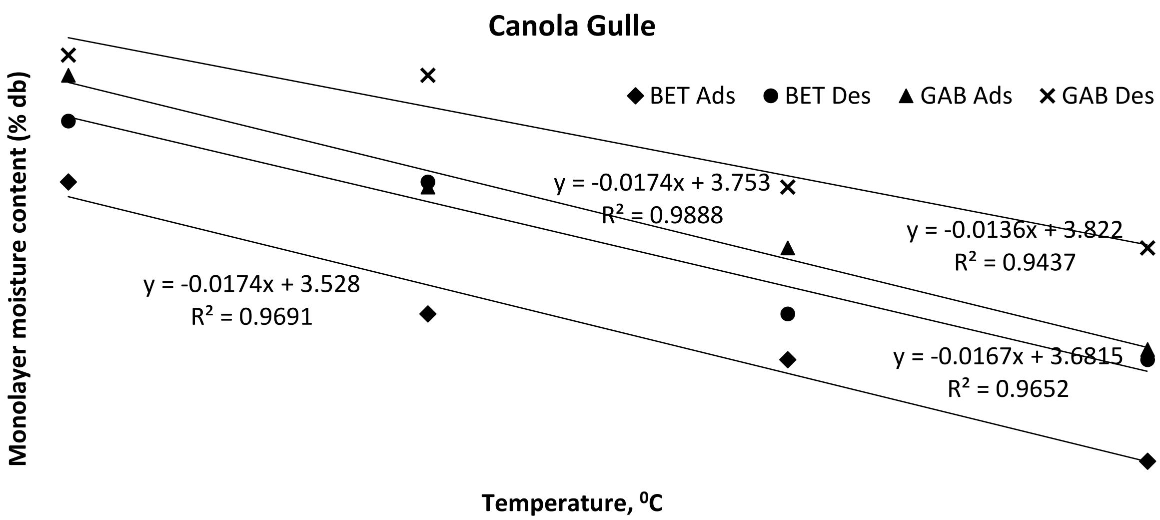
RESULTS AND DISCUSSION

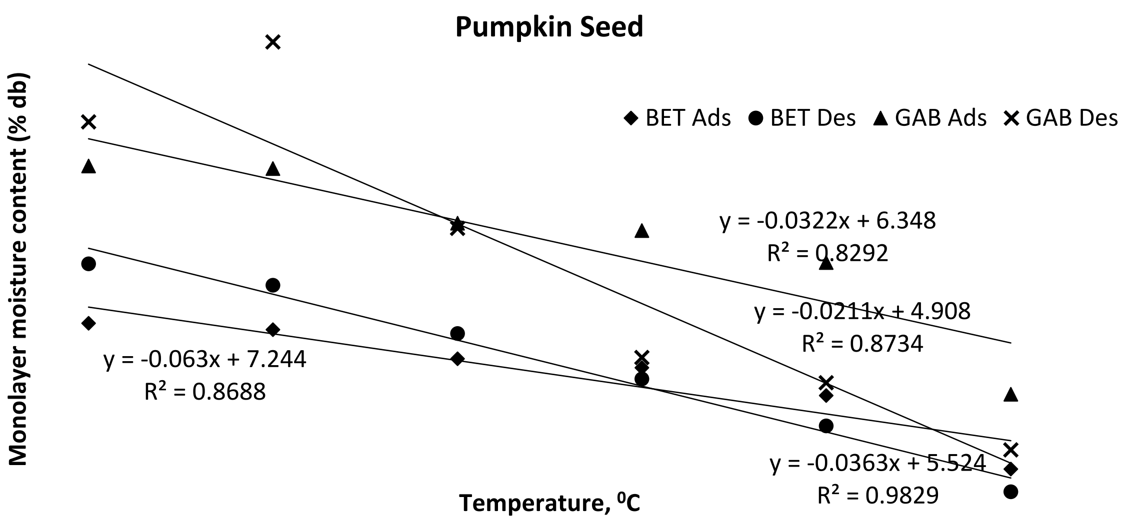
The values of monolayer moisture contents and their variation with temperature are presented in Table 5. The monolayer moisture content of potatoes desiree tuber, canola gulle seed, pumpkin seed and kernel, varied with crop and decreased with increase in temperature for both the BET and GAB models. The decrease in the monolayer moisture content with increase in temperature has been attributed to reduction in the number of active sites due to chemical and physical changes induced by temperature (McMinn and Magee, 2003). Similar observations were obtained by Ajibola *et al.* (2003) for cowpea, Aviara *et al.* (2004) for soya bean, Maleki Majd *et al.* (2014) for grape seed and Aviara *et al.* (2016) for EX-Borno and Sosat C88. The GAB monolayer values were higher than the corresponding BET values. Similar observation was reported by Timmermann *et al.* (2001).This may be attributed to the fact that the BET is related more to moisture sorption in the first layer making it more suitable dry materials, while the GAB is related to the multilayer region, making it more suitable for intermediate to high moisture foods (Maleki Majd *et al.*, 2014). Figure 2 shows that the M_m calculated using the two models varied linearly with temperature. The regression models that could be used to describe the trend of M_m with temperature are presented in Tables 6 and 7. From Figure 2, it can be seen that hysteresis caused desorption monolayer moisture values to be higher than the corresponding adsorption values. However, the results of the analysis of variance (ANOVA) showed that there was no significant difference between the monolayer moisture content of the adsorption and desorption processes determined using both the BET and GAB models for the different products studied. This may be an indication that hysteresis did not have significant effect on monolayer moisture content, implying that hysteresis in each of the products may not have commenced before the monolayer moisture content was attained or that it may have commenced very close to the attainment of the monolayer. Temperature, however, had significant effect.

Table 5. Monolayer moisture content of potatoes desiree tuber, canola gulle seed, pumpkin seed and kernel determined using BET and GAB models at different temperatures

T (°C)	Adsorption		Desorption	
	BET(M_m)	GAB(M_m)	BET(M_m)	GAB(M_m)
	POTATOES DESIREE			
30	4.75	5.41	4.40	5.03
40	4.31	5.00	4.02	4.70
50	3.60	3.88	3.66	4.28
70	2.64	3.86	3.07	3.52
	CANOLA GULLE			
5	3.47	3.68	3.59	3.72
15	3.21	3.46	3.47	3.68
25	3.12	3.34	3.21	3.46
35	2.92	3.14	3.12	3.34
	PUMPKIN SEED			
10	4.57	5.81	5.04	6.16
20	4.52	5.79	4.87	6.79
30	4.29	5.36	4.49	5.32
40	4.22	5.30	4.13	4.30
50	4.00	5.05	3.76	4.10
60	3.42	4.01	3.24	3.57
	PUMPKIN KERNEL			
10	3.85	4.82	4.37	5.40
20	3.83	5.00	4.24	5.79
30	3.87	4.76	3.77	4.52
40	3.64	5.05	3.60	4.21
50	3.42	5.17	3.20	3.84
60	2.78	3.87	2.85	3.60


Potatoes Desiree
BET Ads
BET Des
GAB Ads
GAB Des
y = -0.0495x + 7.105
R² = 0.9613
y = -0.0435x + 6.18
R² = 0.9853
y = -0.0604x + 7.397
R² = 0.641
y = -0.0877x + 9.111
R² = 0.9683
Monolayer moisture content (%db)
Temperature, °C


Canola Gulle
BET Ads
BET Des
GAB Ads
GAB Des
y = -0.0174x + 3.753
R² = 0.9888
y = -0.0136x + 3.822
R² = 0.9437
y = -0.0174x + 3.528
R² = 0.9691
y = -0.0167x + 3.6815
R² = 0.9652
Monolayer moisture content (% db)
Temperature, °C



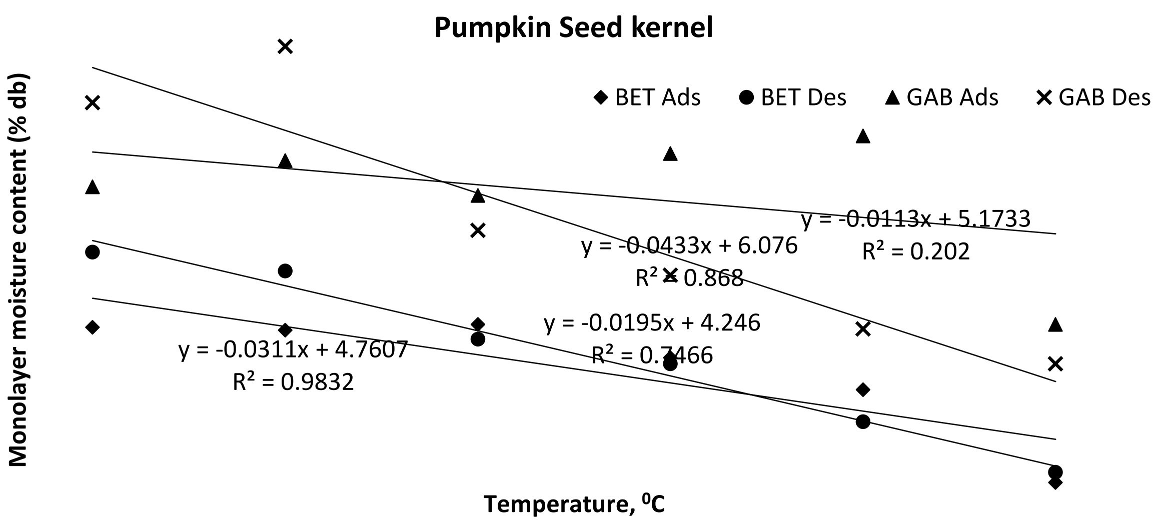


Figure 2. Variations of adsorption and desorption monolayer moisture content of potatoes desiree tuber, canola gulle seed, pumpkin seed and kernel at different temperatures using BET and GAB models.

The relationship existing between monolayer moisture content of potatoes desiree tuber, canola gulle seed, pumpkin seed and kernel and temperature can be expressed using the equations presented in Tables 6 and 7.

Table 6.Relationship between BET monolayer moisture content and temperature

Crops	BET	
	Adsorption	Desorption
Potatoes desiree	$M_m = -0.060T + 7.397$ $R^2 = 0.641$	$M_m = -0.043T + 6.168$ $R^2 = 0.985$
Canola gulle	$M_m = -0.017T + 3.528$ $R^2 = 0.969$	$M_m = -0.016T + 3.681$ $R^2 = 0.985$
Pumpkin seed	$M_m = -0.021T + 4.908$	$M_m = -0.036T + 5.524$

	R^2 = 0.873	R^2 = 0.982
Pumpkin kernel	M_m = -0.019T + 4.246 R^2 = 0.764	M_m = -0.031T + 4.760 R^2 = 0.983

Note:*M_m,* Monolayer moisture content (% db), *T*, temperature (°C), *R^2*, coefficient of determination

Table 7.Relationship between GAB monolayer moisture content and temperature

Crops	GAB	
	Adsorption	Desorption
Potatoe desiree	M_m = -0.087T + 9.111 R^2 = 0.968	M_m = -0.049T + 7.105 R^2 = 0.961
Canola gulle	M_m = -0.017T – 3.753 R^2 = 0.988	M_m = -0.013T – 3.822 R^2 = 0.943
Pumpkin seed	M_m = -0.032T + 6.348 R^2 = 0.829	M_m = -0.063T + 7.244 R^2 = 0.868
Pumpkin kernel	M_m = -0.011T + 5.173 R^2 = 0.202	M_m = -0.043T + 6.076 R^2 = 0.868

Note: *M_m,* Monolayer moisture content (% db), *T*, temperature (°C), *R^2*, coefficient of determination

CONCLUSIONS

The study of the monolayer moisture content of potatoes desiree tuber, canola gulle seed and pumpkin seed and kernel at different temperatures using BET and GAB moisture sorption isotherm models revealed the following:

1. Monolayer moisture content decreased with increase in temperature in both adsorption and desorption for both BET and GAB models.
2. GAB monolayer moisture contents were higher than those of the corresponding BET.
3. Hysteresis caused desorption monolayer moisture contents in both BET and GAB models to be higher than the corresponding adsorption values at all temperatures.
4. Effect of moisture sorption hysteresis on the monolayer moisture content of the products was not significant.
5. Temperature had significant effect on monolayer moisture content.

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DEVELOPMENT OF A LABORATORY SCREW PRESS FOR VEGETABLE OIL EXTRACTION

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ABSTRACT

Screw pressing is one of the common mechanical means of vegetable oil extraction in most parts of the world. In this study, a laboratory screw press for extraction of various vegetable oils was designed, fabricated and evaluated using groundnut seeds. During the design and fabrication of the press, considerations were given to cost of fabrication, simplicity of operation, availability of the machine components, portability and easy mechanisms of oil extraction and extrution of the cake. Performance testing of the screw press was carried out at five different levels of feed rates (4.8, 4.1, 3.5, 2.9 and 2.4 kg/h) on the oil yield and extraction efficiency of the machine at 90^0C regulated temperature for 10 minutes. The optimum oil yield, using the screw press was obtained to be 33.69% with corresponding extraction efficiency of 76.59%. Regression analysis of the data obtained was carried out to generate the regression models and R^2 values that relate the feed rate with the oil yield and extraction efficiency. The production cost of the machine is $260.

Keywords: *Vegetable Oil, Extraction, Laboratory Press, Feedrate, Oil Yield*

INTRODUCTION

Vegetable oil is a triglyceride extracted from a plant seeds. Oil seeds such as groundnut, melon, coconut, palm-kernel etc. has been of very high economic value in Nigeria and other West African countries. Oil extracted from these seeds ranges from a wide variety of domestic to industrial use. Robin (1999). The production process of vegetable oil involves the removal of oil from plants components, typically seeds. This can be done via traditional, mechanical and chemical/solvent methods. The extracted oil can then be purified and if required, refined or chemically altered. Axtell *et al*. (1992).. The traditional method involves processing of oil seeds manually resulting in the production of small quantity of oil which fall short of market demand. Modern equipment and machinery are expensive and are not available in some cases therefore, it is essential to develop small and medium scale processing methods and improve them in order to meet the increasing demand for vegetable oil and fat. (Janet, 2006).

Extraction is the process of separating a liquid (oil) from a liquid solid system with the use of solvents; while expression is the process of mechanically removing liquid containing solids by the use of motorized equipment such as screw press, hydraulic presses, riot presses and mills. The solvent extraction process is capable of removing nearly all of the available oil from the oil seed meal and produces high protein meal with good preservation qualities. The processing vegetable oil in commercial application is commonly done by chemical extraction; using solvent extracts; which produces highly yields and a quicker and less expensive. The most commonly solvent is petroleum derived hexane. This technique is used by most of the newer industrial oils such as Soybean and Corn oils. (Anderson *et al.,*1977).

The expensive nature of extraction equipment and possibly of fire and explosion hazards makes the solvent extraction process unsuitable for the small and medium scale farmers that form the majority of oil processors in a developing nation like Nigeria. The mechanical expression process; though less efficient; is more adaptable for the small and medium scale farmer because it produces an end product free of dissolved chemicals and a relatively low operation costs. (Kathryn *et al*., 1995).

The quantity and quality of oil yield through mechanical expression using a screw press is affected by the pre-pressing and pressing condition such as particles size; heating temperature; heating duration; moisture content; applied pressure and pressing time. Heating increases the oil yield by breaking down the oil cells; adjustment of natural moisture content and coagulation of protein. Efficient mechanical expression; therefore involves a careful establishment of optimum processing conditions for different seeds because the best is some-how different from each oil-bearing seed. (Depmer, 1963). Therefore, the objective of this study is to develop a laboratory level screw press for carrying out oil extraction analysis from various oil bearing seeds.

MATERIALS AND METHODS

Description of the Machine

The isometric view of the screw press is shown on Figure 1. The screw press consists of the frame, piston, press cage cylinder, collector (tray) and the heater band as its major components for efficient operation. The rigid frame which holds the ram shaft is made of 3 inches angle iron and support the pressure created by the screw. It is well constructed and firmly mounted to the work surface before the pressing operation begins. The frame also comprises of two beams and four columns. The piston is a solid screw, and provides the necessary pressure required for the expression of the oil from the seeds. The press cage is a pipe made of mild steel of 10mm thickness, inner diameter 150mm and outside diameter160mm with the overall height of 210mm, it has an opening through which the oilseed would be admitted in to the cage and also consists of perforations at its lower part for oil drainage. The oil is drained into the oil collector placed blow the cage through the perforations. The heater band is attached to the cage to generate the necessary heat required for the oil expression. The oil collector tray is a mild steel plate of 20mm thickness and 200mm diameter. A galvanized plate of 1mm thickness was wedded round the plate for easy collection of the oil. A circular groove of 10mm deep is made on the flat plate and the grove has the same diameter as the external diameter of the cage with little clearance of 0.05mm in order to allow the easy fixing and removal of the press cage cylinder, The heater band generates the heat required for the oil extraction and the electronic temperature controller regulate the current that flows in to the system and thereby regulate the temperature of the press cage.

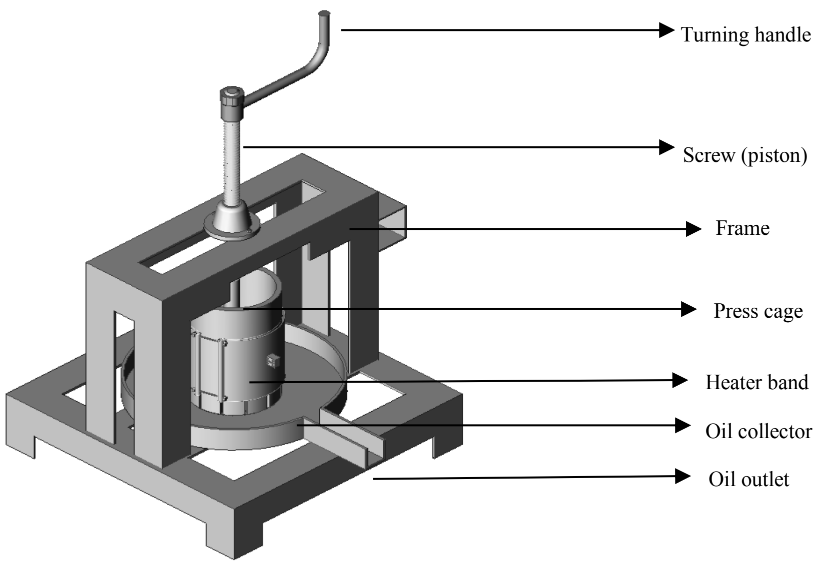

Figure 1: Isometric view of the Screw Press

Design of Machine Elements

Design for Press Cage Cylinder

The press cage is considered as a thick cylinder under pressure exerted by the screw through the compression piston (ram). Therefore the pressure exerted on the press cage cylinder was determined using the following expressions reported by Yusuf, 2012.

$$P = \frac{F}{A} \quad (1)$$

But,

$$A = \frac{\pi D_i^2}{4} \quad (2)$$

Therefore,

$$P = \frac{4F}{\pi D_i^2} \quad (3)$$

Where,

F = Force from the hydraulic jack = 32KN

D_i= Internal diameter of the press cage cylinder and (mm)

P = Applied pressure (MPa)

Combined Stress on the Press Cage Cylinder

Due to the action of applied pressure from the screw through the compression piston, the press cage cylinder is subjected to three principal stresses (i) the hoop (or circumferential) stress (δ_1), the longitudinal stress (δ_2) and the radial stress (δ_3) (Olaniyan and Oje, 2007)

The hoop (or circumferential) stress (δ_1) is given by the relation

$$\delta_1 = \frac{PR_i}{t} \quad 4$$

$$\delta_2 = \frac{PR_i}{2t} \quad 5$$

$$\delta_3 = -P \quad 6$$

Where,

P = maximum pressure applied on the press cage cylinder (MPa)

t = thickness of the press cage cylinder (mm)

Thermal Stresses on the Press Cage Cylinder

According to Dunmdae (1988) as reported by Olaniyan and Oje (2007), the thermal stresses at the heating surface of the press cage cylinder is given as:

$$\delta_a = \frac{-\propto(\Delta T)E}{2(1-\vartheta)} \quad 7$$

Where;

δ_a= stress at outside surface of the press cage cylinder in contact with the heating devices.

$\propto$= coefficient of linear expansively = $12 \times 10^{-6}/^0C$(Olanyan and Oje, 2007)

E = modulus of elasticity of mild steel = 205GN/m^2 (Ryder 1985)

ΔT = temperature change (^0C)

ϑ = poison's ratio = 0.291 for mild steel material

Design of the Compression Piston Ram

Olaniyan and Oje (2007) reported that, for a piston cylinder mechanical oil expression rig, the relationship between the piston diameter and cylinder diameter can be expressed as:

$$D_p = \frac{D_i}{1.0004} \quad 8$$

Where,

D_p= piston diameter (mm)

D_i= inside diameter of the cylinder (mm)

Design of the theoretical Capacity of the Press

The total capacity of the press cage cylinder can be determined by multiplying the capacity (Kg/batch) of machine by it batch capacity as reported by Yusuf, 2012.

$$C_T = C_c \times C_b \quad 9$$

$$C_c = \frac{\pi D^2 h}{4} \times \rho \quad 10$$

Where,

C_T= total capacity (Kg/h)

C_b= Batch capacity (Kg/h)

C_c= Cage capacity (Kg/batch)

D = Diameter of press cage (mm)

h = Height of press cage (mm)

ρ = Density of vegetable oil seeds (Kg/m^3)

Working Principle of the Machine

During the operation of the machine, the material to be press is weighed using weighing balance and then introduced in to the cylinder cage already fixed in the grove made on the oil collector plate, the screw will then be driven down the cage through the handle to supply the necessary pressure for oil extraction. During this period, the heater band and the electronic temperature controller has been plugged and set to the required temperature for the oil expression.

Sample Preparation

The groundnut seeds used for the testing of the screw press were purchased from Uchi market Auchi Edo State, Nigeria. The groundnut after purchase was milled to a uniform granular size using attrition mill for easy pressing operation.

Testing Procedure

The test was carried out using five different feed rates of 4.8, 4.1, 3.5, 2.9 and 2.4 kg/h. The grounded groundnut sample was weighed using lever type weighing balance and later transfer in to the pressing cloth before pressing in order to prevent the grounded samples from coming out of the perforations made on the press cage cylinder. During the pressing operation, the electronic controller device was set to 90^0C as reported by Yusuf *et. a.l.,* (2014) that the optimum temperature for extraction of groundnut oil is 90^0C in order to ensure that the temperature of the sample inside the cage is maintained. Pressing was done for 10 minutes before the cake was extruded and weighed and then the weight of the oil was taken and recorded for each batch. The pictorial view of the screw press is as shown on the plate 1 below.

Plate 1: Pictorial View of the Screw Press

Measurements and Calculations

Determination of Oil Yield

The oil yield is the amount of oil recovered from a kilogram of the seed and it can be expressed mathematically as reported by Yusuf, 2012.

$$OY\ (\%) = \frac{W_{OE}}{W_{OE}+W_{CK}} \times 100\% \qquad (11)$$

Determination of Extraction Efficiency

The extraction efficiency of the machine is expressed as optimum extraction capacity of the machine and it is determined mathematically as:

$$EE\ (\%) = \frac{W_{OE}}{XW_{TS}} \times 100\% \qquad (12)$$

Where;
OE= Oil yield (%)
EE= Extraction Efficiency (%)
W_{OE} =Weight of oil extracted (Kg)
W_{CK} =Weight of cake (Kg)
W_{TS} =Total Weight of Sample (Kg)
X = Oil content of groundnut (44% on average) Yusuf, 2012.

RESULT AND DISCUSSION

The data generated from the calculated values of oil yield and extraction efficiency at temperature of 90^0C and pressing time of 10 minutes are presented in Table 2. The data were subjected to regression analysis to determine the degree of relationship between the feed rates, oil yield and extraction efficiency of the machine. The analysis of variance for the effects of feed rates on the oil yield and extraction efficiency are as shown on the Tables 3 and 4 respectively.

Table 1: Oil Yield and Extraction Efficiency of Crushed Groundnut Seeds at Different Feedrates using the Screw Press

S/N	Feedrates (kg/hr)	Oil yield (%)	Extraction efficiency (%)
1	4.8	23.25	52.25
2	4.1	21.66	49.24
3	3.5	33.69	76.59
4	2.9	28.2	62.52
5	2.4	28.2	62.52

Table 2: Analysis of Variance (ANOVA) for the Effects of Feedrates on the Oil Yield

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	28.348	1	28.348	1.375	.326^{NS}
	Residual	61.866	3	20.622		
	Total	90.214	4			

**Significant at $P \leq 0.05$; NS-Not Significant*

Table 3: Analysis of Variance (ANOVA) for the Effects of Feedrates on the Extraction Efficiency

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	121.394	1	121.394	1.070	.377^{NS}
	Residual	340.428	3	113.476		
	Total	461.822	4			

**Significant at $P \leq 0.05$; NS-Not Significant*

Tables 2 and 3 revealed that the feed rates have no significant effect on the oil yield and extraction efficiency of the screw press at 0.05 confidence limit.

Effect of feed rates on Oil Yield

The effect of feed rates on the oil yield is as shown on the Figure 2. The chart shows the regression model that reflects the relationship between the feed rates and the oil yield.

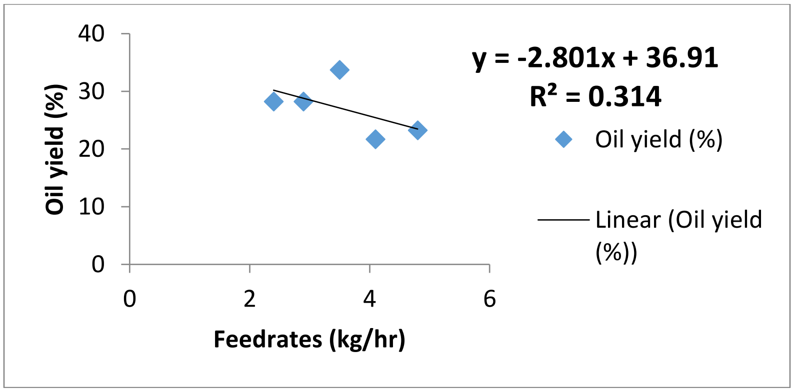

Figure 2: Effect of feed rates on Oil Yield

Effect of Feed rates on Extraction Efficiency

Figure 3 showed the regression model that reflects the relationship between the feed rates and the extraction efficiency of the screw press.

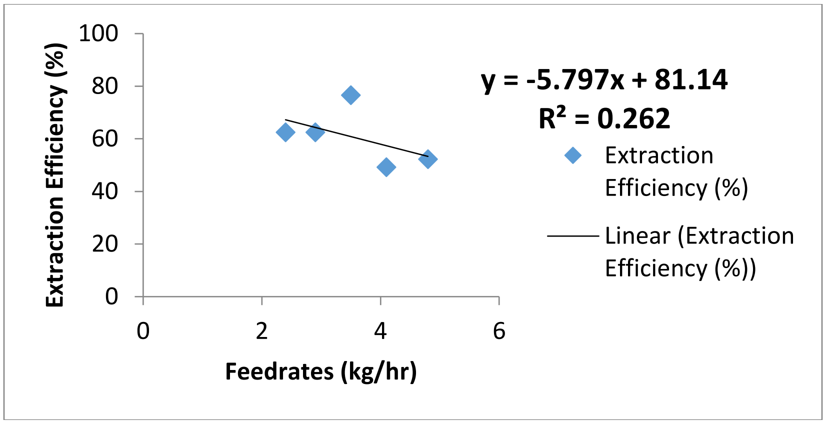

Figure 3: Effect of Feedrates on Extraction Efficiency.

CONCLUSION

The vegetable oil screw press was designed, fabricated and tested. The press was simple enough for local fabrication, operation and maintenance and was found capable of expressing oil from crushed groundnut seeds. The result shows that the optimum oil yields obtain was 33.69% with a corresponding extraction efficiency of 76.59%. Also, the regression analysis of the result shows that the feed rate has no effects on the oil yield and extraction efficiency of the press.

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EFFECTS OF DRYING METHODS AND STORAGE DURATION ON PROXIMATE COMPOSITION OF FLUTED PUMPKIN LEAVES

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ABSTRACT

The effect of drying methods and storage durations on the nutritional qualities of dried packaged fluted pumpkin leaves were investigated. Freshly harvested fluted pumpkin leaves were sorted, washed, drained and sliced. Samples were divided into four portions of 120g each and labelled as sample A, B, C and D. With the initial properties of fresh fluted pumpkin leaves determined using sample A, samples B C and D were freeze-dried, oven dried and sun dried respectively. The initial properties of each dried sample were determined, packaged in sterile polyethylene bags and stored at ambient room conditions. Proximate composition of each samples were determined on monthly basis for three months. Results showed that freshly harvested fluted pumpkin leaves contain 84.00%, 2.16%, 5.21%, 5.32%, 2.00% and 1.28% of moisture, ash, crude protein, crude fibre, fat and carbohydrate content respectively. The moisture, crude fibre, crude protein, fat, carbohydrate and ash content of dried fluted pumpkin leaves decreased significantly ($P < 0.05$) irrespective of the drying method employed. The moisture, ash, crude fibre, and fat content of the dried packaged fluted pumpkin leaves decreased generally as storage period increased. Freezing drying method is recommended for drying of fluted pumpkin leaves in terms of retained proximate composition.

Keywords: *Fluted pumpkin, Drying, Moisture, Crude fibre, Crude protein, Storage*

INTRODUCTION

In Africa, indigenous vegetables remain popular in rural areas, where they are often considered to be more nutritive than exotic vegetables (Horsfall and Spiff, 2005). Food security remains a challenge for Africa and other developing Countries, more than half of the population studied in Africa between 1995 – 2000 experience food insecurity (Fagbemi *et al*., 2005). Reduction in high level of vitamin A and iron deficiencies, due to inadequate dietary intake is one of the major causes of this in-security (Averbeke, 2009). Vegetables have tremendous potential to address poverty alleviation and nutritional security because, they are affordable, easily available, easy to grow, require minimum production inputs, rich in vitamins, minerals, phyto chemicals and anti-oxidants (Eusebio, 2009). Vegetables are vital constituent of West African diet, and are highly important providing low-cost quality nutrition for large parts of the population in both rural and urban areas (Chweya and Eyzaguirre, 1999).

Vegetables are eaten in a variety of ways as a part of meals and snacks; their nutritional content varies considerably. They generally contain little protein, fat and a varying proportion of vitamins, pro-vitamins, dietary minerals and carbohydrate (Fagbemi *et al*., 2005). Among the green leafy vegetables of nutritional importance are Amaranths (*celosia argentea*), Bitter leaf (*Vernonia species*), *Corchurus* species, Sorrel, (*Talinum* species), Fluted pumpkin (*Telfairia occidentails)*, Spinach (*Spinacia oleracea*) and many more, much effort has been concentrated on seeds while leafy vegetables sources have been ignored (Adeogun and Aletor, 1995).

Fluted pumpkin (*Telfairia occidentalis*) which belong to the family of *Cucurbitaceae*, is a tropical vine grown mainly as leaves, the leaves constitutes an important component of the diet of many people in the West Africa countries (Fagbemi *et al*., 2005). The green leaves of fluted pumpkin are generally called *ugwu.* It is well known in Southern Nigeria because of its pleasant taste. The leaves are low in crude fibre, rich source of protein, oil, vitamins and minerals which enhances, nourish, protect and heal the body (Ladeji *et al*., 1995). However, this vegetable pass through different processing methods, which may alter the nutritional quality before consumptions and it, is difficult to assess the quality of the final products in this regards. The present study was therefore aimed at determining the effects of different processing methods and storage duration on some proximate composition of Fluted pumpkin grown in Minna, Nigeria.

MATERIALS AND METHODS

About Six hundred grammes (600 g) of freshly harvested fluted pumpkin leaves *(Telfairia occidentalis)* were obtained from a farm site at *Kpakungun* area in Minna, Nigeria. The leaves were cleaned to aid the picking of the petiole, coloured leaves, diseased and damaged leaves as well as immature leaves. The stripped leaves were washed thoroughly with distilled water to remove dirt and soil. The leaves were cut into slices of approximate 6 mm thickness each using a sharp knife. The sliced leaves were divided into four portions of 120 g each and were labelled sample A, B, C and

D. Sample A was analysed in the fresh form to determine proximate composition to serve as control. Sample B, C and D were freeze dried, oven dried and sun dried respectively. The drying processes were carried out as follows:

i. Sample B was spread evenly on the drying rack and was placed in the lyophilizer to freeze for 30 minutes at -28^{0}C with the compressor on, immediately after freezing the samples were subjected to drying with the vacuum switched on alongside with the compressor to start drying. During the drying process, water was seen boiling off or subliming from the freeze leaves at a lower pressure of 14 Pascal and this was done for six hours for three days.

ii. Sample C was spread evenly on the drying rack and the rack was placed in an electric oven to dry for 5 hours at 60^{0}C. The leaves were turned over frequently to ensure uniform drying and were weighed at two hours interval until a constant weight was maintained (Idris, 2011).

iii. Sample D (sun dried) was spread evenly on a metallic tray lined with foil paper. and dried under direct sun light for at least six hours per day for two days; the leaves were turned over frequently to ensure uniform drying and were measured every two hours until a constant weight was maintained at three consecutive readings (Awogbemi and Ogunleye, 2009).

All the final dried samples were packaged in the polyethylene bags and tightly sealed. Proximate analysis was determined according to the method described by the Association of Official Analytical Chemists (2000), to determine moisture, ash, crude protein, crude fibre and fat contents. The carbohydrate content was determined by subtraction. The group means ± standard error (SEM) was calculated for each analysis and significant difference between means was evaluated by analysis of variance (ANOVA). Post test analysis was done using the Duncan multiple comparison tests. Values of ($p \leq 0.05$) were considered as statistically significantly (Adamu and Johnson, 1997).

RESULTS AND DISCUSSION

The results of the effect of drying methods and storage duration on the proximate composition of fluted pumpkin leaves is as presented in Table 1, freshly harvested fluted pumpkin leaves contain 84.00%, 2.16%, 5.21%, 5.32%, 2.00% and 1.28% of moisture, ash, crude protein, crude fibre, fat and carbohydrate content respectively.

Table 1: Effect of drying methods and storage duration on the proximate composition of dried packaged fluted pumpkin leaves.

Sample	Storage Duration	Moisture Content (%)	Ash (%)	Crude Protein (%)	Crude Fibre (%)	Fat Content (%)	CHO (%)
Fresh Leaves		84.00 ± 1.20^a	2.16 ± 0.01^a	5.21 ± 0.39^a	5.32 ± 0.29^a	2.00 ± 0.19^a	1.28 ± 0.02^a
Freeze Dried leaves	0	9.43 ± 0.40^a	2.85 ± 0.30^b	23.44 ± 0.40^a	20.01 ± 0.01^c	2.50 ± 0.00^b	41.76 ± 0.73^{ab}
	1	11.05 ± 1.34^b	2.50 ± 0.51^b	25.52 ± 3.64^a	18.86 ± 0.39^b	1.84 ± 0.29^a	40.03 ± 2.67^a
	2	11.83 ± 0.28^{bc}	1.66 ± 0.28^a	23.31 ± 0.07^a	18.65 ± 0.04^b	2.01 ± 0.01^a	42.39 ± 0.74^{ab}
	3	12.63 ± 0.23^c	1.50 ± 0.00^a	25.52 ± 0.28^a	16.61 ± 0.01^a	2.01 ± 0.01^a	44.08 ± 0.30^b
Oven Dried Leaves	0	4.63 ± 0.36^b	3.34 ± 0.29^b	30.67 ± 0.23^c	22.68 ± 2.30^b	2.67 ± 0.58^b	35.83 ± 3.20^a
	1	9.38 ± 0.10^b	3.01 ± 0.01^b	29.72 ± 0.17^b	19.31 ± 0.01^a	1.53 ± 0.05^a	36.84 ± 0.19^a
	2	9.81 ± 0.02^c	2.33 ± 0.28^a	29.73 ± 0.02^b	20.67 ± 0.00^{ab}	1.00 ± 0.01^{ab}	36.43 ± 0.27^a
	3	11.16 ± 0.01^d	2.33 ± 0.28^a	29.19 ± 0.01^a	20.01 ± 0.01^a	1.01 ± 0.01^a	36.28 ± 0.30^a
Sun	0	5.04 ± 0.17^a	3.00 ± 0.01^b	30.40 ± 0.01^d	20.08 ± 0.01^d	2.00 ± 0.01^c	39.52 ± 0.01^c

Dried leaves	1	9.26 ± 0.23^{b}	3.17 ± 0.28^{b}	28.71 ± 0.01^{c}	16.00 ± 0.01^{c}	1.53 ± 0.05^{b}	41.31 ± 0.13^{d}
	2	15.41 ± 0.28^{c}	2.33 ± 0.28^{a}	28.01 ± 0.02^{b}	15.33 ± 0.00^{b}	1.00 ± 0.01^{a}	37.89 ± 0.21^{a}
	3	15.76 ± 0.17^{d}	2.16 ± 0.28^{a}	27.90 ± 0.01^{a}	14.49 ± 0.01^{a}	1.01 ± 0.01^{a}	38.66 ± 0.29^{b}

**Value followed by same superscript alphabet are not significantly different at (P<0.05) along the column. Values are Mean ± SEM of triplicate determination.*

The results showed that drying decreases the moisture content of fresh fluted pumpkin leaves from 84% to 9.43%, 4.63% and 5.04% for freeze dried, oven dried, sun dried samples. The initial mean moisture content of the freeze dried leaves was 9.34%, which increased to 12.63% at the end of 3 months of storage. The initial mean moisture content of the oven dried leaves was 4.63% and it increased to 11.16% after 3 months of storage while the initial mean moisture content of the sun dried leaves was 5.04% and increased to 15.76% after 3 months of storage. Moisture content is an index of water activity, the high moisture contents of fluted pumpkin leaves will make it more susceptible to microbial contamination and thus reducing the storage time due to rapid deterioration. Drying is one of the most important methods developed to extend the shelf life of foods and increasing the availability of nutrients to consumers. Thermal processes such as oven dry and sun drying increase storage life of foodstuffs and minimize food-borne diseases (Fellows, 1990). The lower moisture content of dried fluted pumpkin leaves as compared to the fresh sample is a desirable property that will prevent microbial activities and hence increases the storage duration of the leaves (Adeyeye and Ayejugo 1994). However, the increase in moisture content with increase in storage period was probably due to the permeability of the polyethylene bag to air and moisture. This increase in moisture content with storage duration could result to deterioration due to microbial activities if stored for a longer period.

The ash content of fresh fluted pumpkin leaves increases from 2.16% to 2.85%, 3.34% and 3.00% for freeze dried, oven dried and sun dried samples (Table 1). The initial mean ash content of the freeze dried leaves was 2.85%, which decreased to 1.50% at the end of 3 months of storage. The initial mean ash content of the oven dried leaves was 3.34 % and it decreased to 2.33% after 3 months of storage while the initial mean ash content of the sun dried leaves was 3.00% and it decreased to 2.16% after 3 months of storage. The initial mean ash content of the freeze dried leaves was 2.85%, which decreased to 1.50% at the end of 3 months of storage. The ash content gives a measure of total amount of inorganic compounds like minerals present in a sample. The results show that drying generally increases the ash content of fluted pumpkin leaves. This increase in the ash content could be as a result of some inorganic salt trapped in the vegetable during drying (Oboh, 2005). Similar findings have been reported for *T. occidentalis, T. Triangulare* and and *B. alba* (Adegunwa *et al*., 2011). However, statistical analysis also shows the ash content of stored dried leaves decreases significantly (P < 0.05) with increase in storage period.

The crude protein content of fresh fluted pumpkin leaves increases from 5.21% to 23.44%, 30.67% and 30.40% for freeze dried, oven dried and sun dried samples. Proteins are essential organic compounds that help in building and maintaining all tissues in the body; it forms an important part of enzymes, fluids and hormones of the body and also helps form antibodies to fight infection and supplies energy (Johnson, 1996). The present study revealed that storage duration has significant effect on the protein content of the leaves. Statistical analysis shows that protein content of stored dried leaves increases significantly in freeze dried leaves and decreases significantly in oven and sun dried leaves (P < 0.05) with increase in storage period. The trend of the results suggests that oven and sun drying of fluted pumpkin leaves may have denatured the proteins rendering them more susceptible to proteolytic degradation with time (Eugene *et al*., 2008). According to Pearson (1996), plant food that provides more than 12% of its calorific value from protein is considered good source of protein. Therefore, the processed fluted pumpkin leaves meet this requirement. The values of protein for both the fresh and dried stored samples were higher than the reported value for closely related edible leaves of *Solanium meloneana, Solanium acthiopicum* (4.8%) *Solanium lycospersocum* (2.8%), *Solanium nigruim* (3.2%) and *Solanium macrocarpon* (Oboh, 2005).

The crude fibre content of fresh fluted pumpkin leaves increases from 5.32% to 20.01%, 22.68% and 20.08% for freeze dried, oven dried and sun dried samples. The initial crude fibre content of freeze dried samples decreased from 20.01% to 16.61% after 3 months of storage. The initial mean crude fibre content of the oven dried leaves was 22.68% and it decreased to 20.01% after 3 months of storage while the initial mean crude fibre content of the sun dried leaves was 20.08% and decreased to 14.49% after 3 months of storage. Dietary fibre is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in the large intestine. Result of this present study show that crude fibre content of stored dried leaves decreased significantly (P < 0.05) with increase in storage period. This increase in fibre content may be advantageous since the vegetable could enhance digestion and prevent constipation when consumed. High crude fibre in the vegetable according to Ladeji *et al*., (1995) could also help in blood cholesterol and glucose attenuation when consumed. Increasing the fibre content of the diet increases the faecal energy excretion, principally in the form of fat and nitrogen and by virtue of its water holding capacity. Fibre also helps in the formation of soft stools with bulk, which can be easily evacuated (Komal and Kaur, 1992).

The crude fat content of fresh fluted pumpkin leaves increases from 2.00% to 2.50% and 2.67% for freeze dried and oven dried samples, while there were no significant differences between the fresh fluted pumpkin leaves and the sun dried samples. The initial mean crude fat content of the freeze dried leaves was 2.50%, which decreased to 2.01% at the end of 3 months of storage. The initial mean crude fat content of the oven dried leaves was 2.67% and it decreased to 1.01% after 3 months of storage while the initial mean crude fibre content of the sun dried leaves was 2.00% and decreased to 1.01% after 3 months of storage. Dietary fats represent the most compact chemical energy available to man (Kummerow, 2007). The significant decrease ($P < 0.05$) in the crude fat content of stored dried leaves with increase in storage period is a desirable property as excess fat consumptions has been implicated in the etiology of certain cardiovascular disease such as cancer and aging (Kummerow, 2007). The result of the present study is in agreement with general observation that leafy vegetables are low fat containing food (Idris, 2011).

The carbohydrate content of fresh fluted pumpkin leaves increases from 1.28% to 41.76%, 35.83% and 39.52% for freeze dried, oven dried and sun dried samples respectively. Carbohydrates are the most abundant organic material on earth and in vegetable matter may form 50-80 g/100 g of the dry matter (Osei, 2003). The significant increases in carbohydrate content of stored freeze and oven dried samples as well as significant decrease ($P < 0.05$) in sun dried sample is in agreement with the previous report by Sobowale, *et al*., (2010). The higher carbohydrate values for freeze and oven dried sample with increase in storage period indicates that prolong storage increased hydrolysis of complex carbohydrates to release more absorbable carbohydrate (Odenigbo and Obizoba, 2004). This high carbohydrate levels could mean high energy may be provided by the vegetable and this could be good for consumers of the vegetable.

CONCLUSIONS

In conclusion, fluted pumpkin leaves have high moisture content, rich in protein and crude fiber. Fluted pumpkin leaves can be dried to prevent deterioration and be presented in a portable form for storage with minimal loss in qualities. However, among the drying methods used, freeze drying method is the most preferred in terms of retained proximate compositions drying and during storage.

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DETERMINATION OF SOME PHYSICAL AND AERODYNAMIC PROPERTIES OF EGUSI (*COLOCYNTHIS CITRULLUS* L.)

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ABSTRACT

Physical (moisture content, angle of repose and coefficient of static friction) and aerodynamic (terminal velocity) properties of three varieties of egusi seed (P4, TCL39 and I-306) were determined. The angle of repose was measured using a tilted table, the coefficient of friction was measured as the tangent of angle of repose on three different surfaces (Glass, Plywood and Galvanized metal sheet) while the terminal velocity was measured in a vertical wind tunnel coupled to a digital anemometer. The experimental results of moisture content for the three varieties on dry basis were 5.20, 5.18 and 4.78%, respectively. The highest value of 35.8º was recorded for P4, followed by I-30 6 with 32.5º while TCL 39 has the lowest value of 29.4º. The coefficient of friction of the seed on glass, plywood and galvanized metal sheet ranges from 0.35-0.56 for P4, 0.32-0.47 for TCL39 and 0.30-0.42 for I-306, respectively. The average terminal velocities for egusi whole seed, kernel and chaff for P4, TCL 39 and I-306 varieties were: 3.7, 2.22, and 1.21 m/s, 3.36, 2.25 and 1.37 m/s, 3.25, 2.19 and 1.26 m/s, respectively. Coefficient of friction, angle of repose and terminal velocity increased significantly with increase in moisture content.

INTRODUCTION

Egusi (*Colocynthis Citrullus* L.) is a member of the *cucurbitaceae* family (Yusuf *et al*., 2008). It is a widely cultivated and commonly consumed oilseed crop in West Africa (Bankole *et al.,* 2005). The seeds contain 22% of protein, 30% of Fat, and 11% of carbohydrate and as well as good qualities of micronutrients (Oyolu, 1977; Oloko and Agbetoye, 2006).

Economically, the crop plays a vital role in the farming system and well-being of West African rural dwellers as a good source of weed control and soil fertilization; it leaves high residual nitrogen in the soil after harvest, thus helping farmers to maintain and replenish soil nutrient (Yusuf *et al*., 2008). Egusi seeds are rich in oil and protein thereby making them a dietary supplement used as an important ingredient in domestic cooking in Nigeria soup (Victor *et al.,* 2011). Egusi with honey and little salt produce a mixture resembling creaminess of mother milk which can be used as an infant food supplement (Janssen *et al*., 2002). The oil extracted has a lot of uses in the manufacturing industries in making of margarine, shortening and cooking oil while the cake residue is a useful source of protein used in the computation of livestock feeds (Ibiyemi, 2002).

Egusi is still largely processed manually and considering its immense usefulness, there is a need for efficient processing of the seed. This is with a view to increasing its market value and thereby encouraging more farmers to be involved in its production. The traditional method of decorticating and cleaning of egusi is time consuming and labour intensive thereby limiting the availability of the seeds for industrial uses. The earliest traditional system for decortication of egusi by pressing the seed between the thumbs of the two hands in order to break and detach the cotyledon from the shell is tedious and time consuming (Ibiyemi, 2002). Although a few work had been done by researchers and local fabricators which was aimed particularly at improving *egusi* decortications mechanically. However, the cleaning efficiency of available Egusi decorticators remains very low (Victor *et al*., 2011). Makanjuola (1972) developed three impellers for decortication of *egusi* and were tested at different speeds of 1350 rpm, 1650 rpm and 2250 rpm. Makanjuola (1972) found that the number of decorticated seeds increased as the speed of the shaft was increased. Odigboh (1979) constructed a mechanical device for decorticating egusi seeds. In the design, the seeds were confined to move into projected spinning vane discs which were arranged at an angle of 45º. The principle of operation was for the seeds to hit the impact surface and break, but there was no separation unit.

Physical properties of egusi seed and other biomaterials as a function of moisture content are necessary for design and development of relevant machines for handling and processing (Oloyede *et al*., 2015). Today, much data have been published on the physical properties of grains and seeds by other researchers such as (Aviaraet *et al*., 2005) for sheanut, (Koocheki *et al*., 2007) for watermelon seeds, (Polat *et al*., 2007) for pistachio nut and kernel, (Hojat *et al*., 2009) for fennel seed, (Ahmadi *et al*., 2012) for psyllium seed, Akande *et al*. (2013) for locust bean seed and Barwal *et al*. (2012).

A lot more is yet to be done on the cleaning of egusi seeds due to insufficient and inadequate knowledge of the physical and aerodynamic properties of the seed (Oyolu, 1977).Therefore, a thorough understanding of the properties of egusi seeds such as moisture content, angle of repose, coefficient of static friction and terminal velocity that will provide basic information for Engineers concerned to develop an appropriate decorticator for egusi with high decorticating and cleaning efficiencies is necessary. This work studied some properties of egusi seed such as size, shape, surface area, density, moisture content, angle of repose, coefficient of static friction and terminal velocity which affect shelling and cleaning of *egusi* seed.

MATERIALS AND METHODS

Materials

The three selected varieties of egusi used in the study were P4, I- 306 and TCL39. The seeds were bought from Sango Market, Saki, Nigeria. The criteria used for the selection were based on ecological distribution of the seed and visual observation in terms of seed quality (cleanliness and whole seeds). Samples of the three varieties were put in labelled sealed polythene bags and stored in a deep freezer to maintain equilibrium moisture contents of the seeds. The following properties adjudged to affect the shelling and cleaning efficiencies were determined.

Moisture content

The moisture content (wet basis, wb) of egusi was determined using gravimetric method as described by ASAE (2003). Moisture content of the seeds was determined using sensitive weighing balance to record the initial and final weight of the sample which was dried in the oven at a temperature of 65ºC for 24 h. The moisture content was calculated using equation1.

$$.MC_{wb} = \frac{W_i - W_d}{W_i} \quad (1)$$

Where:
MC_{wb} = moisture content, wet basis, %.
W_i = initial weight of sample, kg.
W_d = dried weight of sample, kg

Angle of repose

A standard cylindrical container opened at both ends and placed on a galvanized steel surface was filled with egusi seeds to the brim. Afterwards the container was lifted gradually and finally emptied to form a conical heap of the seeds. The angle of repose was then calculated using equation 2.

$$\theta = tan^{-1}(h/R) \quad (2)$$

Where:
θ = angle of repose, (º)
h = height of the heap formed, cm
R = base radius of the heap formed, cm

Coefficient of static friction

Static coefficient of friction for the seeds was determined with respect to three surfaces, namely; glass, galvanized and plywood using the method described by Solomon and Zeidu (2009). Each of these materials was used on the draft table with a raised scale attached. The tabletop was gradually lifted with an attached screw until the seeds start to roll. The angle at which the egusi seeds started rolling is called angle of inclination.

$$Coefficient\ of\ static\ friction, \mu = tan\theta \quad (3)$$

Where:
θ= angle of inclination at start of rolling (º)

Terminal velocity

The terminal velocity (suspension) of egusi seed and chaff were determined using a vertical tunnel similar to that developed by Babatunde and Olufowobi (2001). For each test, samples of the egusi seed and chaff were placed one after the other through a small door unto a net fixed across the wind tunnel's lower portion. The fan unit was switched on and the air velocity was increased from 1.20 to 2.00, 2.50 and 3.00 m/s by opening an air inlet shutter until the material was suspended in the air stream with little or no vertical movement. The velocity at which the egusi seed and the chaff were suspended, called terminal velocity was recorded from the digital anemometer placed on the outlet chute of the tunnel.

RESULTS AND DISCUSSION

The results of moisture content, angle of repose, coefficient of static friction and terminal velocity determined are presented and discussed as follows.

Moisture content.

The average moisture contents of egusi seeds determined on wet basis is presented in Table 1.The moisture contents determined were 15.53% for P4, 15.19% for I-306 and 14.69% being the lowest was recorded for TCL 39. The velocity of air required to air borne (suspend) the egusi whole seed, kernel and the chaff is higher at high moisture content of the egusi seeds. Moisture content has a significant effect on the terminal velocity, drag coefficient and overall performances of the decorticator in term of decorticating and cleaning efficiency.

Table 1: Mean value of moisture content (wb), and angle of repose of the three egusi Varieties

Variety	Moisture content (%)	Angle of repose (°)
P4	15.53	29.4
TCL 39	15.19	32.6
I 30 6	14.69	35.8

Angle of repose

The experimental results of angle of repose for the three varieties of egusi seeds at different moisture content levels are indicated in Figure 1. The angle of repose was observed to increase linearly from 29.4° – 35.8° for the three varieties with increase in moisture contents from 14.69 to 15.53 % for the three varieties of egusi seeds. It can be seen from the figure that P4 recorded the highest angle of repose with a value of 35.8° at a moisture content of 15.53 %, followed by I-306, 32.5° at a moisture content of 15.19 % while the TCL 39 has the lowest angle of 29.4° at a moisture content of 14.69 %. At higher moisture content, the adhesive force between the metal surface and biomaterial increases, thereby reducing the flowability of the processed egusi seed from the decorticating chamber to the cleaning unit where the separation of the mixture will take place. Similar discovery was made by Victor *et al*. (2011) on engineering properties of three varieties of melon seeds as potential for development of melon processing machines.

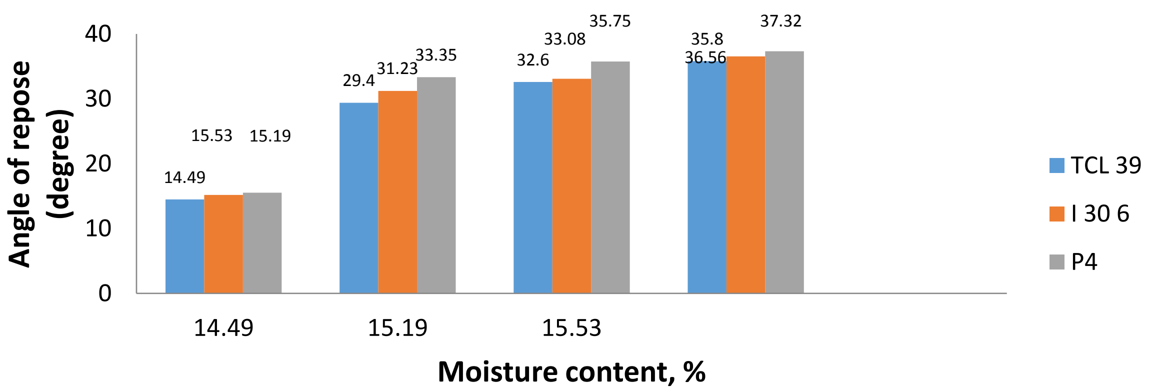

Figure 1: Plot of angle of repose with respect to moisture content

Coefficient of static friction

The static coefficient of friction of egusi seed for the three varieties tested on different surfaces were found to increase linearly for glass, plywood, and galvanized metal surfaces with respect to moisture content as shown in Figure 2. This was due to the increased adhesion between the seeds and the materials surfaces at higher moisture content levels. It was observed that plywood surface has the highest coefficient of friction for the three varieties of egusi with a range of 0.42 – 0.56^o, followed by galvanized surface between the range of 0.41- 0.46 while the least value was recorded for glass between the range of 0.27 – 0.38^o. Coefficient of static friction is of vital practical application in the machine design such as flow of material in the hopper, chute and on sieve (Adejumo *et al*., 2009). Tabatabaeta (2003) observed similar trend in the static coefficient of friction of wheat and recorded lowest static coefficient of friction on glass surface.

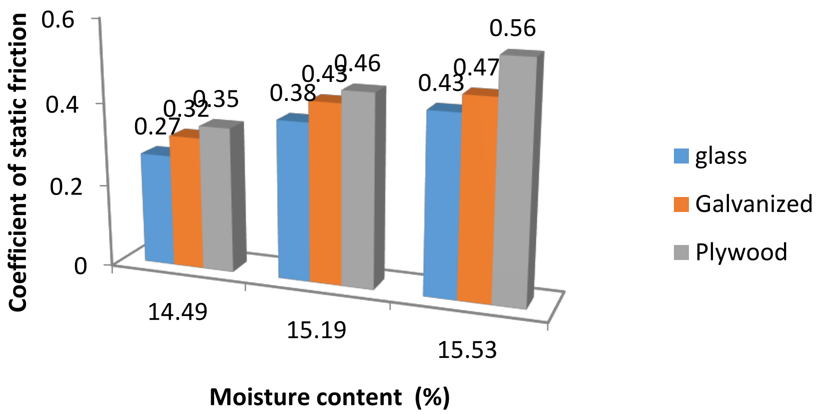

Figure 2: Effect of moisture content on coefficient of static friction.

Terminal velocity

The results of the terminal velocity for the three varieties of egusi seeds for the whole seeds, cotyledons and the chaffs are presented in Table 2. It can be seen from the results that P4 had the highest terminal velocity of 3.76, 2.43 and 1.29 m/s, at a moisture content of 15.53 %, respectively, followed by TCL 39 with 3.21, 2.14 and 1.14 m/s, at a moisture content of 15.19 % while I- 306 recorded the lowest values of 3.13, 2.10 and 1.21 m/s, at a moisture content of 14.69 % for the whole seed, cotyledon and chaff respectively. There must be a reasonable difference in terminal velocities of the kernel and chaff before a mixture of both can be separated. The terminal velocity of the kernel was found to be higher than that of the chaff and this is good for effective separation of the egusi seeds from the chaffs after decortications. Hollatz and Quick (2003) had similar report on pneumatic separation of grain and straw mixtures and found that increasing air velocity increased the proportion of seed lost with chaff. Similar finding was reported by Davis (2010) on engineering properties of three varieties of melon seeds as potential for development of melon processing machine. He found out that the terminal velocity decreases with an increase in drag coefficient and that the moisture content was a major factor affecting the terminal velocity of egusi seed.

Table 2: Terminal velocities of egusi whole seed, kernels and chaffs determined

Moisture content (%)	**14.69**			**15.19**			**15.53**		
Varieties	**P4**	**TCL 39**	**I-30 6**	**P4**	**TCL 39**	**I-30 6**	**P4**	**TCL 39**	**I-30 6**
Whole seeds	3.76	3.21	3.13	3.99	3.28	3.36	4.00	3.58	3.27
Kernels	2.43	2.14	2.10	2.56	2.22	2.19	2.76	2.39	2.28
Chaffs	1.29	1.14	1.21	1.53	1.45	1.27	1.85	1.52	1.31

CONCLUSION

The following physical characteristics moisture content, angle of repose, coefficient of static friction and terminal velocity) of the egusi seeds in relationship to or necessary for the decortications and cleaning of egusi seeds have been determined. The physical properties are moisture dependent.

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EFFECT OF SIZE DISTRIBUTION AND RIPENESS ON SOME PHYSICAL AND MECHANICAL PROPERTIES OF *SPONDIAS MOMBIN* FRUITS

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ABSTRACT

Effect of size distribution and ripeness on some physical mechanical properties of Spondias mombin fruits was studied. The average length of ripe fruits are 27.3, 35.2 and 38.5 mm for small, medium and large, respectively. Also the width and thickness varied from 19.9 to 29.9 mm and 19.2 to 30.0 mm respectively, within the same size distribution. In the case of about to ripe fruits, the length, width and thickness for small, medium and large size distribution also varied from 28.2 to 38.7 mm; 20.9 to 28.9 mm and 19.6 to 28.7 mm, respectively. The length of unripe fruits were 28.1, 35.1 and 38.9 mm for size distribution of small, medium and large, respectively. The width and thickness increased from 21.8 to 29.2 mm and 20.6 to 29.2 mm, respectively, within the same size distribution. As the size increased from small to large the moisture content increased in each case for the three conditions of ripeness. Sphericity and bulk density of the fruit increased with change in the sizes of the fruit from small to large for different conditions of ripeness. The effect of size and degree of ripeness on physical properties was significant ($p < 0.05$). Increase in size and change in orientation gave rise to increase in compressive strain with the highest being 0.169 at large size and longitudinal position. The highest compressive stress of the fruit was observed as 9.00 N/mm^2 when in transverse position. The energy required for breaking the fruit was highest (2.5J) in longitudinal orientation. The effect of size, degree of ripeness and orientation of the fruit on the compressive properties was significant ($p<0.05$).

Keyword: *Physical properties, fracture resistance ripeness, unripe, about to ripe, Spondia mombin*

INTRODUCTION

Hog plum (*Spondias mombin*) is a tree, in the *Anacardiaceae* family. It is native to the tropical Americas, including the West Indies. The tree has been naturalized in Africa, India and Indonesia where it is mostly grown as an orchard tree (Aiyeloja and Opeyemi, 2006). The pictorial view the Spondias mombin fruits are shown in Plate 1.1. It is well adapted to arid as well as humid zones (Aiyeloja and Opeyemi*,* 2006). It has several common names such as "jobo" or hog plum in the Caribbean. In Ghana, it is commonly referred to as "Ashanti" plum; while in Nigeria it is called "iyeye" among the Yorubas (Aiyeloja and Opeyemi, 2006). The fruit has a leathery outer skin and a thin layer of pulp which can be eaten fresh or made into juice, concentrate, jellies and sherbets. The taste from the apple is astringent (Owolarafe *et al.,* 2006). The seed has an oil content of 31.5% (Aiyeloja and Opeyemi, 2006).

Physical and mechanical properties of most agricultural materials have been found to be affected by variety and some processing conditions such as heat-treatment and moisture conditioning as reported by Owolarafe *et al.* (2007), Sirisomboon and Kitchaiya (2009) , Garnayak *et al*. (2008), Pradhan *et al*. (2009), Solomom and Zewdu (2009), Sessiz *et al*. (2007), *Sacilik et al. (2003) and Amin et al. (2004) on palm fruit, jatropha kernels, jatropha* seed, jatropha fruit, niger seed, caper fruit, hemp seed and lentil seeds, respectively, among others. Also the knowledge of these properties is required in the design and development of machines for processing agricultural materials (Akaaimu and Raji, 2006; Dursun and Dursun, 2005; *Ogunjimi et al., 2002; Sirisomboon and Kitchaiya, 2009)*. Some physical properties of the Spondias mombin fruit have been investigated (Owolarafe et al., 2006), the relationship between this and sizes of the fruit and degree of ripeness as they affect the design of processing machines for the fruit has not been reported. This study aims at determining some physical and mechanical properties of *spondias mombin* with particular reference to fruit size and degree of ripeness.

Plate 1.1: Pictorial view of *Spondias mombin* fruits

MATERIALS AND METHODS
Fresh graded *Spondias mombin* samples of different ripeness status were the major material in this category. Samples collected from the Obafemi Awolowo University premises Ile-Ife, Nigeria. The samples were graded according to ripeness (ripe, about to ripe and unripe) and size (small, medium and large) by physical observation.

Determination of Physical Properties
In order to determine the size, shape indices and fruit mass, 20 fruits sample each were graded according to ripeness size distribution (large, medium and small) were collected measurement of each was taken. This measurement was taken five times independently. The parameters determined include length (major diameter) (a), width (minor diameter) (b) and thickness (intermediate) (c) using Vernier caliper. The accuracy of the instrument is 0.01 mm.
Spondias mombin fruit shape was expressed in terms of its sphericity index and aspect ratio. For the sphericity index, S_p, the dimensions obtained for 100 *Spondias mombin* fruits selected at random were used to compute the index using standard method (Mohsenin, 1978) as:

$$S_p = \frac{(abc)^{\frac{1}{3}}\ x\ 100\%}{a} \qquad 1$$

Where a = major, b = minor and c = intermediate
For the aspect ratio, 100 *Spondias mombin* fruits samples were also selected at random for conducting the experiment. Thus measurement of shape indices was calculated using the aspect ratio in equation 2.The aspect ratio (R_a) was calculated as recommended by Maduako and Faborode (1990)

$$Ra = b/a \times 100 \qquad 2$$

Fifty (50) fruits were selected at random from the sample and weighed using a Mettler Toledo PB 153 electronic balance (Mettler Toledo GmbH, Greifensee, Switzerland) to an accuracy of 0.001g. This gives the fruit mass.
The true density (ρ_t) of the fruit was determined by water displacement method. Thirty randomly selected *Spondias mombin* fruits were weighed and lowered into a graduated measuring cylinder containing 1000 ml of water. It was ensured that the fruit was submerged during immersion in water. The increase in volume was noted. The ratio of the mass (kg) of the fruit to the volume (m^3) of water displaced due to the immersed fruit gave the density of the fruit (Amin *et al.,* 2004);
A cylindrical container of known mass and volume was filled with *Spondias mombin* and weighed. The mass of the *Spondias mombin* was calculated by the difference between the weight of the empty cylinder and the mass after it was filled with the *Spondias mombin*. The ratio of the mass of the *Spondias mombin* to the volume of the cylindrical container gives the bulk density (ρ_b). The process was repeated 10 times (Amin *et al.,* 2004);

$$\rho_r = \frac{mass}{volume} \qquad 3$$

The porosity (P) was determined as a function of the bulk density and true density of the fruit. The volume fraction occupied by the fruit is given by the ratio of the bulk density ρ_b to the true density ρ_t of the fruit. ($D_t = \rho_b/\rho_t$). The porosity (void fraction) expressed in percent was calculated from average values of bulk and particle densities using equation 5 (Joshi *et al.,* 1993; Deshpande *et al.,* 1993; Suthar and Das 1996; Jha, 1999; Nelson, 2002).

$$P = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \qquad 4$$

The density ratio (D_t) is expressed as a percentage is given by Owolarafe *et al.*(2007)

$$D_t = \frac{\rho_b}{\rho_t} \times 100 \qquad 5$$

Determination of mechanical properties

The mechanical properties determined in the study include angle of repose, sliding coefficient of friction and fracture resistance.

A regular cylindrical container opened at both ends and placed on a galvanized steel surface was filled with the *Spondias mombin* fruit to the brim. Afterwards the container was lifted gradually and finally emptied to form a conical heap with the fruits.

The tangent of the angle of inclination to the horizontal (tan ø) was calculated from the height (h) and base radius (r) of the formed heap as (Amin *et al*., 2004):

$$\tan\theta = \frac{h}{R} \qquad 6$$

Where, θ is the angle of repose. This was repeated 5 times for each of the 3 ripe conditions

Coefficient of static friction is the tangent of the angle of inclination at which a material begins to slide on the surface. Using the method described by Solomon and Zewdu (2009), five *Spondias mombin* fruits were placed on an inclined plane apparatus with mild steel. The plane portion of the apparatus was raised. The angle of inclination to the horizontal, as soon as the fruits began to slide, was measured from a protractor attached to the inclined plane. The tangent of the angle of inclination measured gives the coefficient of static friction. This was repeated 10 times for each of the ripe conditions (about to ripe, ripe and unripe).

Compression tests were conducted using Universal Compressive Testing Machine (UCTM) controlled by a microcomputer as shown in Plate 2. The fruit was placed between two parallel plates on the machine and compressed till failure occurred (Aviara *et al*., 2007). Two loading orientations were used (transverse and longitudinal) andtwenty-four randomly selected fruits from ripe, about to ripe and unripe were compressed laterally and longitudinally by the UCTM at a compression rate of 5mm/min. Test results, statistics and graph were automatically generated. The compressive load, compressive stress, compressive strain, stress energy and modulus of elasticity were obtained.

Plate 2: The pictorial view of the Universal Compressive Test Machine

Moisture content determination

The moisture content of the *Spondias mombin* fruits was determined by using the standard method (ASAE, 2003). Approximately 100 g of each of the test samples sizes was weighed to the nearest 0.001g in a moistures dish. The initial weights of each moisture dish plus the sample were taken. The dish with *Spondias mombin* sample was placed in an oven at 80°C for 48 hours. At the end of oven-drying, the dish was removed quickly and covered with the lid and placed in a desiccator. The final weight of the moisture dish plus the oven dried sample was taken after reaching room temperature. The moisture content (wet basis) for the sample was calculated by dividing the loss in weight of the sample with the initial weight of the fresh sample (ASAE, 2003). The experiment was replicated five times for each degree of ripeness of the fruit. The moisture content is given as:

$$m = \frac{100Wm}{W_1} \quad (7)$$

Where m = moisture content wet basis (%), W_m = moisture loss, W_1 = initial weight of test sample.

RESULTS AND DISCUSSIONS

Physical Properties of *Spondias mombin* fruits.

The result of the study on size, sphericity and bulk density are discussed as follows. The size distribution of *Spondias mombin* are presented in Table 1. For ripe fruit,the result showed that the length of ripe fruits are 27.3, 35.2 and 38.5 mm for small, medium and large, respectively. Also the width and thickness varied from 19.9 to 29.9 mm and 19.2 to 30.0 mm respectively, within the same size distribution. In the case of about to ripe fruits,

Table 1: Size distribution and moisture content of *Spondias mombin* fruits on the basis of ripeness

Size distribution	Ripe fruits Major (mm)	Ripe fruits Minor (mm)	Ripe fruits Intermediate (mm)	Moisture content (%)	About to ripe fruits Major (mm)	About to ripe fruits Minor (mm)	About to ripe fruits Intermediate (mm)	Moisture content (%)	Unripe fruits major (mm)	Unripe fruits Minor (mm)	Unripe fruits Intermediate (mm)	Moisture content (%)
Small	27.30 1.60*	19.90 0.67*	19.20 1.07*	86.00	28.20 1.89*	20.90 1.80*	19.60 1.22*	78.00	28.10 2.01*	21.80 1.33*	20.60 2.00*	76.00
Medium	35.20 2.19*	26.30 1.36*	25.40 3.45*	88.00	35.30 2.06*	25.90 1..35*	25.70 1.20*	80.00	35.10 0.61*	25.80 0.84*	25.50 0.91*	78.40
Large	38.50 1.22*	29.90 2.04*	30.00 1.31*	89.00	38.70 1.61*	28.90 0.82*	28.70 0.74*	87.30	38.90 1.14*	29.20 0.93*	29.20 0.80*	80.80

* *Values in asterisks are the standard deviation*

Table 2: Physical properties of *Spondias mombin* fruits on the basis of ripeness

Size distribution	Ripe fruits Sphericity (%)	Ripe fruits Mass (kg)	Ripe fruits Volume (m^3) × 10^{-5}	Ripe fruits Bulk density (kg/m^3) × 10^5	About to ripe fruits Sphericity (%)	About to ripe fruits Mass (kg)	About to ripe fruits Volume (m^3) × 10^{-5}	About to ripe fruits Bulk density (kg/m^3) × 10^5	Unripe fruits Sphericity (%)	Unripe fruits Mass (kg)	Unripe fruits Volume (m^3) × 10^{-5}	Unripe fruits Bulk density (kg/m^3) × 10^5
Small	73.00 2.08*	7.70 1.07*	1.17 0.21*	5.81 0.11*	74.00 2.57*	7.00 1.10*	1.25 0.20*	5.78 0.10*	77.00 3.91*	6.90 1.07*	1.17 0.21*	5.81 0.11*
Medium	87.00 3.45*	12.70 1.63*	1.67 0.16*	7.50 0.31*	87.00 2.81*	12.00 1.15*	1.60 0.11*	7.57 0.31*	87.00 1.86*	11.30 1.04*	1.53 0.10*	7.31 0.26*
Large	96.00 3.59*	17.60 1.67*	1.93 0.16*	9.13 0.14*	94.00 1.28*	15.70 1.51*	1.75 0.15*	8.96 0.19*	95.00 1.71*	14.00 1.73*	1.79 1.50*	7.83 0.12*

* *Values in asterisks are the standard deviation*

The bulk density increased as size increased at each level of ripeness of the fruits (Table 2). The bulk density of the fruit was also observed to increase with increase in size of the fruit from small to large. The bulk density of the fruit at different size (small, medium and large) were 5.9, 7.5 and 9.4; 5.8, 7.5 and 8.7; and 5.8, 7.1 and 7.8 x $10^3 kg/m^3$ for ripe, about to ripe and unripe condition, respectively.The result obtained is in agreement with the findings of Prandha *et al*. (2009) and Solomon and Zewdu (2009). The above mentioned datas are very important in handling of the material.

The moisture content of the fruit was noticed to increase with increase in size of the fruit from small to large. The moisture content at different sizes (small, medium and large) were 86.0, 88.0 and 89.0; 78.0, 80.0, 87.3 and 76.0, 78.4 and 80.8 for ripe, about to ripe and unripe conditions, respectively. This result will help in determining quantity and quality of juice extracted at different conditions. The moisture content changed from 86.0 to 89.0% for ripe fruits. This observation could be as a result of more moisture being stored in the pore space as suggested by Murthy and Bhattacharcharya (1998). However this trend did not conform to findings of Visvanathan *et al* (1990) and Dutta *et al* (1988) on their works on moiture content of millet and chickpea, respectively, who obtained a negative linear relation between bulk density and moisture content.

Mechanical Properties of *Spondias Mombin*

The result of the compressive strain, compressive stress, energy required to break fruit, size distribution and ripeness are discussed below.

Compressive strain

The result on compressive strain is discussed in term of size distribution, ripeness and orientation. In Fig.1, it could be observed that increase in size gave rise to increase in compressive strain. The compressive strain for small, medium and large on the longitudinal position are 0.111, 0.140 and 0.169, respectively.While on the transverse position, the compressive strain for small, medium and large were 0.114, 0.111and 0.102, respectively (Table 3.). This result follows the trend reported by Saiedirad *et al*.(2007).

Compressive strain of unripe fruit, (i.e 0.151) was found to be higher than that of ripe fruit, (i.e 0.135) when the fruit was in longitudinal position as shown in Table 4. The compressive strain of unripe fruit was 0.133 which is higher than that of ripe, (i.e 0.123) when the fruit was in transverse position. The result shows that the degree of ripeness affected the compressive strain. This could be as a result of physiological change in the mesocarp of the fruits asripeness progresses.

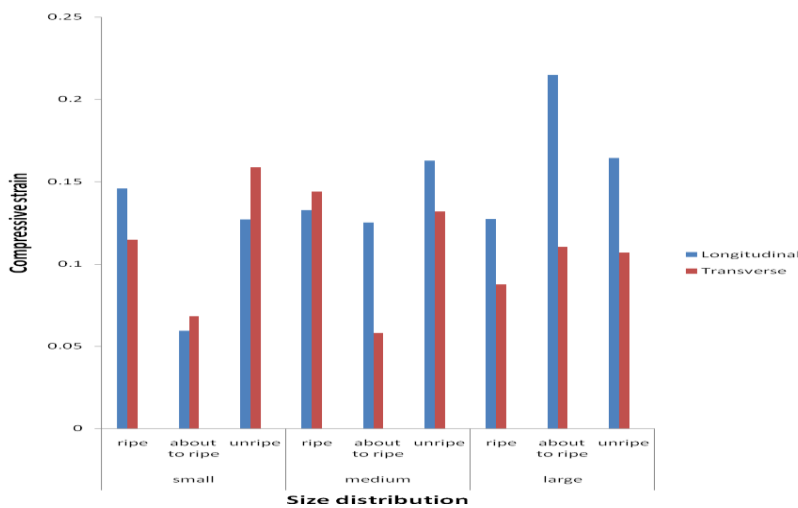

Fig. 1: Compressive strain against size distribution

Table 3: Compressive Strain as Affected by Size Distribution.

Size Distribution	Longitudinal mm/mm			Transverse mm/mm		
	Ripe	About to ripe	Unripe	Ripe	About to ripe	Unripe
Small	0.146	0.059	0.127	0.115	0.068	0.159
Medium	0.133	0.125	0.163	0.144	0.058	0.132
Large	0.127	0.215	0.164	0.088	0.110	0.107

Table 4: Compressive Strain as Affected by Fruit Size and Ripeness.

Ripeness	Longitudinal mm/mm			Transverse mm/mm		
	Small	Medium	Large	Small	Medium	Large
Ripe	0.146	0.133	0.127	0.115	0.144	0.117
About to ripe	0.059	0.125	0.215	0.068	0.058	0.111
Unripe	0.127	0.215	0.164	0.088	0.110	0.107

This trend is in comformity with the observation of Akubuo and Uguru (1999) in his study of fracture resistance to compressive loading of selected bambara groundnut.

Compressive stress

The result of compressive stress on the fruit is also discussed in terms of size distribution, degree of ripeness and orientation. Table 5; shows the effect of size on compressive stress of the fruit. It could be observed that compressive stress of *Spondias mombin* of sizes small, medium and large are 2.13, 3.84 and 3.32N/mm^2, respectively, when the fruit was in longitudinal position. When the fruit was in transverse position, the compressive stress for small, medium and large are 3.32, 3.86 and 5.18N/mm^2, respectively. This shows that as the size increased the compressive stress increased. This trend follows the observation of Baumler *et al.*(2006) on compressive properties of safflower seed.
The result showed a decrease in compressive stress as degree of ripeness decreased, (Table 6). The compressive stress of ripe, about to ripe and unripe are 6.0, 1.8 and 2.17N/mm^2 when the fruit was in longitudinal position and 6.26, 3.40 and 2.02N/mm^2 respectively, when the fruit was in transerve position. Compressive stress increased from 1.8N/m^2 to 7.7N/m^2 and decreased to 1.8N/m^2 as the size increased, while in the transverse position compressive stress increased from 2.3N/m^2 to 4.6N/m^2 and then reduced to 3.4N/m^2. Lastly for the unripe and in longitutional position, the compressive stress decreased from 1.9N/m^2 to 1.4N/m^2 and increased to 2.2N/m^{2}as the size increased. For transverse position, it increased from 1.4 to 1.5 to 3.3N/m^2 as the size distribution increased. This shows that transverse position had higher stress compare with longitudinal position which Gupta and Das (2000) also reported similarly for sunflower and kernel, respectively.

Table 5: Compressive Stress as Affected by Size Distribution

Size Distribution	Longitudinal (N/mm^2) Ripe	About to ripe	Unripe	Transverse (N/mm^2) Ripe	About to ripe	Unripe
Small	2.70	1.77	1.93	4.27	2.27	1.40
Medium	2.50	7.65	1.38	5.50	4.57	1.50
Large	6.00	1.80	2.17	9.00	3.37	3.17

Table 6: Compressive Stress as Affected by Ripeness.

Ripeness	Longitudinal (N/mm^2)			Transverse (N/mm^2)		
	Small	Medium	Large	Small	Medium	Large
Ripe	2.70	2.50	6.00	4.27	5.50	10.73
About to ripe	1.77	7.65	1.80	2.27	45.70	3.37
Unripe	1.93	1.30	2.17	1.40	1.50	3.17

The moisture content and size play major role on compressive stress. This trend follows the observation of Baumler *et al*.(2006) on moisture dependent physical and compressive properties of safflower seed.

Energy to break the fruit

The result of energy to break the fruit is also discussed in terms of size distribution, degree of ripeness and orientation. Table 7 shows the energy to break the fruits of the various sizes.. It could be obsvered that the energy required to break the fruit increase with the energy value provided by the yellow *mombin*, 65.42 kcal/100 g, is similar to that obtained from other tropical fruits such as guava and mango (Julia *et al.,* 2011). From the result it was observed that, the highest energy was at medium size ripe when the fruit was in longitudinal position. When the fruit was in transverse position, the energy required was less than when in longitudinal position.

Further result showed that the energy required to break the fruit decreased with the degree of ripeness from unripe to about to ripe in longitudinal position while in transerve position, energy required to break the fruit increased as degree of ripeness increased from unripe to about to ripe (Table 7).

Table 7: Energy to Break the Fruit as Affected by Ripeness.

Ripeness	longitudinal (Nm)			transverse (Nm)		
	Small	Medium	Large	Small	Medium	Large
Ripe	0.025	0.026	0.090	0.042	0.048	0.109
About to ripe	0.009	0.050	0.008	0.007	0.538	0.028
Unripe	0.015	0.005	0.015	0.007	0.008	0.025

CONCLUSIONS

A study of physical and mechanical properties of *Spondias mombin* fruit as affected by size distribution and ripeness was carried out in this study. The following conclusion could be drawn from the study.

i. The size of *Spondias mombin* fruits ranged from 27.3 to 38.9 mm in length, 19.9 to 29.9mm in breadth while the thickness from 19.2 to 30.0mm with various sizes and degree of ripeness.

ii. As the size increased from small to large the moisture content increased for the three conditions of ripeness (i.e. ripe, about to ripe and ripe) fruits.

iii. Sphericity of the fruit increased with change in the sizes of the fruit from small to large for different conditions of ripeness. Also sphericity increased as the moisture content of the fruit increased from 80% to 85%.

v. The bulk density increased as the size increased at each level of ripeness of the fruits. The bulk density ranges from 5.8 x 10^3 kg/m^3 to 9.4 x 10^3 kg/m^3.

vi. Increase in size gave rise to increase in compressive strain. The compressive strain ranged from 0.111 to 0.169 from small size to large size at different orientation of the fruits.

vii. In the longitudinal position, the compressive strain ranged between 0.125 to 0.163 for different sizes and orientation while in transverse position it ranged between 0.058 and 0.159.

viii. The compressive stress of the fruit varied from 1.77 N/mm^2 to 7.65 N/mm^2 when in longitudinal position while it varied from 1.45 N/mm^2 to 9.00 N/mm^2 when in transverse position.

ix. Energy required for breaking the fruit at longitudinal position varied from 0.007 to 2.5 Nm while it varied from 0.007 Nm to 0.109 Nm in transverse position.

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EVALUATION OF WATERMELON RIND AND STEVIA FOR THE PRODUCTION OF FRUIT JUICE CONCENTRATES

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ABSTRACT

This study reports the use of watermelon rinds formulated with stevia plant for the production of fruit juice concentrate. This is to ascertain the possibility of value addition to the nutritional compositions of the end products. Completely Randomised Design experimental setup was adopted. The samples was divided into six portions: fresh watermelon pulps (FWMP), fresh watermelon rind (FWMR), dried watermelon pulp (DWMP), dried watermelon rind (DWMR), grind stevia sample (DSPS) and the formulated concentrates (WRSC). The samples were analysed using standard laboratory procedures in triplicates and values were statistically analysed using SPSS statistical tool (16.0 version). Vitamin A, C and E in the final product are 0.18±0.02mg/100g, 0.11±0.01mg/100g and 0.12±0.02mg/100g respectively. Total phenol and flavonoid contents of the product increased significantly as it ranged between 0.03±0.02 to 0.57±0.00mg/100g and 0.01±0.00 to 0.07±0.00mg/100g respectively. Stevia sweetener is recommended for food processing industries as this will serves as substitute for sugar non-consuming patients.

Keyword: *Watermelon rind, stevia plant, fruit juice concentrate*

INTRODUCTION

The application of fruit and vegetable wastes for the production of edible substance has taken a boom to reduce environmental pollution. These residues consist of some nutritional components (Polyphenols and antioxidants) essential for human health. However, Larrosa *et al.,* (2002), in a study revealed that Agricultural and industrial residues are attractive sources of natural antioxidants and dietary fibre.

Watermelon (*Citrullus lanatus*) is one of the most widely cultivated crops around the world contains 6% of sugar and 91% of water by weight. Like other fruits, it is very rich sources of vitamins and also serves as other source of health beneficial nutritional constituents including phytonutrients (FAO, 2006). Study revealed that watermelon rinds are edible parts and can be used as vegetable for which citrulline in the sample gives it antioxidant effects that protect consumers from exposure to danger (Leong and Shui, 2002). Therapeutic effect of this fruit has been ascribed to antioxidant compounds (Lewinsohn *et al.,* 2005). However, researchers speculated that the rinds are capable of relaxing blood vessel such as cancer and cardiovascular disease (Rimando *et al.,* 2005).

Watermelon rinds are edible and contain many hidden nutrients, but most people avoid eating them due to their unappealing flavour. They are sometimes used as vegetables. In China, they are stir-fried, stewed or more often pickled. Pickled watermelon rind is commonly consumed in the Southern US (Rattray and Diana, 2012). Bushra, (2013) in a study reported that fresh watermelon contain 170.7 mg, 8.1mg and 0.05 mg of vitamin A, C and E with 19%, 13.5% and 0.5% recommended daily allowable intake (RDAI). Watermelon rind possess significant amount of moisture, ash, fat, protein and carbohydrates 10.61%, 13.09%, 2.44%, 11.17% and 56.00% (Al- Sayed and Ahmed, 2013) and rind contribute 30% of the total weight.

Rimando *et al.,* (2005), also revealed that 1-inch cube of watermelon rind contains 1.8 calories of which majority of the calories is constituted in the carbohydrates, with 0.32 g per serving. Further report stated that one serving provides 2 per cent of the daily recommended intake of vitamin C and 1 per cent of the vitamin B-6 required by human body every day. It is however, essential to find out the way of using watermelon rinds (so-called "wastes") for the formulation of different food products.

Stevia (*Rebaudiana*) is a nutrient rich natural sweetest plant of Asteraceae family used for sweeten tea and beverages centuries back in some part of the world (Ena *et al.,* 2013). The plant leaves naturally contain diterpene glycosides stevioside, rebaudiosides A-F, steviolbioside and dulcoside, which are responsible for its sweet taste and have commercial value all over the world as sugar substitute in foods, beverages or medicines. It is a magical plant which offers sweetness with fewer calories and does not show any side effects on human health after consumption. *Stevia* has many pharmacological and therapeutic applications as suggested by many preclinical and some clinical studies; these are nontoxic and possess antioxidant, antimicrobial, antifungal and anticarcinogenic activity (Ena *et al.,* 2013).

Stevia plant has been reported with a lots of economic importance which can be used as sweetening agent in products like biscuits, jams, chocolates, ice-creams, baked foods, soft drinks, soda, candies and also common beverages like dip tea, coffee and herbal tea that are targeted particularly at the diabetics and also the health conscious consumers (Jaroslav *et al.,* 2006).
Toxicological studies indicated that secondary metabolites embedded in *Stevia* does not have adverse effect on human health and as such, no allergic reactions, teratogenic and arcinogenic effects have been observed after consuming stevia plant as sweetener (Pol *et al.,* 2007).
Stevia plant required warm sunny atmosphere and grow well on sandy soil. However, the preferable and natural climatic weather condition is semi-humid subtropical temperature ranging between 21 to 43^{O}C on average of 24^{O}C (Huxley, 1992).

MATERIALS AND METHODS

Sample Collection and Preparation

Fresh samples of watermelon (sugar baby variety) of 1200±15g weight were procured from a local market in Bauchi, Bauchi State Nigeria. The stevia herb was purchased from a local vegetable market in Dass, also in Bauchi State. The watermelon was washed then the rind was peeled and separated from the washed fresh fruits (pulp), the sample were further cuts into pieces and spread in trays, dried at 50^{O}C for 72 hours using air oven. The sample was grind into fine powder using laboratory mill. The stevia plant was separated from undesirable materials such as sand and other particles, and then pounded to fine powder with the use of a mortar and pestle, samples were mixed and sieved. A tea spoon each from the prepared grind samples (grind stevia stem and grind watermelon rind) were properly stirred together, mixed in a ratio 1:1 proportion and diluted in a glass cup with water. Organoleptic properties were determined and the diluted liquid sample was observed for microbial growth for 92 hours. Other nutritional properties (Vitamin A, C and E among others) were evaluated in the Chemistry Laboratory II of the Department of Chemistry, Faculty of Science, Abubakar Tafawa Balewa University, Bauchi. Bauchi State. Some of the equipment used in this study include: a set of test tubes, beakers, a weighing balance, a graduated cylinder, an oven, sieves, a Soxhlet extractor and a UV-V spectrometer. Standard reagents were also used for the analysis. However, the dried concentrate was used for the evaluation of the nutritional constituents to ascertain the possibility of value addition in the sample mixture.

Experimental Setup

The experiment was fitted into a completely randomised design (CRD) experimental procedure. The watermelon parts were divided into two portions: fresh rind (A), fresh pulp (B), while the stevia was placed in a container tagged sample C. The content of samples A and B were cut separately into small sizes of length 8cm and breadth 3cm to ease the drying process. The samples were dried at temperatures and drying times of 50^{O}C and 72 hours respectively using the oven drying method until the dried (watermelon rind and dried watermelon pulp) samples were obtained. Vitamin A, vitamin E, vitamin C, total phenol content and the total quantity of flavonoids content in samples were determined in three replicates.

RESULTS AND DISCUSSION

The results obtained for samples after being assessed individually showed statistical variations in the nutritional contents (vitamins and phytonutrients contents) in each part (Table 1). This however, revealed that both fresh and dried rinds samples contained significantly lower values in their respective nutritional compositions than the fresh and dry pulp.

Table 1: Nutritional and some Phytonutrient Compositions of Watermelon Parts, Stevia Herb and Concentrate Formulation

Sample	Vitamin A (mg/100g)	Vitamin C (mg/100g)	Vitamin E (mg/100g)	Total Phenol Content (mg/100g)	Total Flavonoid content (mg/100g)
FWMP	0.21 ± 0.00^{c}	0.33 ± 0.00^{d}	0.48 ± 0.00^{c}	0.03 ± 0.00^{b}	0.01 ± 0.00^{a}
FWMR	0.07 ± 0.00^{a}	0.04 ± 0.00^{a}	0.04 ± 0.00^{a}	0.02 ± 0.00^{a}	0.01 ± 0.00^{a}
DWMP	0.53 ± 0.00^{d}	0.82 ± 0.00^{e}	0.48 ± 0.00^{c}	0.03 ± 0.00^{b}	0.03 ± 0.00^{a}
DWMR	0.18 ± 0.00^{b}	0.10 ± 0.01^{b}	0.11 ± 0.02^{b}	0.07 ± 0.00^{a}	0.03 ± 0.00^{a}

DSPS	0.06±0.00[a]	0.15±0.00[c]	0.10±0.01[b]	0.57 ±0.00[c]	0.07±0.00[b]
WRSC	0.18±0.02[b]	0.11±0.01[ab]	0.12±0.02[d]	0.10±0.02[d]	0.03±0.03[a]

** Values are expressed as mean ± SEM, n = 3, Values not sharing a common superscript letter differ significantly at P < 0.05*

FWMP = Fresh Watermelon Pulp, FWMR = Fresh Watermelon Rind
DWMP = Dried Watermelon Pulp, DWMR = Dried Watermelon Rind
DSPS = Dried Stevia Plant Stem, WRSC = Watermelon Rind with Stevia Concentrate

Table 1, indicated that vitamin A content of fresh watermelon rind (0.07±0.01 mg/100g) was significantly lower than that of the fresh pulp (0.21±0.00 mg/100g), while the dry concentrates also revealed that the vitamin A content in the rind (0.18±0.00 mg/100g) was significantly lower than the dried pulp (0.53±0.00 mg/100g). Similar pattern were observed for vitamins C, vitamin E, Phenol and Flavonoid contents in this study.
The result of Vitamin A contents (0.07±0.00 mg/100g) in this study is significantly lower than the reported value of 1.71mg/100g reported by a researcher (Bushra, 2013). Variation in the value could be attributed to difference in the species and maturity stage of the watermelon sample used for the experiment. But the Vitamin E content (0.48±0.00 mg/100g) in this study is significantly higher than the reported value (0.05mg/100g) of the same researcher.
The result of vitamin C (0.11±0.01mg/100g) contents of the end products in this study is however significantly higher than the reported value of 0.081mg/100g by Bushra, (2013). This could be associated with the addition of the mixture of the stevia combination with the watermelon rind along the processing chain which signifies value addition to the juice concentrate. The vitamins contained in the stevia herb are lowest when compared to the watermelon pulp, this is similar for all nutritional content studied (Table 1).
Phytonutrients are described as natural bioactive compounds from plants with general benefits to human health (Erukainure *et al.,* 2010), Flavonoids and phenol contents quantified in this study (Table 1) were observed to be significantly high in the stevia herb (0.07±0.00 mg/100g) and (0.57 ±0.00 mg/100g) compare to in fresh and dried watermelon rind (0.03 ±0.00 mg/100g) and (0.07±0.02 mg/100g) respectively at ($p>0.05$).
The result of fruit juice concentrate formulated in this study was observed to maintain its vitamin A (0.18±0.02) contents while an appreciable increase in the vitamin C contents (0.11±0.01mg/ 100g)is an indication that the sample combination does not affect the nutritional contents of the product after formulation.
There were slight significant ($p<0.05$) reductions in vitamin E contents, total phenolic and total flavonoid contents of the formulated concentrate with values 0.12±0.02(mg/g), 0.10±0.02(mg/100g)and 0.03±0.03 (mg/100g) respectively. These could be attributed to prolong drying time and temperature along the processing chain.

Shelf Stability of the Product
The product concentrate when diluted with water was observed to change its initial taste after the second day (24 hours) and grow moulds from the fourth day (48 hours). This is however in line with the speculated precautions prescribed for all other fruit juice concentrates (Foster clark, Tiara, Jolly juice and Nutri C) after dissolved in water. These produce after dissolved in water also changes their respective taste after few hours.
However, the dried samples of the product concentrate maintained its normal physical characteristics after four months of storage in an air tight container under room temperature as shown in Tables 2 and 3.

Table 2: Shelf Stability of Product Concentrate (Watermelon Rind with Stevia Plant)

Appearance / Month	Dried Concentrate	Diluted Product / day	Observation / day
November, 2015	No sign of spoilage	Day 1	Fresh/ No foul taste
December, 2015	No sign of spoilage	Day 2	Fresh
January, 2016	No sign of spoilage	Day 3	Foul taste
February, 2016	No sign of spoilage	Day 4	Growth of Moulds.

The mean score for colour, mouth feel, taste, consistency and overall acceptability preference to product concentrate obtained from ten (10) trained testers are presented in Table 3.

Table 3: Organoleptic Properties of Sample at Day 1 after4 Months of Product Storage

Sample	Mouth Feel	Taste	Consistency	Colour and Appearance	Overall Acceptability

Product Concentrate	6.40±1.07[b] (Good)	4.90±1.07[c] (Sour)	10.00±0.00[b] (Good)	8.10±0.90[b] (Fair)	3.60±0.98[b] (Good)

Concentrate formulation was subjected to sensory evaluation after four (4) months of storage. Table 3 showed the mean organoleptic scores of ten (10) trained panellists' feelings. A significant Approximate number of 6.40±1.07 panellist attest to the mouth feel of the products after the forth months to be good while the 10.00±0.00 panellist supported that consistency of the product were both preferred and had good remarks, however the colour and taste received approximate values of 8 and 5 mean scores signifying a fair look and a sour taste respectively. An approximate number of 4 panellists enjoyed the overall acceptability of the end product to be good while the others are neither fair nor bitter.

CONCLUSION

The fresh and concentrated forms of the watermelon pulp and rind at similar weights as evaluated in this study reflected that the concentrated forms contained more vitamins and antioxidants. The rinds were also seen to contain a significantly lower concentration of nutrients than the pulp ($p<0.05$) and the stevia was found to have a higher level of antioxidants than the rind and pulp, although lower in vitamin content. The product concentrate was produced, and evaluated to have higher concentration than its constituents in the nutritional composition. The watermelon rinds were evaluated and found to contain some phytochemicals which are useful for pharmacological and agricultural purposes.

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PARBOILING: EFFECTS AND CHALLENGES OF RICE PROCESSING IN NIGERIA

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ABSTRACT:

In Nigeria, rice is important for several reasons including being a major contributor to internal and sub-regional trade. Two types of rice have been mainly cultivated in Nigeria: the African rice (Oryza glaberrima) and the Asian rice (Oryza sativa).Nigeria`s estimated annual rice demand is put at 5 million metric tonnes while it produces on the average about 2.21 million tonnes milled product leaving a deficit of 2.79 million tonnes which is bridged by importation. Rice processing involves several steps: parboiling, milling the shelled rice to remove the bran layer, and an additional whitening step to meet market expectations for appearance of the rice kernels. However, parboiling is very important and very common steps of rice processing and it has been applied to more than half of paddy produce in Nigeria. Parboiling is a pre-milling hydrothermal (hydration and heat) treatment of paddy (rough rice) which brings about substantial physical and chemical alterations in rice. In Nigeria, traditional system of parboiling is the most dominant practice; this traditional parboiling process commonly results in improper gelatinization, discolouring and low market acceptability of the milled rice, due to defects and inadequacies in parboiling process. The method is also time consuming and highly laborious. It is therefore necessary to establish optimum processing conditions required to obtain better qualities of the finished product while saving energy and time. The rice threshing, winnowing and drying should be performed by mechanical equipment/processes. The soaking should be done 24 hours and 12 hours for Water heated to 50°C and 75°C and allowed to come to ambient temperature, while for heated water maintain between 60°C and 72°C the soaking duration should fall in between 8 – 3.5 hours respectively. Steaming duration for small batches takes 2 to 3 minutes while batches of 6 ton may take 20 to 30 minutes. Drying of parboiled paddy from 45-50% (db) to 14-16% (db) needs to be done in two passes at a drying thickness of 2-3 cm and stirred at an interval. The relevant stakeholders in the rice sector development in Nigeria to organize sensitization and training programs on best practices for the rice producer groups in question.

INTRODUCTION

Rice is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glaberima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population. It is the agricultural commodity with the third-highest worldwide production, after sugar cane and maize (FAOSTAT, 2012). The interspecific hybrids between the African and Asian rice resulted into the development of several varieties of rice in Nigeria. Among many varieties of rice found, FARO 61, FARO 60, FARO 52 and FARO 44 are the most common improved varieties while Bisalayi is a popular local varieties produced and consumed in Nigeria.

Nigeria`s estimated annual rice demand is put at 5 million metric tonnes while it produces on the average about 2.21 million tonnes milled product leaving a deficit of 2.79 million tonnes which is bridged by importation (Ubale, 2014). Although there is an increase in rice production, consumption is also increasing annually. Average yearly per capita consumption was 15.8 kg in 1981-199, and by 2007 it is estimated at 27kg. It is, however, primarily an important crop for those farmers who produce it (selling nearly 80 percent of total production and directly consuming only 20 percent), and it generates more income for Nigerian farmers than any other crop in the country.

Rice (*Oryza sativa* L.), providing carbohydrates, proteins, fats, fibres, minerals, vitamins etc.), is considered as one of the major sources of nutrients due to its daily consumption (Heineman *et al,* 2005). Nutritional value of rice per 100 g (3.5 oz; Energy-1,527 Kj, Carbonhydrate-80g, Sugars- 0.12g, Fat-0.66g, Protein-7.13g, Thiamine- 0.0701 mg, Riboflavin- 0.0149mg, Niacin- 1.62 mg, Panthotenic-1.014mg, Vitamin B6-0.164mg, calcium 28mg, Iron-0.85mg, Magnessium-25mg, Manganesse-1.088mg, phosphorus-115mg, Potassium-115mg, Zinc-1.09mg (USDA, 2016).

Rice processing involves several steps: parboiling, milling the shelled rice to remove the bran layer, and an additional whitening step to meet market expectations for appearance of the rice kernels. Parboiling is very important and very common steps of rice processing and it has been applied to more than half of paddy produce in Nigeria (Umogbai, 2013). In Nigeria, traditional system of parboiling is the most dominant practice. The traditional parboiling process commonly results in improper gelatinization, discolouring and low market acceptability of the milled rice, due to defects and inadequacies in parboiling process. The method is also time consuming and highly laborious.

PARBOILING

The parboiling techniques for paddy originated in India. It is now widely employed all over the world (USAID, 2005). It consists of three stages:

- Soaking of paddy to saturation moisture content (SMC).
- Steam heat treatment of the soaked paddy to partially gelatinize the rice starch. This process also help to eliminate white portions and cementing crack developed in rice during harvesting and/or threshing
- Drying the steamed product to moisture content adequate for milling.

Advantages of Parboiling (Elbert, 2000):

- Improve head rice yield
- Makes de-husking easier
- Reduces grain breakage during husking and milling
- Improve swelling of rice during cooking (largely dependent on variety)
- Improve the storage ability of milled rice
- Parboiling also removes cooked rice volatiles including free fatty acids, inactivates enzymes such as lipase and lipoxygenase, kills the embryo
- Translucency and shiny nature of milled rice.

Parboiling Methods

Traditional method:
This method involves the cleaning and prolongs soaking of paddy rice in cold water for about 20 hours to give it a moisture content of 30-35%. After which the rice is put in parboiling equipment (usually pots/drums) with fresh cold water and boiled until it begins to split. The rice is then sun dried on bear floor (road sides/house floors) and in some few cases woven mats are used, cooled and ready for milling after it attains the moisture content that is suitable for milling.

Fig 1: Traditional method of rice drying in Nigeria

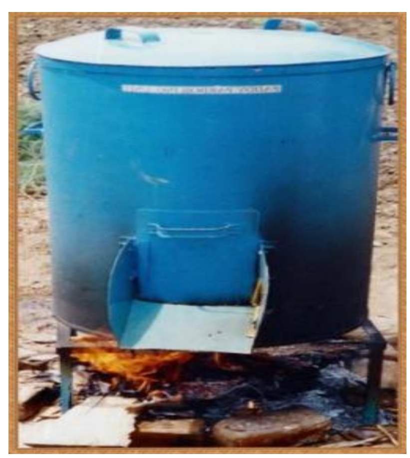


Fig 2: Small scale rice parboiling equipment

Semi-modern method:
In later methods of parboiling, the rice is soaked in hot water, and then steamed for boiling which only takes 3 hours rather than 20hours of the traditional method [www.immi.gov.an (2009)].The process of hot water soaking is carried

out by heating water to about 60 – 70℃ while steaming is usually achieved through the use of false bottom to the rice parboiling tank or pots. Alternatively, steaming is done by introducing the steam to the steaming tank/chamber from independent boiler through the steam pipes. The moisture content of the paddy increases to about 38% during steaming. Saturated steam at a pressure of 1 to 5 kg/cm^2 is normally used for steaming. Steaming duration depends on the steaming arrangement. For small batches, steaming takes 2 to 3 minutes while batches of 6 ton may take 20 to 30 minutes (agropedialabs.iitk.ac.in).

Industrial Method: In Nigeria, apart from the traditional method which is inefficient and laborious, paddy can also be parboiled in industries by using the direct soaking parboiling method. In the direct soaking parboiler method, about 16tons of paddy is parboiled per batch. To parboil a ton of paddy in a modern plant, the steam required at a pressure of 4 to 5 kg/cm^2 is about 120 kg for soaking, 60 kg for steaming, and 20 kg for losses, for a total of 200 kg of steam per ton of paddy.The heat required for soaking and steaming a ton of paddy is 83,000 kcal and 17,300 kcal respectively (agropedialabs.iitk.ac.in).

Fig3: Industrial Parboiling system

Parboiling Steps and their Effects on Physical and Chemical Properties on Milled Rice:
Parboiling brings about substantial physical and chemical alterations in rice grains, although each of the parboiling processes has its own specific effects on the quality of milled rice.

Soaking
Soaking is a hydration process in which the diffusion controlled water uptake migrates into the rice kernel (Delphande *et al.,* 1994) and subsequent heating leads to irreversible swelling and fusion of starch granules.

a. Effects of Soaking on Head Rice Yield:
Soaking, a hydrothermal treatment, during parboiling involves diffusion of water into grains at the same time, some of the grain constituents leach out to the soaking water. Mir and Bosco (2013) revealed that soaking temperature, one of the most important parameter of parboiling, affected head rice yield. Increase in soaking temperature was associated with increase in head rice yield. Such increase in head rice yield might be attributed to partial gelatinization of starch and thereby increase in grain hardness.

b. Soaking induced changes in chemical composition of rice:
Chemical compositions of any grains are utmost important as it determines grain's nutritional value, storage life, digestibility etc. Soaking had significant effect on chemical compositions of rice grains:

i. **Effects on Starch:-**There were reported cases of significant differences in starch content of soaked and un-soaked rice. Kale *et al* (2013) reported that soaking treatment decreased the starch content of PB1121.Sareepuang *et al.* (2008) also reported loss in starch content of aromatic rice (KDML105) from 64.52% (un-soaked rice) to 63.88%, 63.58% and 64.13% for rice grains soaked at 40 °C, 50 °C and 60 °C, respectively. Decrease in starch content after soaking might be due to leaching of amylose during heating in water (Singh *et al,* 2006).
ii. **Effects on amylose content:-**Otegbayo *et al*, (2001) reported that, apparent amylose content decreased after soaking which was found to be more at extreme soaking temperatures (40 °C, 50 °C, 75 °C and 80 °C) compared to the intermediate temperature range (60 °C to 70 °C). The reduction might be the net effect of soaking time and temperature on leaching and formation of amylose lipid complexes, which

was more at extreme soaking conditions. Thus, soaking at intermediate temperatures could be beneficial (Derycke *et al,* 2005)

The amylose content of starches usually ranges from 15 to 35%. High amylose content rice shows high volume expansion (not necessarily elongation) and high degree of flakiness ((Tokumoto, 2013). High amylose grains cook dry, are less tender, and become hard upon cooling. In contrast, low-amylose rice cooks moist and sticky. Intermediate amylose rice is preferred in most rice-growing areas of the world. Based on amylose content, milled rice is classified in "amylose groups", as follows (Tokumoto, 2013):

- Waxy (1-2% amylose),
- Very low amylose content (2-9% amylose),
- Low amylose content (10-20% amylose),
- Intermediate amylose content (20-25% amylose) and
- High amylose content (25-33% amylose).

iii. **Effect on protein:** Ibukun *et al,* 2008 reported a decrease off crude protein content of paddy after soaking. The highest decrease (10.92%) was found at 80 °C for nonbasmati variety Offada, possibly due to leaching of proteins during soaking (Ibukun, 2008). It has also been noted that during soaking, the protein bodies sink into the compact starchy endosperm which makes proteins less extractable and thus lowers estimate value (Otegbayo *et al,* 2001).

iv. **Effect on crude fat:** Otegbayo *et al* (2001) reported a slight reduction in crude fat content which occurred at higher temperatures, which might be attributed to leaching and rupturing of the fat globules.

v. **Effect on crude fibre/crude ash:** Sareepuang *et al* (2008) reported significant decrease in crude fat content of aromatic rice (KDML105) with increase in soaking temperature up to 60 °C. Difference in crude fat content of brown and polished rice revealed that the maximum amount of fats is located in bran layer. Soaked polished rice had 20.27% higher crude fat content than un-soaked polished rice, indicating the diffusion of fat globules into the starchy endosperm during soaking. Study also revealed that soaked brown and soaked polished rice had higher (1.32%–17.11%) amount of crude fibre content than un-soaked brown and un-soaked polished rice, indicating the higher nutritional value of soaked rice.
Like crude fibre content, crude ash content also increased by 3.75%–23.75% after soaking. Increase in temperature caused the increase in both, possibly due to leaching of other constituents of rice. Ash content of un-soaked PB1121 has also been reported by Singh *et al* (2011) in the range of 0.66%–0.99%.

vi. **Changes in mineral composition:**
Mineral composition is one of the most important indicators of nutritional value of food. Kale *et al* (2015) reported that decrease in minerals after soaking was observed in PB1121, which might be due to leaching loss during soaking. Decreases (up to 13.30% in Ca, 16.66% in Fe, 5.76% in Na and 2.31% in K) in mineral composition of non-basmati rice with increase in severity of parboiling have also been reported by Ibukun (2008). It might be due to leaching of minerals from the husk and bran into the starchy endosperm during soaking process. Rice husk contains large amount of mineral composition. Minerals leached into the soaking water and also diffused into the endosperm of rice, and therefore, caused the decrease in the mineral content of husk and corresponding increase in that of the bran and polished rice.

vii. **Changes in glycaemic index:**
Glycaemic Index (GI) is one of the most important quality characteristics of rice. Rice with high GI is not suitable for diabetic people. It is considered that rice with high amylose content has lower GI. Kale *et al.* (2013) revealed that un-soaked PB1121 rice was a medium GI (56–69) food due to its high apparent amylose content (27.26%). Soaking thus reduced GI of rice at temperature greater than or equal to 60 °C.

viii. **Changes in starch characteristics:**
Pasting properties of rice starch represents the quality of starch and can be related with the cooking and textural properties of cooked rice. Rice with lower viscosity values, when cooked, gives non sticky, firmer grain with reduced gruel loss and improved texture (Patindol *et al*, 2008). Peak viscosity, a rapid increase in viscosity due to swelling of starch granules, indicates the ability of starch granules to swell; Soponronnarit *et al,* 2006 observed decreased in peak viscosity (from 1 075 to 526 cP) with increase in soaking temperature. This was due to decreased swelling ability and water-binding capacity of starch granules, which further indicated the partial gelatinization of starch during soaking at higher temperatures (Soponronnarit *et al*, 2006; Mir and Bosco, 2013). Similar results were observed for final viscosity, breakdown viscosity and setback viscosity. Decrease in setback viscosity of soaked rice flours

after soaking indicated the decrease in their tendency to retrograde upon cooling. Decrease in viscosity with increase in severity of parboiling has also been reported by Patindol *et al* (2008).

Steaming:
The use of steam for gelatinizing the starch is preferred to other methods of heating as it does not remove any moisture from the rice. Condensation adds water and increases the total quantity of water absorbed.
Steaming has other advantages such as:

- Its high heat can be applied at a constant temperature,
- It is relatively easy to handle,
- it gives relatively high degree of control of the paddy temperature,
- it can be stopped instantly, and
- It has a higher heat transfer rate than other media (such as hot water)

a. *Effects of steaming on rice translucency*:
The presence of white portions or chalkiness in grain is an important quality indicator in rice. Chalkiness causes softness in grains and has other unwanted effects. Chalkiness can be determined by visualizing a grain with the naked eyes or by the use of transmitted light (Bhattacharya, 1996). One major importance of parboiling is its effectiveness in eliminating white core in rice grains, thereby improving the translucency of rice kernel. Adequate soaking enables water to reach the centre of rice grains and facilitates the elimination of white portions when enough heat from steam is applied to paddy. Steaming resulted in gelatinization of rice starch, thereby converting the opaque crystalline starch in rice into a clear amorphous structure. Typical change in translucency during parboiling of selected paddy rice is shown in Figure 4 for FARO 61 variety.
Chijioke, *et al*., (2015) reported that translucency varied from 23.67 – 93.00, 27.67 – 91.00, 19.67 – 74.67, 28.00 – 92.67 and 22.33 – 82.33 for Bisalayi, FARO 61, FARO 60, FARO 52 and FARO 44, respectively, between 0 – 20 mins steaming. Percentage change in translucency of parboiled rice is shown in Figure 5.

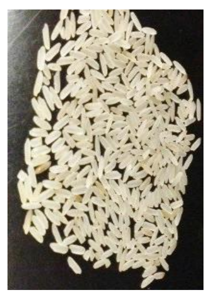
R A:  B:  C:  D: 

Figure 4: Typical change in translucency during parboiling of FARO 61 rice variety.
Legend: R: Untreated sample; A: 5 min; B: 10 min; C: 15 min; D: 20 min

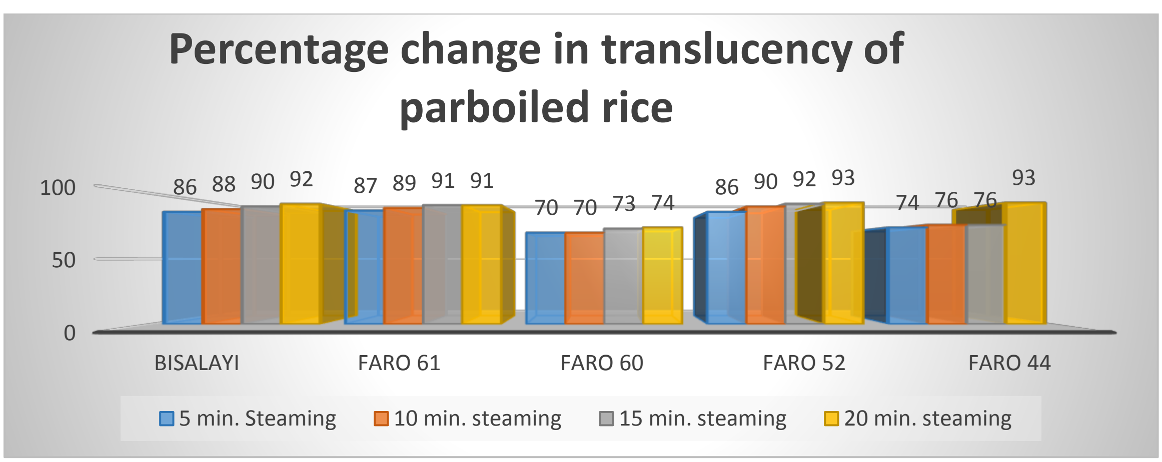


Figure 5: Percentage change in translucency of parboiled rice (*Source: Chijioke, et al,, 2015*)

b. ***Effects of steaming on rice hardness:*** Parboiling process greatly improves milling quality of paddy rice by imparting hardness to the grains so making them resistant to breakage during milling. This reduces breakage losses and increases yield during milling and is of economic advantage to rice producers and millers. Harder grains are less susceptible to insect attack and to the development of moulds Islam *et al*. (2002) reported that hardness of rice increases during parboiling, especially, due to heat treatment. Islam *et al.* (2002) studied the gelatinization properties of rice with respect to different parboiling conditions. They observed a decrease in gelatinization enthalpy with severity of parboiling and related it to the degree of starch gelatinization during heat processing. They also proposed that during parboiling, rice starch only requires 40% gelatinization for maximum head rice yield to be obtained.
Hardness of rice was found to increase with steaming duration and ranged from 59.45 – 113.65, 79.39 – 158.17, 77.24 – 136.70, 73.59 – 136.65, and 73.14 – 126.20 for Bisalayi, FARO 61, FARO 60, FARO 52 and FARO 44, respectively (Chijioke, *et al*.; 2015). Differences in values of initial hardness of the selected varieties of paddy could be due to different levels of cracks or fissures imparted on paddy during harvesting and threshing. Thus during parboiling, the starchy endosperm melts and re-unites to seal all cracks, thereby, imparting hardness to rice. Figure 6 shows the percentage increase in hardness during steaming of paddy.

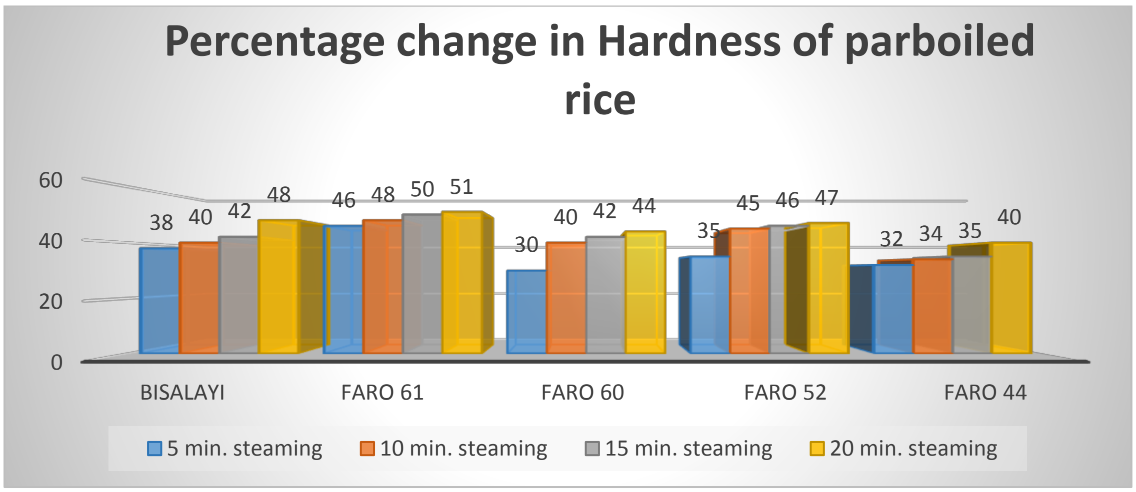


Figure 6: Percentage change in hardness of rice due to parboiling (*Source: Chijioke et al, 2015*)

c. ***Effects of steaming on rice lightness value:***
Discolouration of rice as a result of parboiling is another important quality indicator that affects market value and consumer acceptability of the product. The lightness value of selected varieties of rice significantly decreased with steaming time. Islam *et al.* (2002) reported that sever parboiling, such as extended steaming time greatly affect the colour of parboiled rice. Mir and Bosco (2013) reported that difference in genetic makeup could also result into varietal difference in colour of parboiled rice.
The effect of steaming on the lightness value at different times is as shown in Figure 7. The lightness value decreased as the steaming time increases with values of 78.34 – 58.98 N, 71.27 – 58.67 N, 73.85 – 59.06 N, 70.21 – 57.00 N and 69.75 – 58.67 N for Bisalayi, FARO 61 FARO 60, FARO 52 and FARO 44 respectively, corresponding to 0 – 20 min of steaming Chijioke, *et al* ,**(**2015**)**. Steaming time significantly affected lightness value of Bisalayi (local variety) more than the FARO varieties. This clearly shows that prolonged steaming period during parboiling of rough rice adversely affects lightness and colour quality of rice.

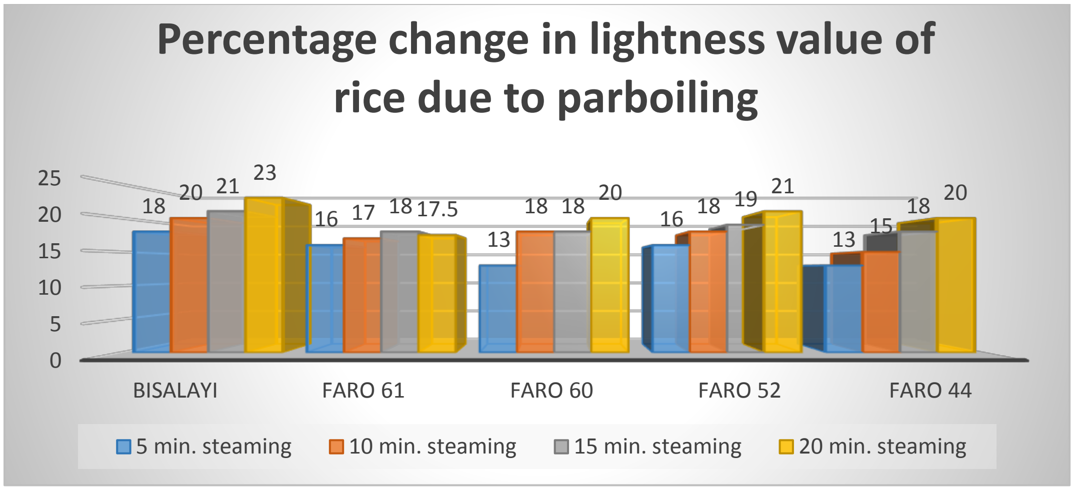


Figure 7: Percentage change in lightness value of rice due to parboiling (*Source: Chijioke, et al., 2015*)

Drying:
Effects of drying in rice parboiling process (Ayamdoo *et al.,* 2013):

- The art of drying evaporate the moisture and this concentrates solutes in the kernel
- Drying will also stop microbial pathogens from developing on steamed paddy.
- It compresses the gelatinous amylose starch together in a compact mass and delocalizes it from the husk making de-husking (milling) easier.
- Also, during drying amylopectin retro gradation increases and perfection of the crystalline amylose-lipid complexes occur.
- Drying complete amylopectin retro gradation process and hence complete the cementing of the rice kernel fissures/cracks there by increasing the hardness of the rice kernel.
- Rice that is well dry is expected to have high head yield during the milling process, thus underscore the importance of drying step in rice parboiling process.

CHALLENGES of RICE PARBOILING IN NIGERIA:

a. The prolong soaking effects::
   - Prolong soaking causes the leaching of rice constituents in the soaking water thus leads to reduction of starch [i.e. amylose (linear) and amylopectin (branched) molecules] which plays a vital role as a determinant of rice quality (Otegbayo *et al*, 2001; Ibukun, 2008; Sareepuang *et al*, 2008). Rice with moderate amylose content is considered to be more qualitative; thus, moderate soaking duration is much preferable. In other words, soaking decreases the amylose content due to leaching thereby reducing rice quality.
   - Proteins, fats, fibre, ash and mineral compositions in rice are susceptible to hot soaking and their contents decreases with increase soaking period (Otegbayo *et al,* 2001). This is as a result of exchange of minerals between the paddy (bran /kernels) and it surrounding water. Thus, prolong soaking can affect the cooking quality of rice.

b. Since most of the parboiled rice come from local producers, the processes vary among producers. Such variation may result in quality differences in the end product and possible over utilization of energy during steaming operation. Moreover, the resultant milled rice tends to have the following characteristics:
   - low hardness value of the rice grains
   - moulds growth,
   - weevils attack of the rice kernels,
   - obnoxious smell,
   - discolouration of grains,
   - admixture of deleterious substances
   - Inability to maintain optimum moisture content of the parboiled grains (14%).
   - Fermentation

- excessive leaching of soluble solids
- Low head yield

c. The cost of processing represents an increasing share of the production cost for local rice. Of this cost, parboiling makes up 75% of the processing cost, with milling contributing 17% and other operations accounting for the remaining 8%. This has obvious implication for cost effectiveness since there are very few integrated large milling plants that can handle the parboiling process in the country.

d. The use of fuel wood is the major energy source use by traditional rice parboilers in Nigeria for steaming and other parboiling operations that requires heat as a source of energy. This has environmental implications (de-forestation and pollution) and also constitutes serious health hazard to the rice parboilers.

e. Loss of rice due to inefficient drying method is also not insignificant. Sun drying is the most popular and traditional method of drying. This method is completely dependent upon weather and it needs specially constructed large floor area that restricts the capacity of a mill to a certain extent. Excessive losses will occur due to scattering, birds, rodents etc.

f. The traditional method of steaming of paddy currently been practice by the local rice processors causes insufficient gelatinization. It also causes non uniformity in moisture content of rice at different portion in the cooking pot as the steaming process is usually carry out by application of heat directly to the cooking pot. This process make the rice at the bottom of the pot to be over steamed while those at the medium and top to be moderately and less steamed respectively. This results into low head yield which is one of the major quality deficiency elements of our local rice.

g. Most of the existing parboilers had bogus capacities which are not attractive to the processors and also difficulties in transporting it from the construction site to the desired site of operation. Also, the cost of constructing and purchasing the parboilers in Nigeria has been on the high side, thus the local processors could not afford it and the aim of the innovation is yet to be achieved.

h. Other post-harvest practices (e.g. harvesting and drying) before the parboiling process have significant impact in the success recorded in the parboiling process. For example, application of bad practices during threshing will lead to grain fissure/body cracks and if not properly handle during parboiling process may cause low yield recovery during milling.

i. Although parboiled rice is claimed to have a better shelf-life than raw rice because of the gelatinized starchy endosperm, its slightly open hull also makes it more exposed to insect attack.

j. Although parboiled grains are harder than raw rice, they are also susceptible to fissuring during drying, particularly below 18 percent moisture when free water becomes scarce in the grain

k. It is a well-documented fact that a common problem with parboiling, especially by employing high temperature and pressure and longer processing time, is darkening of the grain. Also, steaming operation, which bring about the gelatinization of starch, requires a lot of energy to produce steam for the process

l. Poor government support to agricultural sector development and policy inconsistency is affecting the development of rice processing in Nigeria. For example, weak support to research institutions, weak extension services, poor funding of agricultural sector, issues of foreign rice importation e.t.c.

m. Poor attitude of rice producers towards embracing new innovations in rice production and processing.

WAY FORWARD:

a. To ensure uniformity in the quality of local milled rice, improve method that will effectively handle the shortcomings on the existing parboiling systems should be introduced within the rice processing communities in Nigeria. However, the use of combination soaking procedure (hot soaking between 60℃ and 80℃), which reduced the soaking time to 4 h should be consider for further improvement. Although, the major concern for this and other methods of the same kind is the involvement of high temperatures during soaking, which could lead to loss of quality of milled rice. The optimum parboiling process requirements are recommended as followings:

Soaking of Paddy:

- The heat required for soaking a ton of paddy is 83,000 kcal
- The following time-temperature combination is considered optimum for soaking:

S/No.	Temperature, °C	Time, h
1	Water heated to 50°C and allowed to come to ambient temperature	24
2	Water heated to 75°C and allowed to come to ambient temperature	12
3	Maintained at 60°C	8
4	Maintained at 65°C	6
5	Maintained at 70°C	4
6	Maintained at 72°C	3.5
7	Steam at 0.5 atm. Pressure	0.4

Steaming of paddy:

- The heat required for soaking a ton of paddy is 17,300 kcal at a pressure of 4 to 5 kg/cm^2
- Steaming duration depends on the steaming arrangement. For small batches, steaming takes 2 to 3 minutes while batches of 6 ton may take 20 to 30 minutes.
- While splitting of the husk indicates completion of the steaming process, it is not a necessary condition and paddy can be completely parboiled without any splitting.

Drying of paddy:

- Drying of parboiled paddy from 45-50% (db) to 14-16% (db) needs to be done for proper milling and storage.
- Sun drying of paddy is generally practiced
- For uniform drying, it is important that paddy is spread in 2-3 cm thickness layer and stirred at an interval of half hour
- It is also important that paddy is dried in two passes instead of continuous drying. In first pass, paddy moisture content should be brought down to 18-20% and rest in second pass.

b. The federal government of Nigeria and other relevant stakeholders to organize training for parboilers regarding the optimum soaking, steaming and drying methods using appropriate equipment/devices. Moreover, the training programme should also be follow up by financial support and linkage to good market to ensure sustainability of the whole process.

c. the following should be put into consideration in order to reduce health hazard and cost enquired by the rice parboilers on energy during rice processing,
   - There is need to introduce efficient energy saving sources that will be in conformity with socio-economic profile of the parboilers. For example, using of energy saving stove (metal and mud type) using husk as burning fuel.
   - Also, drying paddy in a mechanical dryer using husk as burning fuel.

d. In an attempt to alleviate the setback suffered by the local rice processing using the traditional method of rice parboiling in Nigeria, using drums, fired with wood, there is need to designed/improved on the existing parboiler that would ensure, ease of parboiling, saved time, high cooking quality and parboils paddy in large quantities per batch.

e. In order to avoid other post-harvest short comings before the parboiling process, threshing, winnowing and drying should be performed by mechanical equipment/processes.

f. There is need for the government to strengthen all relevant institutions that are introduce to support rice sector development in Nigeria and re-equipped them with necessary resources (policies inclusive) that will ensure their optimum service delivery to the target stakeholders. Also, for rice production to be boosted, Nigerian government need to introduce institutions to monitor production and distribution of local rice.

g. Adequate sensitization/awareness program should be organized by the relevant stakeholders with the sole aim of achieving technology transfer in best practices of rice parboiling. This may be achieve by engaging rice processors on practical demonstration of steps that are involve in best practices through field days. Moreover, economic and social benefits of the recommended parboiling process should be emphasized and should be made known to the rice producers.

CONCLUSION:

It is well documented fact that parboiling process increased the head rice yield (when the rice starch is 40% gelatinized during parboiling of paddy and that extensive parboiling or extensive starch gelatinization is not required to obtain maximum head rice yields). Parboiling process also had potential of concentrating nutrients especially proteins among various parts of rice kernel. This suggests that parboiling of Nigeria rice must be given a priority. However, it is necessary to establish optimum processing conditions required to obtain better qualities of the finished product while saving energy and time.

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EFFECT OF PROCESSING TECHNIQUES ON THE QUALITY OF INSTANT POUNDED YAM FLOUR.

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ABSTRACT
This study was undertaken to evaluate the effect of processing methods on the quality of Instant pounded yam flour (IPYF). Five methods were used to produce IPYF. The methods investigated were different size reduction and drying methods. Also, effect of unpeeled yam before steaming was also investigated.The yield, chemical and physical properties of the flours were determined. The yield of the IPYF ranged from 18.94-20.56%. Significant differences (p<0.05) were observed in the proximate composition of the samples. The processing methods significantly affected the swelling index and water absorption capacity of the IPYF flour. AFHP sample showed the highest value in swelling index and water absorption capacity. The processing methods positively affected the colour as samples have high degree of whiteness which is one of the quality parameters for IPYF with ACHP being the whitest. Processing methods significantly affected the pasting properties of the IPYF with ASHP the least through viscosity while Setback viscosity of samples ACKU and ACHP (1371 RVU) are equal and the highest

Key words: Pounded yam, Flash drying, IPYF, Yam and Flour

INTRODUCTION:

Yam, (*discorea spp*) is an important staple food that is grown extensively in Nigeria. Yam is grown majorly for food and income; it can be processed in diverse ways such as boiling, roasting, frying, pounding and making into flour for Elubo (yam flour) and instant pounded yam. Pounded yam is a special and delicious delicacy in Nigeria (Olaoye and Oyewole, 2012). Traditional method of producing pounded yam involves making pieces into dough after boiling by pounding with a mortar and pestle (Ferede *et al.,* 2010); the drudgery involved in making pounded yam led to the development of instant pounded yam flour (FIIRO, 2005).

There are indications that yam has great prospect of contributing to closing the projected food deficit in Africa in the 21st century, if efforts are made to identify and overcome the constraints to its production. Processing of yam increases its shelf life, adds value to the tuber (from where it is processed) before being exported to enhance its economic value, reduce waste and cut down the cost of transporting the product to longer distances compared with the heavy wet tubers that are unprocessed. The fact that yam can be preserved by processing helps to stabilize prices during off harvest season.Instant Pounded Yam Flour (IPYF) is a value-added product derived from white yam (FIIRO, 2005; Asiru *et al.,* 2013). The recent acceptability and popularization of IPYF is fuelled by consuming elites and socialites both home and abroad (Komolafe and Akinoso, 2005; Akinoso and Olatoye; 2013). This is because all that is required in the preparation of IPYF is by dissolving a measured mass of the flour in a specified volume of boiled water and carefully stirring the mixture over heat until dough with smooth consistency similar to pounded yam is obtained.

According to FIIRO (2005), the process technology for the production of IPYF consists of simple operations whose unit operations are: yam selection and weighing, washing, peeling and slicing, sulphiting, parboiling, drying, milling and packaging. Generally, drying as a unit operation is an energy consuming process which accounted for higher percentage of energy consumption/utilization in any food industry (Singh, 1986; Ramirez *et al*., 2006; Akinoso and Olatoye, 2013); and it remains critical unit operation in food processing which determines the quality characteristics of the final products (Krokida *et al*., 1998). Due to the present need for reduction in production cost, the need to conserve energy through the reduction of the drying time utilized in food processing is very necessary (Aiyedun *et al*., 2008; Wang, 2009); and among those factors that affect the efficiency of drying operation is the thickness as well as the surface area of the product to be dried (Mohammed, 2009).

This study focused on production of instant pounded yam flour (IPYF) using two drying methods namely: ; considering the effect of varying sizes and size reduction methods such as slicing, chipping and chunking on quality of IPYF and the effect of peeling and unpeeling of the skin on quality parameters.

MATERIALS AND METHODS

Source of sample

Discorea rotundata variety (Abuja type) was obtained from a local market called Ile-Epo market at Abule Egba, Lagos. The yams were bought relatively wholesome, void of sprouting and mechanical damage.

Preparation

IPYF was produced using FIIRO (2005) and Asiru *et al.* (2013) modified methods. About 36kg of yam tubers each was used to produce instant pounded yam flour using five different processing methods.

Method I

This is a conventional method used in FIIRO for IPYF production. Thirty six kilogram (36 kg) of the tubers were washed with cold tap water and manually peeled with stainless steel knives. The peeled tubers were thinly sliced (0.5mm thickness), treated with sodium meta-bisulphitethen steamed for 30mins in a parboiler, cooled and hot air dried in a cabinet dryer at 75^0C, milled after drying then cooled, packaged and labelled ASHP.

Method II

Another Thirty six kilogram (36 kg) of the tubers was washed with cold tap water and manually peeled with stainless steel knives. The peeled tubers were cut in to chunks (50mm thick), pre-treated with sodium meta-bisulphitethen steamed till cooked for 45mins in a parboiler, cooled at room temperature then hot air dried in a cabinet dryer at 75^0C, milled with an hammer mill, cooled, packaged and labelled ACKP (Asiru *et al*., 2013).

Method III

Thirty six kilogram (36 kg) of yam tubers was washed with cold tap water. The unpeeled tubers were cut into chunks (50mm thick), pre-treated with sulphite then steamed till cooked for 45mins in a parboiler, cooled at room temperature, then peeled before hot air dried in a cabinet dryer at 75^0C. It was then milled with a hammer mill, cooled, packaged and labelled ACKU (Asiru *et al*., 2013)

Method IV

36 kg of the tubers was washed with cold tap water and manually peeled with stainless steel knives. The peeled tubers were chipped (0.36 mm thickness) using an adaptable FIIRO designed cassava chipping machine,and pre-treated with sodium meta-bisulphite for about 30mins then boiled for 15mins in a parboiler, cooled and hot air dried in a cabinet drier at 75^0C, milled after drying, then cooled, packaged and labelled ACHP.

Method V

Thirty-six kilogram (36 kg) of the tubers were washed with cold tap water and manually peeled with stainless steel knives. The peeled tubers were cut into chunks (50mm thick) and pre-treated with sodium meta-bisulphite for about 30mins, steamed for 30mins in a lagged double walled parboiler, then cooled at room temperature. After cooling, it was granulated with a grater and dried in a flash drier at 165^0C, milled with a hammer mill, packaged and then labelled AFHP (Asiru *et al*., 2013).

Determination of yield of IPYF

This was determined using the expression

$$Yield(\%) = \frac{Weight\ of\ instant\ pounded\ yam\ flour}{Weight\ of\ unpeeled\ y□m\ tuber}$$

Determination of chemical properties of IPYF

Moisture content, ash, crude fibre, crude fat, crude protein and carbohydrate were determined by the method of AOAC (1990), carbohydrate was estimated by the difference method (% carbohydrate = 100% - sum of percentage of moisture, ash, fat, crude fibre and crude protein contents)

Determination of physical properties

Bulk density of IPYF was determined by the method described by Chau and Cheung (1997). For loose bulk density, an empty calibrated centrifuge was weighed. The tube was then filled with a sample to 5 ml. The weight of the tube and its contents was taken and recorded. The weight of the sample alone was then determined by difference.

For pack bulk density, the tube was filled with a sample to 5 ml and the tube was constantly tapped until there was no further change in volume. The weight of the tube and its contents were taken and recorded. The weight of the sample alone was then determined by difference.
Densities were calculated from the values obtained as follows:

$$Density = \frac{Weight\ of\ sample}{Volume\ occupied}$$

Determination of Water Absorption Capacity (WAC):
Water absorption capacity (WAC) of the IPYF samples was determined by the modified method of Phillips *et al.* (1988).
WAC was calculated as follows:

$$WAC = \frac{W_2 - (W_0 + W_1)}{W_0} \times 100$$

Determination of Oil Absorption Capacity (OAC):
Oil absorption capacity (OAC) of the IPYF samples was determined by the modified method of Phillips *et al.* (1988).
OAC was calculated as follows:

$$OAC = \frac{W_2 - (W_0 + W_1)}{W_0} \times 100$$

Determination of swelling power:
Swelling power of the IPYF samples was determined by the procedure described by Takashi and Seib (1988).

$$Swelling\ power = \frac{Weight\ of\ wet\ mash\ of\ sediments}{Weight\ of\ dry\ matter\ in\ the\ geeeel}$$

Determination of Dispersibility:
Dispersibility of the IPYF samples was determined by the method described by Kulkarni *et al.* (1991)

Colour Determination
The colour of the IPYF samples was measured with a Minolta CR-310 (Minolta camera Co. Ltd, Osaka, Japan) tristimulus colorimeter, recording L*, a* and b* values. L* represented lightness (with 0= darkness/ blackness to 100= perfect/brightness); a* corresponds to the extent of green colour (in the range from negative= green to positive = redness); b* represents blue in the range from negative=blue to positive=yellow.

Determination of Pasting Properties
Pasting characteristics of the IPYF samples was determined with a Rapid Visco Analyser (RVA) as described by Adebowale *et al. (*2008).

Statistical Design and Analysis
All data obtained were subjected to analysis of variance (ANOVA) using SPSS version 17.0 software package.The significance of treatment of means was tested at $P < 0.05$ probability level using Duncan's New Multiple Range Test (DNMRT) (Steel and Torrie, 1980).

RESULTS AND DISCUSSION
The results of the experiments and effect of processing methods on physical, chemical and yield of IPYF are presented in Figures 1-5 and Tables 1-4.
Figure 1 showed the yield of IPYF from the five methods of production used. The yield of IPYF samples ranged from 18.94% to 20.56%. ACKU sample had the highest yield of 20.56%.This is likely due to the breakdown of cementing material between the peel and fleshy portion thereby making peeling easy and reducing the loss during peeling (Ekwu *et al.,* 2014). The low yield of AFHP can be attributed to losses during the peeling of the chunks in addition to loss during granulation.

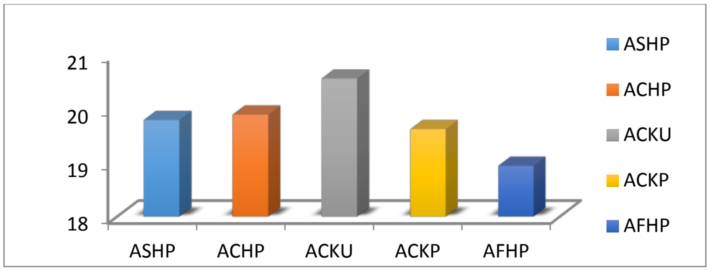

Figure 2: Effect of Processing Methods on the Yield of IPYF Samples

The sensory properties of IPYF samples (Table 1) from different methods of production showed a significant difference ($P<0.05$) only in the attributes of colour and aftertaste while all the other attributes do not differ significantly. This implies that any of the production methods could be adopted for the production of Instant Pounded Yam Flour that would meet the sensory specification of the consumers.

The proximate composition of the IPYF samples is as presented in Table 1. There are significant differences ($p<0.05$) between the moisture content of samples which can be attributed to the different processing methods, especially drying. The moisture content of the IPYF samples ranged from 6.97 to 8.77 g/100g. The minimum and maximum moisture content of samples ACKU and ACKP can be attributed to the thickness of the slices. However, the moisture content of all the samples are below 10% recommended by FIIRO (FIIRO, 2005), the low moisture content are advantageous as the samples will store well if kept in air tight packages.

Table 1. Result of Proximate Analysis of IPYF

Proximate Composition	ASHP	ACKP	ACKU	ACHP	AFHP
		2(1)	2(2)		
Moisture Content (%)	7.50^{bc} ± 0.30	7.37^{c} ± 0.17	6.97^{d} ± 0.15	7.80^{b} ± 0.20	8.77^{a} ± 0.18
Crude Protein (%)	7.51^{a} ± 0.19	5.38^{c} ± 0.21	4.85^{d} ± 0.11	4.43^{e} ± 0.28	6.11^{b} ± 0.27
Crude Fat (%)	0.17^{bc} ± 0.02	0.18^{b} ± 0.03	0.15^{bc} ± 0.03	0.27^{a} ± 0.04	0.12^{c} ± 0.02
Total Ash (%)	2.04^{c} ± 0.04	2.20^{b} ± 0.05	2.01^{c} ± 0.05	1.92^{d} ± 0.03	2.37^{a} ± 0.03
Crude Fibre (%)	1.50^{d} ± 0.04	1.36^{e} ± 0.02	1.69^{c} ± 0.04	1.79^{b} ± 0.03	2.20^{a} ± 0.05
Carbohydrate (%)	81.10 ± 0.60	83.51^{c} ± 0.38	84.33^{b} ± 0.41	83.78^{bc} ± 0.09	80.43^{d} ± 0.41

Values in the same rows with different superscripts are significantly different ($p<0.05$).

The protein content of all the IPYF samples ranged from 4.31 – 7.51%. The protein content of samples ACKP, ACKU, ACHP and AFHP were lower than the control (ASHP) produced with the FIIRO conventional method. However, the protein contents are in agreement with findings of Abara *et al*. (2003) and Abara (2011) that reported values of 2.31%, 5.75% and 6.35% in the wet and dry tissue of *Discorea bibifera.* There are significant differences in protein content ($p<0.05$) of samples and this may be due to the different processing methods used.

Fat content of samples range of 0.12 to 0.27% were significantly ($p<0.05$) lower than values gotten for instant flours by Oladeji *et al*. (2013).This indicates that parboiling reduces the fat content of yam and the low fat content will enhance the storability as rancidity would be reduced (Ekwu *et al.,* 2014).

Ash content of the samples ranged from 1.92 to 2.37%, these values have a significant difference ($p<0.05$). The difference can be attributed to the different processing methods. The values of the IPYF samples are higher than those reported by Oladeji *et al.* (2013) this is probably due to leaching of organic matter more than mineral during boiling thereby resulting in high concentration of mineral in the samples (Ekwu *et al*., 2014).

The crude fibre content ranged from 1.36 – 2.20% and is significant ($p<0.05$) between samples. The values are significantly higher than Oladeji *et al.* (2013) reported values. The high crude fibre in IPYF samples suggests that the samples can help in contributing to healthy conditions of the intestine when consumed.The AFHP sample has the highest value of fibre. This may be due to the age of the tubers (Njoku and Banigo, 2006)
The results of some physico-chemical characteristics of Instant Pounded Yam Flour produced using different production methods differs significantly ($P<0.05$) in all the characteristics investigated (Table 2). The loose and pack bulk densities ranged from 0.805 to 0.855 and 0.888 to 0.970 respectively.
These densities are important for determining package requirement, material handling and applications in wet processing in the food industry.The bulk densities are greater than the result of instant yam flour reported by Oladeji *et al.* 2013 this means the particle size are smaller. The small particle size of the IPYF samples makes it a potential food for allergic infants and persons with gastro intestinal disorder as reported by Opara (2007) for taro flour.
Water absorption capacity (WAC) ranged from 222.55 to 513.59. WAC describes flour – water association ability under limited water supply and this could be attributed to the presence of greater amount of hydrophilic constituents like soluble fibre and lower amount of fat content as shown in Table 2.
Oil absorption capacity (OAC) of the samples ranged from 77.67 to 90.29 with IPYF sample from ACHP having the highest mean value. The highest OAC could suggest the presence of a large proportion of hydrophobic groups as compared with the hydrophilic groups on the surface of protein molecules (Subagio, 2006). The oil absorption can also be influenced by the lipophilicity of protein (Kinsella, 1976).
Water binding capacity ranged from 243.00 to 552.88. AFHP have the highest mean score and significantly differs from other samples. According to Mayaki *et al*. (2003) this could be due to high fibre content and high content of un-degraded starch granules in the flour. As reported by Soni *et al*., (1985) and Ekwu *et al*. (2014) Not listed high water binding capacity of AFHP implies good functionality when used as composite flour.
The swelling power measures the hydration capacity of flour sample as it is a weight measure of swollen starch granules and their occluded water. The values ranged from 484.16 to 935.92 with AFHP having the highest swelling power while ACKUsample had the least mean value. The result follows the same trend reported by Eriksson *et al.* (2014) on cassava and wheat flour composite; they reported that the swelling capacity of flours is associated with bonding forces in their starch granules.

Table 2: Effect of Processing Methods on the Physical Characteristics of IPYF

Physico-Chemical Characteristics	ASHP	ACKP	ACKU	ACHP	AFHP
		2(1)	2(2)		
Loose Bulk	0.820 ^{cd}	0.830^{bc}	0.845^{ab}	0.805^{d}	0.855^{a}
Density (g/ml)	± 0.002	± 0.002	± 0.003	± 0.025	± 0.005
Pack Bulk	0.888^{de}	0.900 ^{cd}	0.875^{e}	0.945^{b}	0.970^{a}
Density (g/ml)	± 0.002	± 0.004	± 0.003	± 0.017	± 0.004
Water Absorption	222.55^{d} ±	295.10^{b}	254.46^{c}	229.41^{d}	513.59^{a}
Capacity	3.71	± 2.64	± 3.08	± 4.73	± 3.92
Oil Absorption	78.64^{b}	70.59^{c}	86.00^{a}	90.29^{a}	77.67^{b}
Capacity	± 1.82	± 2.93	± 2.46	± 3.75	± 2.09
Water Binding	249.00^{d}	274.51^{b}	258.00^{c}	243.00^{e}	552.88^{a}
Capacity	± 2.14	± 2.86	± 2.50	± 3.00	± 3.94

Values are means of triplicate determinations. ± SD value
Mean values with different superscript within the same row are significantly different ($P<0.05$).

The colour parameters of IPYF samples ranged from 89.26 to 92.35 for L* value, -0.99 to -1.43 for b* value, and 13.14to 17.71 for a* value respectively (Table 3.). The result revealed that all the samples have high lightness values which indicate a high degree of whiteness which is one of the quality parameters for IPYF. However, sample AFHP has the highest mean value for yellowness index.

Table 3: Effect of Processing Methods on Colour Parameters of IPYF

COLOUR PARAMETERS	ASHP	ACKP 2(1)	ACKU 2(2)	ACHP	AFHP
L*	89.98^{d} ± 0.04	89.26^{e} ± 0.02	91.81^{b} ± 0.14	92.35^{a} ± 0.06	90.57^{c} ± 0.06
a*	-1.08^{b} ± 0.02	-0.99^{a} ± 0.01	-1.00^{a} ± 0.01	-1.09^{b} ± 0.00	-1.43^{c} ± 0.02
b*	15.96^{b} ± 0.01	14.65^{d} ± 0.01	15.76^{c} ± 0.02	13.14^{e} ± 0.12	17.71^{a} ± 0.02

Values are means of triplicate determinations. ± SD value
Mean values with different superscript within the same row are significantly different (P<0.05)
Note: L (black/white), a* (red/green) and b* (yellow/blue)*

The pasting characteristics of Instant Pounded Yam Flour produced showed that AFHP has the highest value for most of the pasting characteristics with the exception of setback viscosity and pasting temperature (Table 4)

The pasting temperature ranged from 61.85-86.35 with AFHP having the least Pasting temperature. A higher pasting temperature according to Numfor *et al*. (1996) indicates a higher gelatinization time. This lower swelling property of starch, the breakdown viscosity of AFHP indicates that it has the strongest starch structure (Svanberg, 1987). ASHP had the lowest breakdown viscosity which implies a weak cross linking within granules (Oduro *et al*., 2005). Peak viscosity of AFHP significantly differs from other samples, this indicates high elasticity and gel strength, and this is an indication according to Osungbaro (1990) that it has the highest starch content. Setback viscosity of samples ACKU and ACHP (1371 RVU) are equal and the highest, this indicates high potential for retrogradation of the samples (Otegbayo *et al*. 2006); other samples set back viscosity vary significantly and this determines their gel stability in food products.

The trough viscosity of the samples ranged from 1542 to 3397 RVU. ASHP had the least trough viscosity which implies the sample would be more prone to rupture during pasting and its cooked paste will not be as stable as other samples (Adebowale *et al*., 2008).

Table 4: Effect of Processing Methods on the Pasting Properties of IPYF

Pasting Characteristics	ASHP	ACKP 1	ACKU 2	ACHP	AFHP
Peak Viscosity	1693	2489	2551	2818	3785
Trough Viscosity	1542	2129	2167	2628	3397
Breakdown Viscosity	151	360	384	190	388
Final Viscosity	2403	3275	3191	3999	4008
Setback Viscosity	861	1146	1371	1371	611
Peak Time	6.53	5.80	5.87	7.00	5.87
Pasting Temperature	86.35	79.00	80.60	82.40	61.85

CONCLUSION

From the results obtained from this study, the processing method using un-peeled yam increases yield and gives high carbohydrate product, and also, the functional and pasting qualities such as water binding capacity. Swelling property of flash dried product surpasses cabinet dried products. This implies high fibre which would be advantageous to health associated with low fibre intake. Products made from ACHP and ACKU will be more stable than those made from other methods especially ASHP that will more readily suffer retro-gradation.

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IDENTIFYING VARIETIES: AN IMPERATIVE TOOL IN DETERMINATION OF OIL CONTENT OF CASTOR SEEDS

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ABSTRACT

This paper reports experimental studies on determination of oil content of four varieties of castor seeds available in North Eastern Nigeria, the castor varieties used were White Big Size (WBS), Black Big Size (BBS), Grey Medium Size (GMS) and Grey Small Size (GSS). Soxhlet extractor was used for the oil extraction, while Methanol was used as solvent for the extraction process. The extracted oil was characterized to determine some of the properties. Mass of oil extracted from the four varieties revealed that the GMS gave the highest oil content of 54.5% followed by the GSS of 40.17%. The WBS gave oil content of 35.5% and the least of 29.67% was observed from the BBS. The obtained seeds oil content and oil properties were subjected to analysis of variance (ANOVA) using full factorial design in the Design-Expert statistical package (Stat-Ease Inc. 7.0 USA), and model equations were generated. The results of the statistical analysis shows that the observed differences between means of the oil content from these four castor seeds are significant at 5% level.

***Keywords**: Castor seed, Soxhlet extractor, methanol, extraction, castor oil*

INTRODUCTION

Castor plant, (*Ricinus communist L.)* is a member of the Euphorbiaceae, which contains a vast number of plants mostly native to the tropics (Akpan, *et al. 2006)*. In Nigeria, castor is obtained in every part of the country. Its seed contains 40 to 60 % oil (Olaoye, 2000, Olaniyan, 2010). The seed is referred to differently depending on the locality where it is found. The Yorubas call it '*Lara*', the Hausas refer to it as '*Zurma*', and the Kanuris call it '*Kwolakwola*', while the Igbos refers to it as *Ogilisi* (Oluwole, 2010). The oil extracted from the seed is traditionally used as medicinal ointment, illuminant, and as raw material in the soap making industry. At present, the potential of castor oil is not fully explored in Nigeria. Figure 1 shows the pods of four common varieties of the crop that have been identified. These have been named as White Big Size (WBS), Black Big Size (BBS), Grey Medium Size (GMS) and Grey Small Size (GSS) (Oluwole, 2010). Castor seed oil is a colourless to very pale yellow liquid with mild or no odor or taste (Akpan *et al., 2006*). The oil is essentially a pure triglyceride and contains almost 90% of glyceryltrianoleate (Marter, 1981). Castor oil is an amber viscous liquid and is sometimes known as ricinus oil (Marter, 1981). The oil itself contains a number of fatty acids such as oleic acid, liniteic acid, stearic acid and palmitic acid. Among the vegetable oil however, castor oil is distinguished by its high content of ricinoleic acid than any other vegetable oil (Chakrabarti and Rafiq, 2008). Castor oil is unique as it is the only source of an 18- carbon hydroxylated acid with one double bond (Chakrabarti and Rafiq, 2008). The product uniformity and consistency of castor oil are significantly high for a naturally occurring material. It has unsaturated bond, high molecular weight, low melting point and very low solidification point which make it industrially useful. Castor oil have applications in the manufacturing of soaps, lubricants, hydraulic and brake fluids, paints, dyes, coating, inks, cold resistant, plastics, varnishes, lacquers, oil clothes, linoleum grease, waxes and polishes, nylon, pharmaceuticals and perfumes and also as a raw material in the manufacturing of various chemicals (Oluwole, 2010). At present, the processing of castor to extract its oil is not in commercial scale in Nigeria. This study aims at the extraction of castor oil from four varieties of the seeds commonly found in Borno State, Nigeria in order to determine their oil contents.

MATERIALS AND METHODS

Materials and Preparation

100 kg of each four varieties of unshelled castor seeds used in this study were obtained from farmers in Kawuri village of Konduga Local Government Area, Borno State, Nigeria.

The undehulled castor were prepared by cleaning (removing dirt and stones by hand picking) and stored in polyethylene bags according to varieties namely: A-White Big Sized (WBS); B- Black Big Sized (BBS); C- Grey Medium Sized (GMS); and D- Grey Small Sized (GSS). Each variety was kept under shade for 2 days to equilibrate (Oluwole *et al*., 2012). About 5 kg of undehulled castor was taken from each variety and were manually dehulled to obtain intact seeds and decorticated. The decorticated seeds were stored in separate sealed polyethylene bags to maintain the moisture level of the samples.

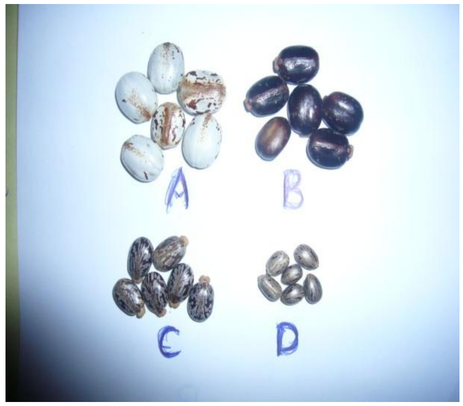

Figure 1.Common Castor seeds: A -WBS; B -BBS; C -GMS; D –GSS
((WBS)-White Big Size, (BBS)-Black Big Size, (GMS)- Grey Medium Size and (GSS)-Grey Small Size)

Castor Seed Oil Content Determination

The seeds were prepared by decorticating (removing the endocarp) and winnowing to separate the shell from the cotyledon. About 250 g of each decorticated seed sample was milled to reduce the particle size. 200 ml of methanol was poured into round bottom flask. Twenty grams of milled seed sample was placed in the thimble and was inserted in the centre of the extractor. The Soxhlet was heated at 60 ^{O}C using electric heating mantle. When the Methanol solvent was boiling, the vapour rose through the vertical tube into the condenser at the top. The liquid condensate dripped into the filter paper thimble in the centre, which contained the milled seed sample to be extracted. The extract seeped through the pores of the thimble and filled the siphon tube, where it flowed back down into the round bottom flask. This was allowed to continue till there is no more trace of oil dropping which took about 3hrs 30min. The thimble was then removed from the tube, dried in the oven, cooled in desiccators and weighed to determine the reduction in weight. The experiment was replicated three times for all the four varieties of castor seeds. At the end of the extraction, the resulting mixture containing oil and methanol was heated to remove methanol (solvent) from the oil.

The seed oil content was determined following the method reported by Olaniyan (2010) as:

$$Q_o = \frac{M_O}{M_S} \times 100\% \quad (1)$$

Where

Q_O = oil content, %

M_O = mass of oil extracted, g

M_S = mass of milled seed, g

Characterization of Castor Oil

The oils extracted from the four castor seeds varieties were investigated for some physio-chemical properties following the methods reported by Akpan *et al.* (2006), Olutoye and Garba (2008) and Shridhar *et al.* (2010). The properties included acid value, saponification value, iodine value, refractive index, viscosity, specific gravity, peroxide value and pH value.

Determination of acid value (AV)

Method described by ASTM (2002) was used. Twenty-five ml of diethylether was mixed with 25ml of ethanol in a flask. 2g of each oil sample was dissolved in the prepared solution. 1ml of 1% phenolphthalein was added and then heated in a water bath for 15min. The hot mixture was titrated with 0.1ml sodium hydroxide (NaOH) as base, using phenolphthalein end point (pink) as an indicator. The end point was noted when the addition of a single drop produced a slight colour change persisting for at least 15sec this was replicated three times. The acid value was determined using the following formula:

$$\text{Acid Value (AV)} = \frac{\text{Titration (ml)} \times 5.61}{\text{weight of sample used}} \qquad 4$$

Determination of Iodine Value (IV)

Wij's method was applied to determine the iodine value (IV) as reported by Mesfin (2008). About 2g of oil sample was dissolved in 10 ml carbon tetrachloride in a 250 ml conical flask. 20 ml of 0.2N Wij's solution (prepared by dissolving 9 g of iodine trichloride in a mixture of 700 ml glacial acetic acid (purity at least 99%) and 300 ml carbon tetrachloride) was added from a burette. The flask was closed, mixed and allowed to stand in the dark at about 20 - 30 °C for 30min. After standing for 30 min, 15 ml potassium iodide solution and 100 ml water were added. The iodine liberated by the process was titrated with sodium thiosulphate solution while shaking and starch indicator was added towards the end of titration (and volume V_a was recorded). Blank determination was made with the same quantities of reagent at the same time and under the same conditions (and the volume V_b as recorded). Finally the iodine value (IV) was determined using the following formula:

$$\text{Iodine value (IV)} = \frac{(V_b - V_a)1.269}{\text{wt of sample (g)}} \qquad 5$$

where, V_a = volume of thiosulphate solution used in the test, ml

V_b = volume of thiosulphate solution used in blank, ml

Determination of Saponification Values

Method described by Shridhar*et al.,*(2010) was used to determine the saponification value. Two grams of the oil samples was weighed into 250 ml conical flask with accuracy of 1mg. 50ml of 0.5N ethanolic potassium hydroxide solution was added to the cold oil and the reflux condenser attached to the flask. The mixture was heated, and as soon as the ethanol boils, the flask was shaken occasionally until the oil was completely dissolved, 1ml of phenolphthalein indicator was added and the hot soap solution obtained was slowly titrated with 0.5N hydrochloric acid (and volume V_a was recorded). And a blank determination was carried out upon the quantity of potassium hydroxide solution at the same time and under the same conditions (and volume V_b was recorded). The saponification value was calculated as follows:

$$\text{Saponification value (SV)} = \frac{(V_b - V_a)28.05}{\text{wt of sample}} \text{ (Mg KOH/g)} \qquad 6$$

Where, V_a = volume of hydrochloric acid used in the test, ml

V_b = volume of hydrochloric acid used in blank, ml

Determination of Peroxide Value

The method described by Mesfin (2008) was used to determine the peroxide value. Five grams of oil sample was weighed with accuracy to 5mg into a 250ml conical flask. 30ml of the solvent (2 volumes of glacial acetic acid and 1 volume of chloroform) was added and air above the liquid was displaced with carbon dioxide. Then 1ml of the potassium iodide solution was added and a homogenous solution resulted. The solution was allowed to stand in the dark for 1 min, and 30ml water was added. This solution was then titrated with 0.1M sodium thiosulphate solution, using a few ml of starch as indication (the volume V_a recorded). A blank determination was simultaneously run and (the volume V_b recorded). This was repeated three times. The peroxide value was calculated as follows:

$$\text{Peroxide value (PV)} = \frac{1000 \times 0.1\,(Va - Vb)}{\text{Wt of oil sample}} \qquad 7$$

where, V_a = volume of sodium thiosulphate solution used in the test, ml

V_b = volume of sodium thiosulphate solution used in blank, ml

Determination of Refractive Index

The refractive was determined using method described by Akpan *et al.* (2006), Olutoye and Garba (2008) and Shridhar *et al.* (2010): Refractometer (model: RFM 340. Bellingham & Stanley ltd) was used in this determination for each of the castor oil samples, few drops of the oil samples were transferred into the glass slide of the refractometer. Water at 30^o C was circulated round the glass slide to keep its temperature uniform. Through the eyepiece of the refractometer, the dark portion viewed was adjusted to be in line with the intersection of the cross. At no parallax error, the pointer on the scale printed to the refractive index. This was repeated three times and the mean value noted and recorded as the refractive index.

Determination of relative density (Specific gravity)

The relative density was determined using method described by Akpan*et al.* (2006), Olutoye and Garba (2008) and Shridhar*et al.* (2010): A clean and dry density bottle of 25ml capacity was weighed (W_0) and then filled with the oil sample, stopper inserted and weighed to give (W_1). The oil was substituted with water after washing and drying the density bottle and weighed to give (W_2). The expression for specific gravity is:

$$\text{Sp. gr.} = \frac{(W_1 - W_0)}{(W_2 - W_0)} = \frac{mass\ of\ substance}{mass\ of\ equal\ vol.of\ water} \qquad 8$$

WhereW_o = mass of density bottle,(g); W_1 = mass of density bottle and substance, (g) and W_2 = mass of density bottle and water, g

Determination of viscosity

The viscosity was determined using method described by Akpan *et al.* (2006), Olutoye and Garba (2008), Shridhar *et al.* (2010) and Oluwole *et al*., (2015): A clean, dried viscometer with a flow time about 200 seconds for the fluid to be tested was selected. The sample was filtered through a sintered glass (fine mesh screen) to eliminate dust and other solid matters in the liquid sample. The viscometer was charged with the oil sample by inverting the tubes thinner arm into the liquid sample and suction force was drawn up to the upper timing mark of the viscometer, after which the instrument was turned to its normal vertical position. The viscometer was placed into a holder and inserted to a constant temperature bath set at 29^{o}C and allowed for approximately 10 min for the sample to come to the bath temperature at 29^{o}C. The suction force was then applied to the thinner arm to draw the sample slightly above the upper timing mark to the lower timing mark was recorded.

Determination of pH value

Two grams of the oil sample was poured into a clean dry 25ml beaker and 13ml of hot distilled water was added to the sample in the beaker and stirred slowly. It was then cooled in a cold – water bath to 25^{o}C. The pH electrode was standardized with buffer solution and the electrode immersed into the sample and the pH value was read and recorded.

The obtained seeds oil content and oil properties were subjected to analysis of variance (ANOVA) using full factorial design in the Design-Expert statistical package (Stat-Ease Inc. 7.0 USA), and model equations were generated.

RESULTS AND DISCUSSION

The results of experimental and the predicted oil content of the castor seeds is presented in Table 1. It is observed from this table that the GMS gave the highest oil content of 54.5% followed by the GSS, which gave 40.17%, then the WBS which gave 35.5% and the least oil content was observed from the BBS, which gave 29.67%. This may probably be the reason why researchers get different oil contents since they did not specify the varieties of castor seeds used. Table 2 shows the ANOVA table for the oil content. It is revealed from Table 2 that the observed difference of seed oil content with seed variety is significant at 5% level. Figure 2 shows that the experimental (actual) values are close to the predicted values.

Table 1: Experimental and predicted oil contents of the castor seeds

S/No.	Seed Variety Actual	Seed Variety Coded {A_1 A_2 A_3}*	OIL CONTENT (%) Actual	OIL CONTENT (%) Predicted
1	WBS	{ 1 0 0 }	34.50	35.50 ^{c}
2	WBS	{ 1 0 0 }	36.00	35.50 ^{c}
3	WBS	{ 1 0 0 }	36.00	35.50 ^{c}
4	BBS	{ 0 1 0 }	29.00	29.67 ^{d}
5	BBS	{ 0 1 0 }	29.50	29.67 ^{d}
6	BBS	{ 0 1 0 }	30.50	29.67 ^{d}
7	GMS	{ 0 0 1 }	55.00	54.50^a
8	GMS	{ 0 0 1 }	54.50	54.50 ^{a}
9	GMS	{ 0 0 1 }	54.00	54.50 ^{a}
10	GSS	{ -1 -1 -1 }	39.50	40.17 ^{b}
11	GSS	{ -1 -1 -1 }	40.00	40.17 ^{b}
12	GSS	{ -1 -1 -1 }	41.00	40.17 ^{b}

a,b,c,d: means values on the same column with the same superscript are not significantly different (p>0.05)

*where A stands for Seed variety; for WBS, {A_1 A_2 A_3} = {1 0 0}

For BBS, {A_1 A_2 A_3} = {0 1 0};
For GMS, {A_1 A_2 A_3} = {0 01}
And for GSS, {A_1 A_2 A_3} = {-1 -1 -1}

Table 2: ANOVA for Oil Content of castor seeds

Source	**Sum of Squares**	**df**	**Mean Square**	**F Value**	**p-value Prob > F**	
Model	1011.90	3	337.30	622.71	< 0.0001	significant
A-seed Variety	*1011.90*	*3*	*337.30*	*622.71*	*< 0.0001*	
Pure Error	4.33	8	0.54			
Cor Total	1016.23	11				

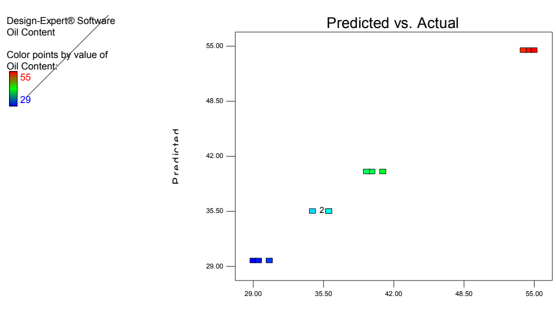

Figure 2: Actual vs Predicted Values of oil Content of Castor Seeds

Multiple Regression Models

Table 3 presents the regression coefficient of oil content model. The negative coefficient term in Equation 9 obtained from Table 3 indicates that the WBS and BBS had negative influence on the oil content, while the positive terms indicates that the GMS and GSS had positive influence on the oil content.

Table 3: Regression coefficient of the oil content

Term	Coefficient Estimate	Df	Standard Error	95% CI Low	95% CI High
Intercept	39.96	1	0.21	39.47	40.45
A_1	-4.46	1	0.37	-5.31	-3.61
A_2	-10.29	1	0.37	-11.14	-9.44
A_3	14.54	1	0.37	13.69	15.39
A_4	0.21	1	0.37	-0.60	1.06

R^2 = 0.9957

Oil content ($\mathbf{O}_C$) = $39.96 - 4.46A_1 - 10.29A_2 + 14.54A_3$ 9

where A stand for the coded value of seed variety (for WBS, values of $\{A_1, A_2, A_3\} = \{1, 0, 0\}$; for BBS = $\{0, 1, 0\}$; for GMS = $\{0, 0, 1\}$ and for GSS = $\{-1, -1, -1\}$.
In order to validate the model developed, the coded terms $\{A_1, A_2, A_3\}$ in equation 43 were substituted with their corresponding values as described above. The model predicted that oil contents of GMS, GSS, WBS and BBS were 54.50, 40.17, 35.50 and 29.67 respectively as expressed in Equations 10 – 13, as presented in Table 1.

Oil content $(\mathbf{O}_C)_{WBS} = 39.96 - 4.46$ 10

Oil content $(\mathbf{O}_C)_{BBS} = 39.96 - 10.29$ 11

Oil content $(\mathbf{O}_C)_{GMS} = 39.96 + 14.54$ 12

Oil content $(\mathbf{O}_C)_{GSS} = 39.96 + 0.21$ 13

Table 4 shows the results of oil properties obtained from four varieties of castor seeds. It is observed from this table that acid value, saponification value and pH value of extracted oil from castor seed varieties indicated significant difference at 5 % level. These results agree with the findings of Adeeko and Ajibola (1989), Olaniyan and Oje (2007) and Olaniyan (2010).

Table 4: Results of the oil properties of castor seeds

	Factors		Response							
S/No.	Seed Variety	Seed Condition	Acid Value	Saponification Value	Iodine Value	Specific Gravity	Viscosity	Refractive Index	pH Value	Peroxide Value
1	WBS	Dehulled	2.00^a	183.43^a	82.33	0.965	1465	1.4773	4.01^b	8.6
2	BBS	Dehulled	1.40^b	180.11^b	84.76	0.956	1430	1.4771	4.01^b	9.6
3	GMS	Dehulled	1.01^c	165.32^d	85.78	0.965	1222	1.4772	4.04^a	4.3
4	GSS	Dehulled	1.40^b	178.69^c	85.23	0.905	1325	1.4774	4.02^{ab}	6.2

In each column, means with the same letters are not significantly different but means with different letters are significant at P ≤0.05

CONCLUSION

In this study, oil was extracted from four varieties of castor seeds using soxhlet extractor, in order to determine the oil content of the seeds. The conclusion derived from this study shows that the GMS had the highest oil content of 54.5%, followed by the GSS (41.17%), then the WBS (35.5%) and the least of 29.67% is from the BBS. The acid value, saponification value and pH value significantly differs while iodine value, specific gravity, viscosity, refractive index and peroxide value show no significant difference at 5% level. This information would be of help to castor oil processors in selecting the appropriate castor seed for commercial purpose.

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COMPARATIVE STUDY OF AFRICAN CAT FISH (*Clarias gariepinus*) PROCESSING METHODS

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ABSTRACT
This study was conducted to determine the various processing methods (oven drying and smoking) method as they affect quality of fish. The fish variety chosen for this study was African Catfish (Clarias gariepinus) because of its abundance in the South Eastern Coast of Nigeria. The fish was bought fresh from a river coast in Itu Local Government Area Akwa Ibom State. The fish was transported in an iced packed container to the Research Laboratory in University of Uyo, Uyo, thereafter it was kept in a refrigerator at -4^{O}C for safe keeping until processing begun. Prior to processing the fish was brought out and allowed to attain equilibrium temperature with the surrounding before processing. The fish samples were then eviscerated, cut into 5cm length of assorted thickness ranging between 3 to 4cm before drying it in a convective air oven. The moisture content, proximate composition and total volatile basic nitrogen of the fresh, oven dried and smoked fish samples were determined. The smoked fish samples were bought from an open market at Akpan Andem market at Uyo, brought to the Research Laboratory of University of Uyo and kept inside a desiccator until the commencement of the various test. These quality parameters were also evaluated for smoked fish bought from the open market. There was decrease in the moisture content of the fresh , oven dried and smoked catfish from 71.74 ± 0.090 % for fresh, 34.80 ± 0.179 % for oven dried and 14.77 ± 0.059 % for smoked catfish) The result shows the mean values of crude protein (18.12 ± 0.241% for fresh, 26.44 ± 0.113 % for oven dried and 39.66 ± 0.451 % for smoked catfish) , fat and oil (5.60 ± 0.141 % for fresh,18.66± 0.071 % for oven dried and 24.85 ± 0.062 % for smoked catfish), ash content (1.30 ± 0.213 % for fresh,1.35 ± 0.042 % for oven dried and 1.74 ± 0.034 % for smoked catfish), The total volatile basic nitrogen (TVNB) of the fresh , oven dried and smoked samples were 4.10 ± 0.063 , 3.24± 0.066 and 3.09 ± 0.100mgN/100gm flesh respectively This implies that although all fish samples dried met the minimum quality standard for fish of not exceeding 30mgN /100gm flesh, smoked fish in this study has a better quality parameter for human consumption when compared with the fresh and oven dried fish samples.

Keywords: *catfish, fresh, smoked fish, oven dried*

INTRODUCTION
Fishes are aquatic "cold blooded" animals. (Eyo, 2001). They live in water with their body temperature changing with the temperature of the surrounding environment**.** Fishes are distinguished from other vertebrate by their possession of permanent gills and fins adapted solely for aquatic life. They belong to the super class *Pisces* and phylum *chordata.* Fishes are aquatic animals that live in water and breathe by means of gills. Other aquatic vertebrates are crocodiles, frog, toad, whales, dolphins and sea turtles. Some aquatic invertebrates such as shrimps, crabs, lobsters and oysters etc also exis in the same environment.

Fish is one of the major animal protein foods available in the tropics. This has made fishery an important aspect of study. According to Olatunde (1989), fish constitutes 40% of animal protein intake in Nigeria; unlike any other animal protein source with one problem of religious taboo or health hazard, fish is eaten across the country. According to Abba (2007), Nigeria has the resource capacity (12 million ha inland water and aquaculture) to produce 2.4 million metric Tonnes of fish every year, with an estimated demand at 1.4 million metric tonnes. If our productive capacity is adequately utilized, the production would outstrip demand with excess product to export Fish protein also provides vital protein constituents which enable the body to carry out certain functions such as growth. Unfortunately, however, fish is one of the most perishable of all stable commodities, and in the tropical climate of most developing countries it will become unfit for human consumption within about one day of capture, unless it is subjected to some form of processing (Ames et al, 1999). As soon as fish dies spoilage begins to set in. This spoilage is accompanied by various physical and chemical changes in the gills, eyes, slime and skin tissues. Microbial activities account for major spoilage in fish (Eyo, 2001). Thus there's the need for processing techniques ranging from sun drying, drying in solar dryers and with mechanical dryers, smoking, salting, freezing and irradiation. Since water is essential for the activity of all living organisms its removal will slow down, or stop, microbiological or autolytic activity and can thus be used as a method of preservation (Clucas, 1982). In traditional method of preserving fish, the action of the sun and wind is used to effect evaporative drying. In recent times, smoking kilns and artificial dryers are used to obtain product of high quality. According to Davies et al; (2009) solar drying produced better quality dried fish compared to that of sun drying due to reduction in insect infestation and other contaminants. Traditionally, fish is not filleted before smoking, but large fish (e.g. catfish) is normally cut into portions the choice of whether fish will be hot-smoked or smoked-dry depends on the type of fish to be smoked and how long the product is going to be stored. Results from previous studies have shown that the hot smoked process takes about 1 -3 hours and yields a product with about 35 - 45 % moisture content, but with a limited shelf-life of 1 - 3 days at ambient temperatures. The smoke-dry process takes about 10 - 18 hours, and sometimes 3 – 4 days and yields fish of 10 - 15% moisture content, sometimes even below 10% with a shelf-life of 3 - 9 months when stored properly. In a study conducted by Davies and Davies (2009), it was reported that six different types of traditional fish processing techniques were in use in the Niger-Delta region of Nigeria. These techniques were characterized with inefficient utilization of fuel wood, poor quality of fish due to lack of control over the temperature of the fire and smoke density, labour intensive and low capacity. Three improved technologies were equally observed in Bayelsa State,Nigeria. They are; drum oven, mud oven, and chorkor kiln. The chorkor kiln proved to be a successful technology with high efficiency in the fuel used, easy to operate and maintained, high product capacity per batch and produces evenly smoked fish which fetches high market value. Ichsani and Wulandari (2002) developed a Solar Dryer combined with kerosene stove to dry Fish. The hybrid solar drying system could be used in all seasons and gives alternative for selecting the source of energy. This drying system was able to provide better product quality than the open sun drying. Bellagha et al, (2002) in their work to determine the drying kinetics and characteristic drying curve of lightly salted sardines *(Sadinella aurita),* reported that higher air temperature produced a higher drying rate and reduced drying period. This was due to the increase of flow rate of heated air to the products and acceleration of water migration from inside to the surface of the fish. Similarly, drying rate increased with increase air velocity but reduced at higher air flow velocities, due to hardening of the fish surface caused by protein modification as a result of the combined effect of heat and salt. Fish weight loss in solar dryer differs in the ecological zones of Nigeria with the North-East recording highest value while the value for weight loss was least in South-South; this was attributed to the influence of relative humidity on drying. Drying method is however dependent on the nature of fish to be dried, size, quantity and consumer requirement in taste, quality and economic considerations although some other reported researches on fish drying vis-à-vis the drying rate and other connecting factors have also been documented, (Chukwu and Shaba, 2009).In literature various methods have been used to process various types of fishes with a wide variety of results. These results show a wide range of moisture content, nutritional content and bacterial load depending on the processing method used. In this work the objective will then be to determine the quality parameters of the two processing methods (oven drying and smoking) of cat fish, obtain results and compare it with the quality standard for dry fish so as to know the most appropriate method of processing it for consumption.

MATERIALS AND METHODS

Sample Collection and Treatment

Fresh sample of African catfish (*Clarias gariepinus),* were purchased from a fisherman at Itu river site in Itu Local Government Area, Akwa Ibom State, Nigeria. The samples were then packed in an iced packed container and transported to Department of Agricultural and Food Engineering laboratory, University of Uyo. The samples were then kept in a deep freezer at -4^{0}C to maintain it freshness before processing for drying. Prior to oven drying, the fresh fish samples were then brought out and kept outside for about 3 minutes to enable its temperature to equilibrate with the environment before preparing it for oven drying. Samples were then taken for moisture content determination and the fish eviscerated, cut into 5cm length with thickness varying from 3 to 4cm for oven drying. The temperature of the oven was set at 80^{0}C and the relative humidity maintained at the prevalent atmospheric condition. The samples were dried until equilibrium moisture content was obtained. The smoked samples were purchased at Akpan Andem Market in Uyo Local Government Area of Akwa Ibom State, Nigeria. The smoked fish samples were then wrapped in aluminium foil and kept inside a desiccator at room temperature in the laboratory before carrying out further test on them.

Quality Assessments of the Fish Samples

The following analysis were carried out on the processed dried and smoked fish samples.
(i) Proximate assessment
(ii) Chemical analysis (Total volatile basic nitrogen)

Proximate Analysis

The proximate analysis was done on the processed samples and were analysed chemically according to the methods described by the Association of Official Analytical Chemist (A.O.A.C, 2002). Initial and final proximate analysis of the smoked and oven dried samples were determined. The parameters determined were crude protein content, moisture content, ash and Nitrogen free extract (NFE).

Crude Protein Content

Crude protein content of the samples was determined by a standard method for analysing protein in fish or fish meal (AOAC, 2005). This consists of three techniques of analysis which include; Digestion, Distillation and Titration
The percentage Nitrogen in this analysis was calculated using the formula:

$$\%N = (Titre\ value\ x\ Normality\ of\ HCl\ x\ Atomic\ mass\ of\ Nitrogen\ x\ Vol\ of\ flask\ x100) / Weight\ of\ sample\ digest\ (mg)\ x\ Vol,\ of\ digest\ (ml) \quad (1)$$

The crude protein content is determined by multiplying percentage nitrogen by constant factor of 6.25

$$Percentage\ crude\ protein\ (\%) = \%N\ x\ 6.25 \quad (2)$$

Crude Fibre Content

The samples were made after digestion of the fish boiled dilute acid to hydrolyse the carbohydrate and protein followed by digestion in dilute alkali to effect saponification of the fat content of the fish. Samples were dried at 100^{0}C overnight, Cooled in desiccators, and weighed (W_1.)(g) Samples were further put in furnace at 600^{0}C for 6 hours, Cooled in desiccators and reweighed (W_2)(g). The loss in weight during incineration represents the weight of crude fibre in the samples.

$$\%Fibre = [\ (W_1 - W_2) / Weight\ of\ sample]x100 \quad (3)$$

Dry Matter and Moisture Content

The sample was weighed into a previously weighed crucible (g) (W_0). The crucible plus sample taken was then transferred into oven set at 105^{0}C to dry for 3 hours. At the end of 3hours the crucible plus sample was removed from the oven and transferred to desiccators, cooled for ten minutes and then weighed and recorded. The crucible plus sample was then transferred back into the oven to dry for 30 minutes. It was removed and transferred to desiccators, cooled and also weighed and recorded. This process was repeated until a constant value was recorded for all samples.

$$Percentage\ dry\ matter\ (\%) = [(W_2 - W_0)/(W_1 - W_0)\ ]x100 \quad (4)$$

Where W_0 is the weight of empty crucible, W_1 is the weight of crucible plus sample and W_2 is the weight of crucible plus oven dried sample.

$$Percentage\ moisture\% = [(\ W_1 - W_2)/(W_1 - W_0)]\ x100\ or\ Moisture\ \ 100\% - \%Dry\ matter \quad (5)$$

Ash Content

The sample was weighed into a porcelain crucible. This is transferred into the muffle furnace set at 600^{0}C and left for 4hours. The crucible and its content were cooled to about 100^{0}C in air at room temperature in desiccators and weighed. The percentage ash was calculated from the formula

$$Ash\ content\ \% = (Weight\ of\ ash\ (g) / Original\ weiht\ of\ sample\ (g))x100 \quad (6)$$

Fat or Oil Extracts

The sample was weighed into in a filter paper and tight with a thread. An empty beaker was weighed and recorded as W_0. The sample was then transferred into the soxhlet extractor; hexane was poured into it until it was completely soaked. The apparatus was set at 100^{o}c for extraction of the fat. The extracted oil, mixed with hexane was poured into the beaker and then transferred to a water bath for evaporation of the hexane. The remaining oil plus beaker was removed, cooled in a desiccator, weighed and recorded as (W_1)(g)
The percentage fat or oil was obtained by the formula below

$$Fat\ content\ \% = [(W_1 - W_0\ ) / Weight\ of\ sample]\ x\ 100 \quad (7)$$

where W_0 = initial weight of dry beaker, and W_1 = the weight of beaker plus oil or fat after extraction

Nitrogen – Free Extract (NFE) Determination

The nitrogen free extract (NFE) calculation was made after the completion of analysis of the crude protein, moisture, ash and on other extract by adding the percentage values on dry matter basis and subtracting them from 100%

$$NFE\ \% = 100 - [(\%\ \ crude\ proein) + \%(crude\ fibre) + \%\ (moisture\ content) + \%\ ash\ content + \%(fat\ and\ oil\ content)] \quad (8)$$

Total Volatile Basic Nitrogen

The fish sample was macerated with 100 ml of tap water and washed into the distillation flask with 200ml tap water, followed by addition of 2.0gm of magnesium oxide (Mg_2O) and few anti bumping agents added to the 500ml recurring flask followed by addition of two drops of screened methyl-red indicator. The apparatus was connected up with

receiving tube dipping below the boric acid solution. The distillation flask was then heated with gas flame from Bunsen burner to enable the mixture to boil for 10minutes (before distillation was carried out) for another 25minutes. The distillate was titrated with 0.1N sulphuric acid (H_2SO_4).
The titre value was multiplied by 14 to obtain total volatile base nitrogen in mg N/100gm sample.

RESULTS AND DISCUSSION
The result of the experiment carried out on the fish samples is hereby presented Tables 1. Table 1 shows the value of proximate composition of fresh, dried and smoked catfish with their mean values and standard deviation.

Table 1: Proximate Composition of fresh, dried and smoked Catfish

	Fresh Cat fish	**Dried Cat fish**	**Smoked Cat fish**
Parameters (%)	**Mean**	**Mean**	**Mean**
Moisture content	71.74 ± 0.090	34.80 ± 0.179	14.77 ± 0.059
Crude protein	18.12 ± 0.241	26.44 ± 0.113	39.66 ± 0.451
Fat and oil extract	5.60 ± 0.141	18.66± 0.071	24.85 ± 0.062
Crude fiber	1.44 ± 0.300	3.25 ± 0.092	3.31 ± 0.015
Ash content	1.30 ± 0.213	1.35 ± 0.042	1.74 ± 0.034
N.F.E	1.80 ± 0.014	3.10 ± 0.092	3.17 ± 0.031

The fresh catfish also recorded lower average in the crude protein and fat extract probably because the fat and protein had not condensed due to the high moisture content. Similar results were obtained by Kumolu-Johnson et al; (2010) who worked on *Clarias gariepinus*. He found that fat and protein content of fresh fish were lower than that of dried fish due to the high moisture content of the sample. The average ash content of fresh catfish was found to be 1.30 ± 0.213%. Nitrogen free extract had an average of 1.80 with a standard deviation (sd) of 0.014 which is in line with the findings of Ahmmed et al., (2011) who found that for tilapia fish, nitrogen free extract had a value 1.72 0 ± 0.018% .
The proximate composition of oven dried catfish had a mean moisture content of 34.80 ±0.179% , indicating about 50% decreased in the moisture content of fresh fish. The recorded values showed a gradual reduction in moisture content due to the processing method to enhance fish preservation. Sablani et al; (2002) reported that oven-drying produced better quality dried fish compared to that of sun drying due to reduction in insect's infestation and other contaminants. The reduction in the moisture content during oven drying leads to increase in the percentage of total protein, lipid and ash content. Similar finding was also reported by Egbal et al; (2010) who worked on *Oreochromis niloticus* (Tilapia). From the result one can observe that the moisture content of oven dried fish is higher than that of smoked fish and hence will have a limited time for storage when compared with that of smoked fish. Other proximate composition such as crude protein, fat and oil extract, crude fiber, ash and nitrogen free extract (NFE) had values higher than that of fresh cat fish but a little lower than that of smoked catfish.
The proximate composition of smoked catfish had a mean value of 14.77 %. ±0.059. This shows about 90% reduction in the moisture content of fresh catfish. A significant change was observed in the dried fish in term of changes in appearance, taste and smell. Similar finding was reported by (Bruhiyan et al; 1986, who worked on fresh and smoked *Atlantic mackerel*. It was found that as the moisture content approaches equilibrium value of 15% wb there will be changes in colour, flavor appearance, taste and smell. A similar observation was also made by Kolodziesjka ,2002 who worked on sensory quality of hot smoked *mackerel.* Yanar 2007 worked on quality changes of hot smoked catfish during refrigerated storage and found a similar trend in terms of organoleptic property changes. The increased in the protein, lipid and ash content was due to increased water loss during smoking. The protein content had a mean value of 39.66 ± 0.451% fat was 24.85 ± 0.062% and Similar findings were reported by Egbal et al; (2010) who worked on *Oreochromis niloticus* (tilapia)and *Clarias lazera fish*

Table 2: Total Volatile Basic Nitrogen (TVBN) of Catfish

Sample	Mean (mgN/100gm)
Fresh	4.10 ± 0.063
Oven dried	3.24± 0.066
Smoked	3.09 ± 0.100

Table 2 shows the Total Volatile Basic Nitrogen (TVNB) of fresh, oven dried and smoked catfish. From the table, fresh catfish recorded the highest TVBN value followed by the values of oven dried while the smoked catfish recorded the least values. A TVBN value exceeding 30mgN/100g of sample is indicative of fish spoilage (Pearson, 1973). This is the minimum standard for estimating fish quality standard for consumption. The result shows that fresh fish has TVBN value of 4.10 ± 0.063 mgN/100g of fish flesh, oven dried cat fish has a value of 3.24± 0.066mgN/100g and whereas smoked fish has a value of 3.09 ± 0.100mgN/100g of fish flesh. It could be observed that though the samples have not gone bad judging from the minimum quality standard for fish, the fish sample with highest quality is smoked catfish.

From this result it could be seen that all the fish samples tested met the stipulated quality standard of not exceeding 30mgN/100g of flesh suitable for human consumption.

CONCLUSION

This study clearly indicates that the proximate values obtained could be useful at enabling consumers choose fish based on their nutritional values, besides providing an up to date nutritional qualities of food consumed. However, different nutritional components of fish changes with respect to the method of processing. Oven drying and smoking could improve the protein content though quality could be compromised alongside other vitamins and prevents lipid oxidation in fishes. From the work it has been found that smoked cat fish has a better quality standard in terms of TVBN when compared with fresh and oven dried catfish. In a similar manner, the smoked catfish has the lowest moisture content with the highest proximate composition necessary for consumption.

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PROSPECTS AND CHALLENGES OF LIQUID-LIQUID SEPARATION IN NIGERIAN FOOD AND PHARMACEUTICAL INDUSTRIES USING PERVAPORATION TECHNOLOGY

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ABSTRACT

Efficient separation processes are needed to obtain high grade products in food and pharmaceutical industries. This has prompted the adaptation of such advanced separation techniques that were utilized as analytical tools in chemical and biochemical laboratories as Microfiltration (MF) and Ultrafiltration (UF), Reverse Osmosis (RO), Electro osmosis, Electrophoresis, Electro dialysis (ED) and Pervaporation technology (PVT)for application in liquid-liquid separation in the industries. Of these advance separation techniques, pervaporation technology has been shown to be a more efficient membrane process for liquid separation. In its industrial application, pervaporation can be used for solvent purification, reuse and recovery (thus enabling green process design for the environment and energy efficient). In spite of its wide application in food and pharmaceutical industries, pervaporation technology has not been shown to have found industrial application in Nigeria, hence the need to discuss the technology as one of the methods of advance separation techniques that should be utilized in the country's food and pharmaceutical industries. The past decades witnessed substantial progress and exciting breakthroughs in both the fundamental and application aspects of pervaporation technology. The focus of this paper was on examining the fundamentals and research progress of pervaporation technology and discussing the prospects and challenges that could face its application in the Nigerian food and pharmaceutical industries. The technology is environmentally friendly and has high separation efficiency for example in bioethanol dehydration, very low energy requirement, but very high installation costs. The paper suggests that research into the application the technology in Nigeria should be given high priority.

***Keywords**: Pervaporation technology, liquid-liquid separation processes, Bioethanol, membrane separation, Nigeria.*

INTRODUCTION

The separation, concentration, and purification of molecular mixtures are major problems in chemical industries. Efficient separation processes are also needed to obtain high-grade product in food and pharmaceutical industries to supply communities and industry with high quality water, obtain high grade biofuels and remove toxic or recover valuable components from industrial effluents. A multitude of separation techniques such as distillation, precipitation, crystallization, extraction, adsorption, and ionic exchange are in use (Smitha *et al.,* 2004). More recently these conventional separation methods have been supplemented by a family of processes that utilize semi-permeable membranes as separation barrier.

Membrane and membrane separation processes were first introduced as an analytical tool in chemical and biochemical laboratories. They developed rapidly into industrial methods and processes with significant technical and commercial impacts (Lonsdale, 1982; Baker, 2004). Today membranes are used to produce portable water from sea and brackish water, to clean industrial effluents and recover valuable constituents, concentrate, purify or fractionate macro-molecular mixtures in the food and pharmaceutical industries, and to separate gases and vapors in petro-chemical industries. They are also key component in energy conversion and storage system, in chemical reactors, artificial organ and in drug delivery devices.

The membranes used in the various applications differ widely in structure, function, and the way they operate. However, all membranes have several features in common that make them particularly attractive tools for the separation of mixtures, and the most important is the fact that the separation is performed by physical means at ambient temperature without chemical alteration of the constituents of the mixture (Asada, 1991). This is mandatory for the application in artificial organ and many drug delivery systems as well as in the food industry or in downstream processing of bio products where temperature-sensitive substances must often be handled. Furthermore membrane properties can be tailored and adjusted to specific separation task, and membrane processes are often technically simpler and more energy efficient than conventional separation techniques. They are equally well suited for large scale continuous operation as for batch-wise treatment of very small quantities (M'nif*et al.*, 2007).

Pervaporation is one of the types of membrane separation technique and it has found use in such application areas as water purification, chemical and food processing, drug delivery, biofuel dehydration and medical treatment. It is a membrane separation technology that can be used for the concentration of volatile compounds with the advantage of operating at moderate temperatures and pressures. It is a technique in which a liquid mixture can be separated by partial vaporization through a non-porous selective membrane. The driving force for the mass transfer is a chemical potential gradient established by applying a difference in partial pressure across the membrane (Karlsson and Tragardh, 1996).

In spite of its wide application in food and pharmaceutical industries, the pervaporation technology was not found cited in literature as being of industrial application in Nigeria, hence the need to discuss the technology since it is one of the advanced separation techniques that need to be applied to the food and pharmaceutical industries in the country. The aim of this study therefore was to discuss pervaporation technology as one of the advanced separation techniques, examine its industrial applications, and determine its prospects and challenges for application in Nigerian food and pharmaceutical industries.

LIQUID-LIQUID SEPARATION

Processes involving liquid- liquid separation occur in a wide number of operations in the food and pharmaceutical industries. Examples are dehydration of ethanol, acids, syrups, biodiesel, purification of water by removal of organic compounds (Shao and Huang, 2007), concentration of fruit juice and recovery of organic compounds from waste water (Lipnizki and Field, 1999) to mention a few. Whereas the separation strategies adopted by these industries follow the conventional processes such as distillation, crystallization, drying, and so forth, the formulation of new products may entail that these industries' handling of liquid- liquid separation needs would require special strategies for the separation and purification of desired product (Koros, 1995). The separation strategy adopted is extremely important from economic and health point of view. Mostly these special strategies utilize membrane separation technologies

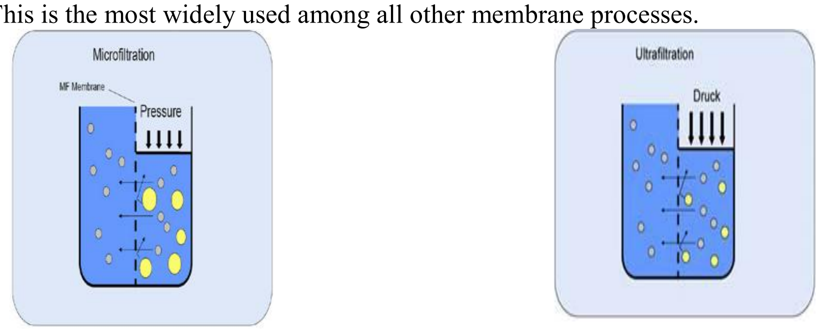
The suitability of a separation technique depends on number of factors that includes: improved selectivity, improved energy efficiency, development of new process configurations and integration, economic viability, environmental safety and compatibility and sustainability (Asada, 1991).

TYPES OF MEMBRANE SEPARATION IN FOOD AND PHARMACEUTICAL INDUSTRIES

Some of the membrane separation techniques usually employed in the food and pharmaceutical industries include Microfiltration and Ultrafiltration (MF and UF), Reverse Osmosis (RO), Electrodialysis (ED), Electrophoresis and Electroosmosis.

Microfiltration and Ultrafiltration (MF and UF)

This is a process for separating materials that are colloidal in nature from true solutions using polymeric membranes (Figure 1a and 1b). It is used for purification of aqueous streams, concentration, purification, and recovery of valuable products. This is the most widely used among all other membrane processes.



(a) (b)

Figure 1: Membrane filtration setups, (a): Microfiltration and (b): Ultrafiltration (*Source: Lipp et al. 2005*)

The membrane filtration process has been largely used in water treatment for treating natural water, drinking water (Bottino *et al.*, 2001), wastewater, reservoir water (Lipp *et al.*, 2005) and oily water (Mueller *et al.*, 1997). The technique has also been exploited for the treatment of algae-rich water (Liang *et al.*, 2008), the removal of virus from water and wastewater (Madaeni *et al.*, 1995), and the removal of colloids and natural organic matter from surface water (Tsai *et al.*, 2011). Several efficient water-treatment technologies that combine the MF/UF process along with other processes like precipitation (Zhang *et al.*, 2008), electroperoxidation (Drogui *et al.*, 2001), ozonation (Schlichter *et al.*, 2004), and photo oxidation (Malek *et al.*, 2006), have also been developed. In the food processing industry, membrane filtration is used for processing dairy products (Morin *et al.*, 2007), honey (Barhate *et al.*, 2003), fruit/vegetable juice (Vaillant *et al.*, 2001, Mondal*et al.*, 2011), clarification of wine, and decolourization of sugarcane solution (Hamachi *et al.*, 2003). The technique is also used for the recovery of biomolecules like proteins, enzymes, vitamins and carbohydrates from milk products (Nelson and Barbano, 2005, Kosikowski and Mistry, 1990), vegetable oils (Wu *et al.*, 2007), fishery products (Afonso and Bórquez, 2002), poultry processing wastewater (Lo *et al*., 2005), fermentation products and peels of citrus fruits.

Reverse Osmosis (RO)

This is a liquid/liquid separation process that uses a dense semipermeable membrane, highly permeable to water and highly impermeable to microorganisms, colloids, dissolved salts, and organics (Figure 2). This is the first membrane-based separation process to be widely commercialized. The technique is largely used for water treatment (Molina and Casañas, 2010) for namely, production of demineralized or potable drinking water, desalination of seawater and brackish water, pure boiler water makeup in industrial fields, and in food processing industries for process effluent and wastewater treatment and reuse.

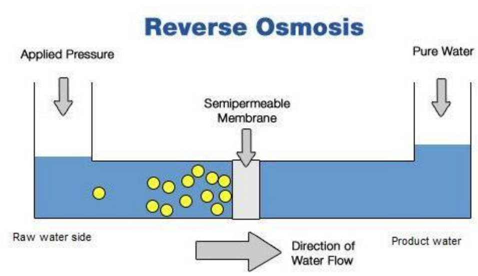


Figure 2:Reverse Osmosis setup, (*Source*: *Wang and Tarabara, 2007*)

The largest single application area of reverse osmosis is desalination of seawater and brackish waters (Schrotter *et al.*, 2010). Cellulose acetate membranes and thin-film composite membranes made from aromatic polyamides (Duan *et al.*, 2010) are widely used for this purpose. Several pretreatment methodologies like flocculation/precipitation, MF/UF (Kruithof *et al.*, 1998), nanofiltration (M'nif*et al.*, 2007), adsorption, electrocoagulation (Prihasto *et al.,* 2009) of seawater prior reverse osmosis have been applied to increase the membrane life by reducing membrane fouling. RO separation of seawater and brackish water containing high total dissolved solid (TDS) is considered to be less energy consuming than electro dialysis. It has also been used to remove boron from water (Tu *et al.*, 2010). Other applications of reverse osmosis separation technique include purification of lactic acid from fermentation broth (Liew *et al.*, 1995), separation of organic/inorganic compounds from their aqueous solutions (Liu *et al.*, 2008), separation of organics from multicomponent mixtures (Weißbrodt *et al.*, 2001).

Electrodialysis (ED)

This is an electrochemical separation process by which ionic species are separated from an aqueous solution (Figure 3) or from other uncharged components using electrically charged membranes under the driving force of electrical potential difference.

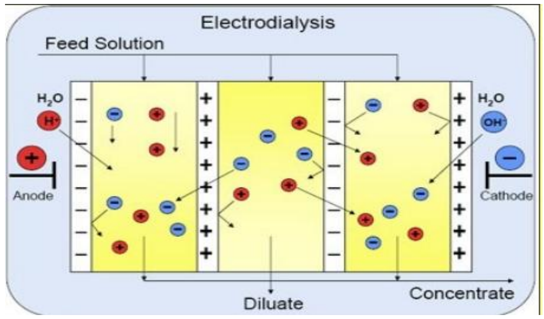


Figure 3: Electrodialysis setup, (*Source: Bazinet and Moalic, 2011*)

The most important industrial application of electrodialysis is in the production of potable water. This technique is widely used for the removal of dissolved metal ions and solids from industrial processed/waste streams and concentration of metal ions from their solutions (Nataraj *et al.*, 2007). The removal of inorganic contaminants like fluoride, nitrate (Hell *et al.*, 1998), and boron, from dilute aqueous streams are also performed by electrodialysis method (Banasiak and Schäfer, 2009) through different ion-exchange membranes (Sata, 1994). It has been utilized in the concentration and separation of salts (Demircioglu *et al.*, 2003), acids (mineral and organic) (Rohman *et al.*, 2010) and bases from aqueous solutions, separation of monovalent ions from multiple charged components (van der Bruggen *et al.*, 2004), and separation of ionic compounds from uncharged molecules (Vyas *et al.*, 2001). Due to the diversity and practicability of the technique, it can be a versatile tool to meet specific needs from chemical (Habe *et al.*, 2009), food (Atungulu *et al.*, 2007) and pharmaceutical industries. A modified form of electrodialysis with ultrafiltration membrane has been developed and used to separate valuable biomolecules (Firdaous *et al.*, 2009) on the basis of their electrical charge and size or molecular weight. In this process, the conventional electrodialysis cell is used with some of its ion exchange membranes are replaced with ultrafiltration membranes (Bazinet and Moalic, 2011). This enables compounds of higher molecular weight than the membrane cut-off to be separated and so extends the field of application of electrodialysis to biological charged molecules.

Electrophoresis

Electrophoretic separation is one of the major techniques for molecular separation in the cell biology laboratory for analytical purposes. It is an inexpensive and powerful technique for separation at the molecular level. Electrophoretic separation technique is based on the differential migration of electrically charged particles in an electric field (Figure 4). The technique is applicable only to ionic or ionogenic materials (Zhai *et al.*, 2001). The media used in biochemical applications are usually aqueous solutions, suspensions or gels.

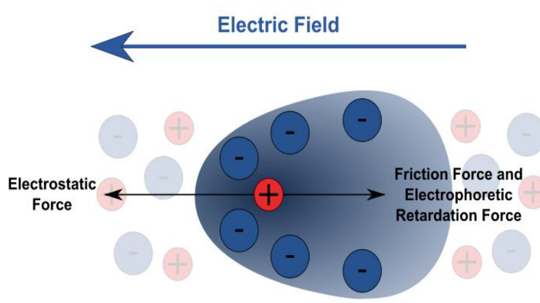


Figure 4: Electrophoresis setup, (*Source: Zhai et al., 2001*)

Zone electrophoresis is characterized by the complete separation of charged solutes into separate zones. Many of the earlier separations of this type were carried out using filter paper in durum cell. Capillary electrophoretic technique has been used for the separation of DNA and proteins in biotechnology and cell-biology applications (Piergiovanni, 2007). Prior to dramatic improvements in chromatographic techniques, continuous electrophoresis was popular for purifying proteins such as enzymes and amino acids. Electrophoresis is still invaluable on an analytical scale, but large scale electrophoretic separations were not established because the technique does not translate well to large sizes, mainly because of the difficulties to remove the generated heat during the separation and also because the process is very slow (Gübitz and Schmid, 2001).

3.5 Electroosmosis

Electroosmosis, also called electroendosmosis, is the motion of polar liquid through a porous membrane or any other porous structure under the influence of an applied electric field (Figure 5). If a solution is separated by a porous diaphragm and an e.m.f. is applied between the electrodes placed on each side of the diaphragm, there will be a flow of liquid from one side to the other. The movement of liquid is also known as electroosmotic flow (Herr*et al.*, 2000).

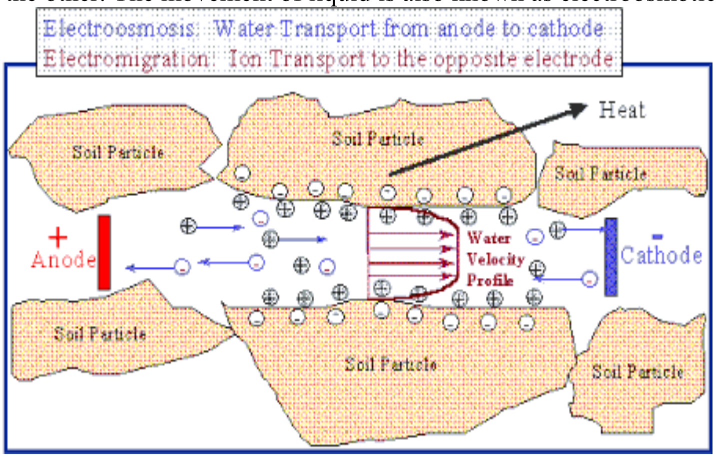


Figure 5: Electrosmosis setup, (*Source: Zhaiet al., 2001*)

Electroosmotic separation technique has industrial importance for separation of water from colloidal suspensions as it consumes less energy than the conventional technique like evaporation. The most recent development in this technology has involved enhanced mixing efficiency by introducing a non-uniform zeta potential, and the enhancement in mixing was experimentally observed by Herr *et al.* (2000). The purified water was claimed to be equivalent to distilled water and could be obtained at a much lower cost. Electroosmotic separation technique was applied along with vacuum separation technique for the separation of iron oxide ultrafines (Grant *et al.*, 1992).A sludge (water treatment process sludge) treatment method by electroosmotic dewatering was proposed by Buijs *et al.* (1994). Al-Asheh *et al.* (2004) reported the use of direct current electroosmosis dewatering technique to concentrate tomato to the conventional paste suspension. The process was claimed to save 70% of energy as compared to the evaporation technique. The electroosmotic technique has been used by several researchers for removing water soluble organics from soil for soil remediation purpose (Schultz, 1997) and dewatering of filter cakes of activated sludge (Laursen and Jensen, 1993).

PERVAPORATION TECHNOLOGY

The first report in the area of pervaporation was published as early as in 1906, concerning the hydrocarbon–alcohol solutions' selective transport across a thin rubber sheet. In 1917, the term pervaporation was presented by Kober in his article about selective permeation of water through colloidion (also known as cellulose nitrate) bags. During the 1950s and 1960s, attempts were made to commercialize pervaporation, but the first successful industrial-scale application obtained in 1982 was an alcohol dehydration plant by Gesellschaft Für Trenntechnik (GFT) (Néel, 1991). Nowadays, industrial pervaporation plants are in operation at least for ethanol dehydration, the recovery of volatile organic compounds (VOCs) from water and the separation of organic compounds and mixtures (Baker et al., 1997).

Principles of Pervaporation

Pervaporation is a process in which a liquid stream containing two or more miscible components is placed in contact with one side of a non-porous polymeric membrane or molecularly porous inorganic membrane(such as a zeolite membrane) while a vacuum or gas purge is applied to the other side. The components in the liquid stream sorb into/onto the membrane, permeate through the membrane, and evaporate into the vapor phase (hence the word 'pervaporate'). The resulting vapor, referred to as 'the permeate' is then condensed. Due to different species in the feed mixture having different affinities for the membrane and different diffusion rates through the membrane, even a component at low concentration in the feed, can be highly enriched in the permeate. Thus, the permeate composition may widely differ from that of the vapor evolved after a free vapor–liquid equilibrium process. A schematic diagram of the pervaporation process is shown in Figure 6. As depicted in the Figure, by separating the extracting vapor phase from the feed liquid with a membrane which is selective for Species 1, the permeate vapor is enriched in Species 1 relative to the feed liquid.

The main process units of a pervaporation process: the feed source, feed pump, heater, membrane module, condenser, and vacuum pump, are pictorially shown in Figure 7.The properties of the membrane material dictate the separation achieved in the process. For example, if the membrane is hydrophobic, then the membrane will preferentially permeate organic compounds relative to water and the permeate will be enriched in the organic compounds. Alternatively, if the membrane is hydrophilic, then water will be enriched in the permeate and the organic compound in the feed liquid will be dehydrated. The general process components are the same, only the membrane material has been changed. The dehydration of organic solvents, particularly those which form azeotropes with water (such asethanol and isopropanol) is the main commercial use of pervaporation today (Jonquieres *et al.*, 2002).

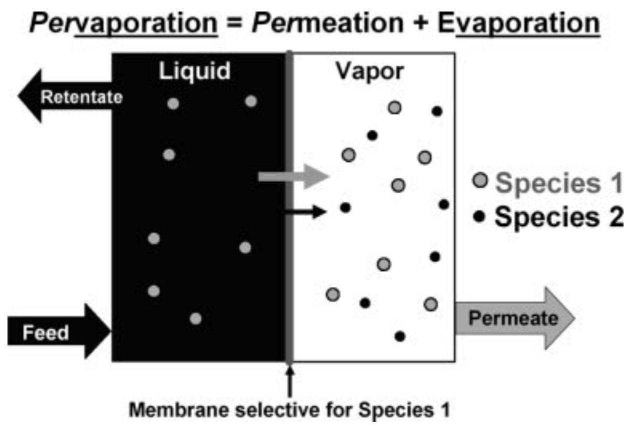


Figure 6: Schematic diagram of pervaporation process, (*Source: Vane, 2005*)

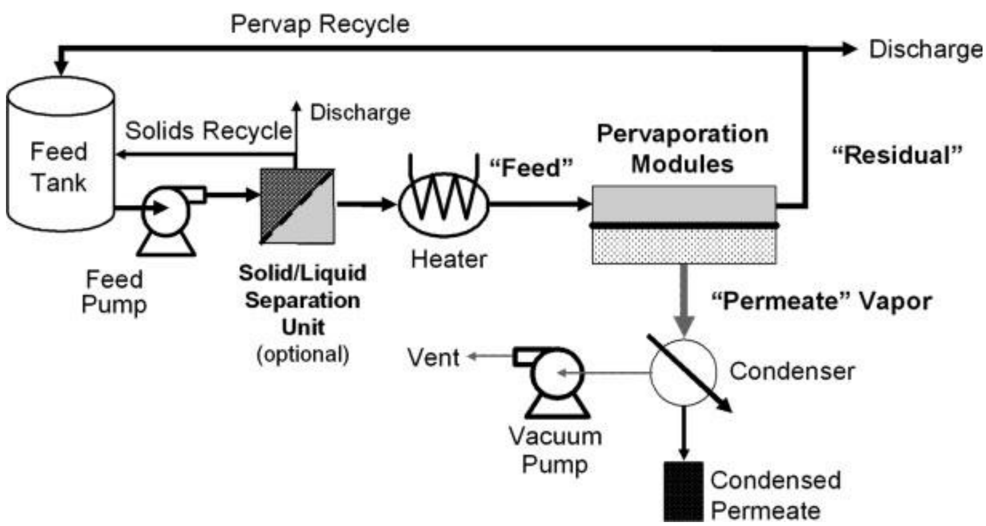


Figure 7: Flow diagram for generic pervaporation system, (*Source: Vane, 2005*)

Lipnizki *et al.* (1999) already reported that pervaporation can be classified into three main areas depending on the permeating component as hydrophilic (for separating compound water from aqueous-organic mixtures like breaking of azeotropes of binary mixtures and dehydration of multi compound mixture), hydrophobic (for separating organic compound from aqueous-organic mixtures like removal of beer from water and recovery of aromatic compound in food industries) and organophilic (for separating organic compound from organic–organic mixtures like separating ethanol from ethyl tetra-butyl-ether (ETBE) and separating of benzene and cyclohexane) (Figure 8). In the dehydration application, pervaporation competes with molecular sieve sorption and ternary or vacuum distillation. For the production of biofuels, pervaporation can therefore be applied to both the recovery of alcohols from water and for the dehydration of the alcohols to meet fuel dryness specifications. According to ASTM standardD4806, the maximum amount of water allowed in fuel ethanol is 1 vol% (0.8 wt %), (Vane, 2005). The driving force for transport across the membrane in pervaporation is the chemical activity difference of a species between the bulk feed liquid and the bulk permeate vapor. The mass transport across the membranes involves three successive steps: (i) Upstream partitioning of the feed components between the flowing liquid feed and the upstream surface layer of the membrane. (ii) Diffusion of the components through the membrane. (iii) Desorption of the components at the permeate side of the membranes (Nagai, 2010). A typical pervaporation set up is shown in Figure 9.

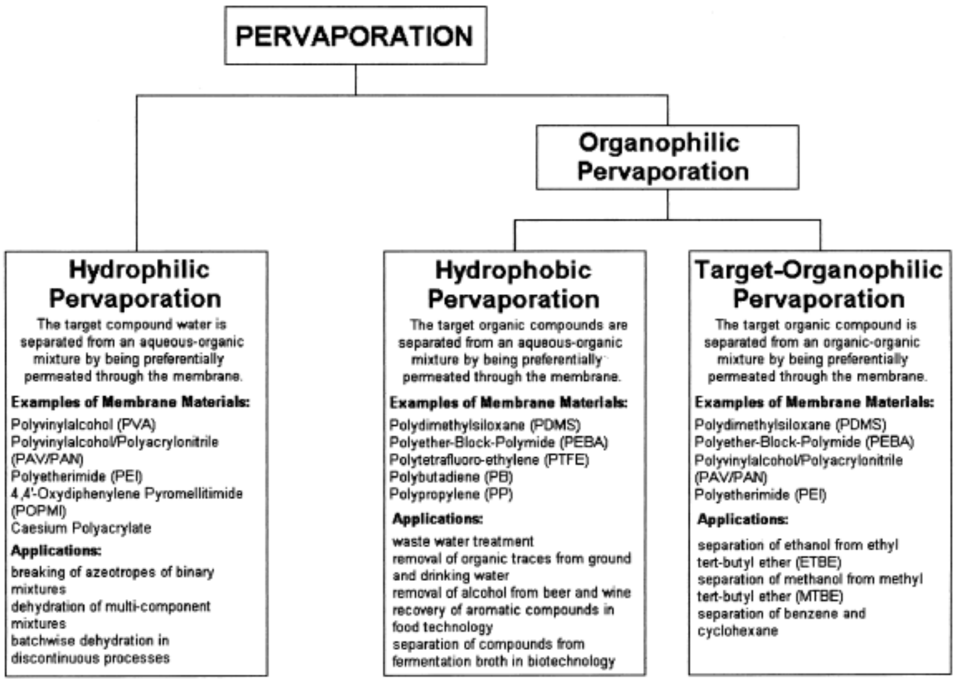


Figure 8: Area of pervaporation membrane and application, (*Source: Lipnizkiet al., 1999*)

Figure 9: Pervaporation setup, (*Source: Wang et al., 2007*)

Pervaporation can be considered the so-called "clean technology," especially for the separation of volatile organic compounds (Hitchens *et al.*, 2001, Peng *et al.*, 2003). The technology is highly used for the separation of organics like aliphatic and aromatic alcohols, acids, benzene, toluene, tetrahydrofuran, ethylene glycol, \from dilute aqueous solutions (Hasanoğlu *et al.*, 2007). It is also extensively used for the separation of organic/organic mixtures (Smitha, 2004), organic azeotropic mixtures (Hasanoğlu, 2005) and isomers (Chen *et al.*, 2000). The technique has been studied for the recovery of natural aroma compounds in the food industry.

It differs from pressure-driven membrane separation processes involving porous membranes, such as microfiltration, where the general separation concept is primarily based on molecular size exclusion. It is a process very similar to vapour permeation, the only difference being that in the latter the feed is not liquid, but a vapour. It should, however, be clearly distinguished from membrane distillation (Lipnizki *et al.*, 2002) in which a porous membrane is in contact with a liquid feed, and feed components evaporate through the membrane pores. In this case, the membrane polymer does not have any selective impact on the solute transport, but merely serves as a mechanical barrier (Hasanoğlu, 2005). Pervaporation membrane separation can be considered as one effective method and energy-saving process for the separation of the ethanol/water azeotropic system (Huang *et al.*, 2008; Huang and Rhim, 1991; Shao and Huang, 2007 and Wang *et al.*, 2007). It should be noted that the role of the vacuum in pervaporation is merely the efficient desorption and removal of solutes from the membrane downstream surface, hence maintaining the driving force of the process (Zhang and Drioli, 1995).

Types of Pervaporation Membranes

Pervaporation membranes are dense homogeneous media which allow separationto occur. The membranes most commonly used are the asymmetric, composite and hollow fiber membranes. The asymmetric membrane has the structure and flat sheet configuration shown in Figure 10. It combines very thin and highly selective separation layers with rigid, mechanically and thermally stable backing layers(Huang *et al.*, 2008, Feng and Huang, 1997).

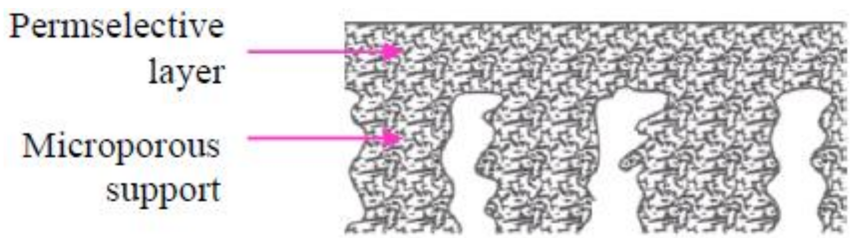


Figure10: Structure of an asymmetric membrane, (*Source: Feng and Huang, 1997*)

The structure of a composite membrane consists of a selective layer and a substrate made from different materials (Figure11). Composite membranes are capable of combining the properties of different materials. Their permselectivity, mechanical stability and strength also depend on those of the different materials (Feng and Huang, 1997). Composite membranes are typically prepared by first casting the microporous support, followed by deposition of the selective dense layer on top of the support by casting, coating or in situ polymerization.

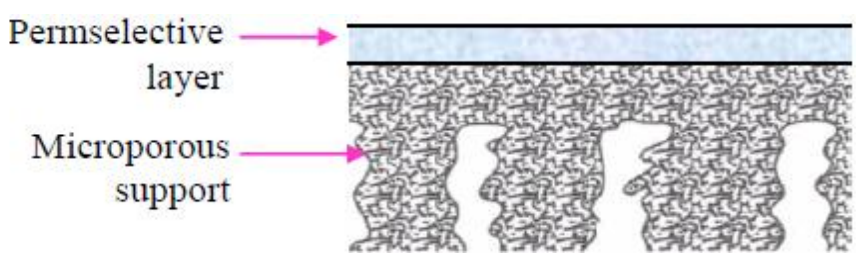


Figure 11: Structure of a composite membrane, (*Source: Feng and Huang, 1997*)

Hollow fiber membranes have the advantages of large surface to volume ratio, high packing density, and mechanical self-supporting properties (Figure12). Although hollow fiber membranes are very popular in many other membrane processes, its utilization in pervaporation membranes has been far behind that of polymeric flat membranes. This may be due to (1) the permeate pressure build up at the lumen side which normally leads to a significant decrease in the driving force; (2) the free-standing hollow fibers may exhibit more severe swelling than flat membranes cast on non-woven fabrics (Liu *et al.*, 2005).

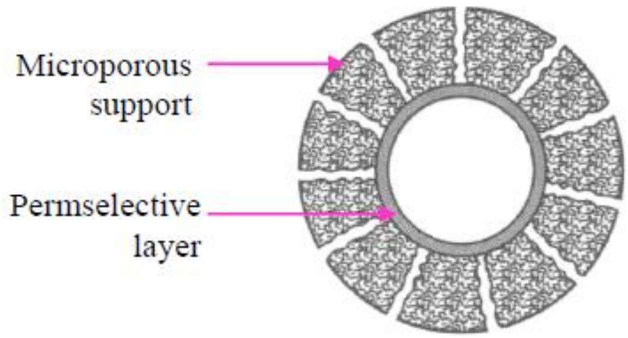


Figure 12: Structure of a hollow fiber membrane, (*Source: Feng and Huang, 1997*)

The membranes used in pervaporation process are classified according to the nature of the separation being performed.

Pervaporation Membrane Separation Modules

The application of membrane pervaporation technology in liquid-liquid separation requires the development of high quality membrane modules. The earliest designs were based on simple filtration technology and consisted of flat sheets of membrane held together in a type of filter press. This arrangement formed the basis of the plate-and-frame modules. Systems containing a number of membrane tubes were then developed, and the spiral-wound and hollow-fiber modules became introduced later (Huang *et al.*, 2008; Huang and Rhim, 1991). Spiral-wound and hollow-fiber modules widened the industrial application of this technology and dominated commercial market for quite a long period. However, recently, new generation of plate-and-frame pervaporation modules was developed for some special applications. The refined design and new manufacturing techniques made the new plate-and-frame configurations to become more competitive than the system used to be (Huang and Rhim, 1991).

Plate-and-Frame Modules

Plate-and-frame modules were among the earliest types of membrane systems and the design has its origin in the conventional filter-press and used stainless steel. Membrane feed spacers and product spacers are layered together between two end plates (Figure13). Many plate-and-frame units developed for small-scale applications were expensive, compared with their alternatives. The leaks caused by the many seals were another serious problem. Another disadvantage was that the plate-and-frame design gave the lowest surface area/unit-volume ratio (Huang and Rhim, 1991).

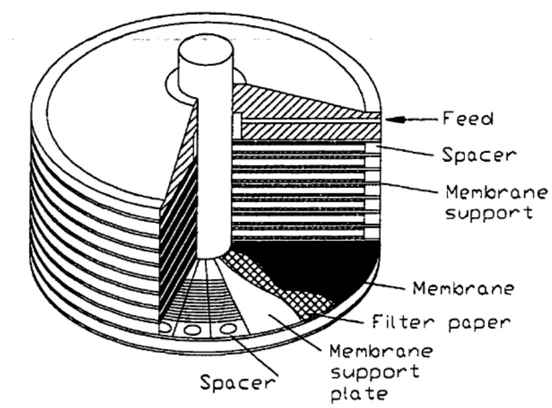


Figure 13: Plate-and-frame module, (*Source: Huang and Rhim, 1991*)

Hollow-Fiber Modules

Hollow-fiber membrane modules are formed in two basic geometries. The first is the closed-end design (Figure 14) and used, for example, by Monsanto in their gas separation systems or Dupont in their reverse osmosis fiber systems. In this module, a loop of fiber or a closed bundle is contained in a pressure vessel. The system is pressurized from the shell side and permeates pass through the fiber wall and exits via the open fiber ends. This design is easy to make and allows very large fiber membrane areas to be contained in an economical system. Because the fiber wall must support a considerable hydrostatic pressure, the fiber usually have small diameter in the order of 100μmID and 150-200μmOD (Feng and Huang, 1997).

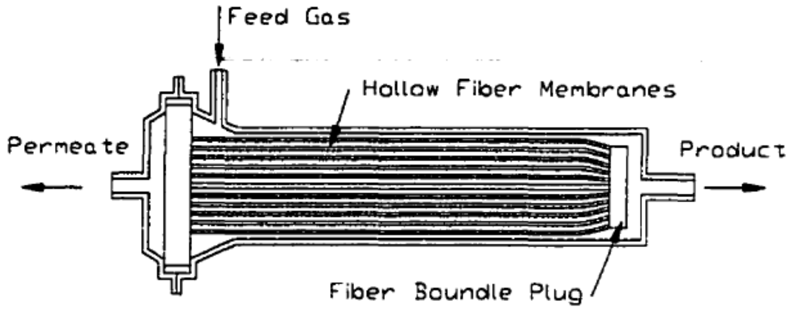


Figure 14: Hollow fiber module (type 1), (*Source: Feng and Huang, 1997*)

The second type of hollow-fiber module is the flow through system (Figure 15). The fibers in this type of unit are open at both ends. In this system, the feed fluid can be circulated on the inside of the fibers. The fibers often have larger diameters than the very fine fibers used in closed loop systems (Feng and Huang, 1997). These so-called spaghetti fibers are used in ultra-filtration pervaporation and in some low to medium pressure gas applications, with the feed liquid circulated through the lumen of the fibers. Feed pressures are usually limited to less than 150psig in this type of application.

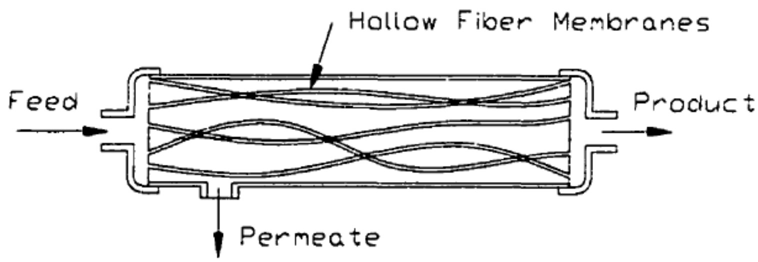


Figure 15: Hollow fiber module (type 2), (*Source: Huang and Rhim, 1991*)

Spiral-Wound Modules

The design shown in Figure 16is the first and simplest design consisting of a membrane envelope wound around a perforated central collection tube. The wound module is placed inside a tubular pressure vesse1 and feed gas is circulated axially down the module across the membrane envelope, where it spirals towards the centre and exits via the collection tube. The major problem for this module is the large pressure loss, especially with high flux membranes. Spiral-wound modules are the more widely used configuration throughout the industry (Huang and Rhim, 1991).

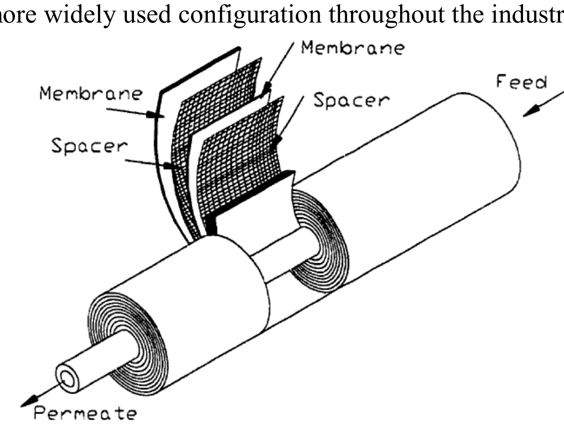


Figure 16: Spiral wound module, (*Source: Huang and Rhim, 1991*)

Tubular Module

Tubular modules consist of several hollow thin-walled porous tubes that are arranged in the configuration shown in Figure 17. Their initial cost is usually high but this is normally offset by the benefit of resistance to membrane fouling because of good fluid hydrodynamics (Huang and Rhim, 1991). This makes them to be preferably used in many industrial pervaporations setups.

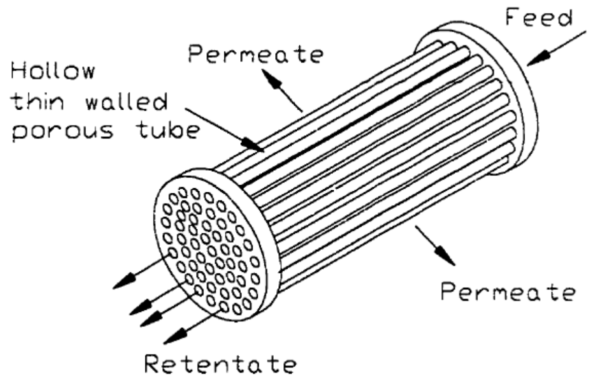


Figure 17: Tubular module, (*Source: Huang and Rhim, 1991*)

Evaluation of Pervaporation Efficiency

The efficiency of pervoporation separation is determined by properties of the volatile organic compound being targeted, the membrane and operating variables and condition. The evaluation and understanding of pervoporation operating variables is critical for volatile organic compound removal from water. These variables include permeate pressure, feed temperature and concentration, module geometry and liquid feed velocity. A change in one parameter can result in a change in separation efficiency (Peng *et al.*, 2003).

Flux and Separation Factor (Selectivity)

The behavior and effectiveness of separation of a pervaporation membrane used to separate a binary liquid mixture can be characterized by two parameters namely: the permeate flux"*J"* (g/m^2-h) and the separation factor "α".These are mathematically defined as follows (Weihuaxu, 2001):

$$J = \frac{w}{m\,t} \qquad (1)$$

and

$$\alpha = \frac{Ya/_{Yb}}{Xa/_{Xb}} \qquad (2)$$

where: w in equation 1 is the weight of the permeate, m is the membrane area and t is the permeation time. In equation 2, y and x are the concentration of components 'a' and 'b' in the permeate and feed respectively. The permeate flux J through the membrane is defined as the amount of permeate per effective membrane area and time (Weihuaxu, 2001). The separation factor is the concentration ratio of two components in the permeate divided by the ratio in the feed, or it can be termed the enrichment factor which is defined as the ratio of components concentration in the permeate to the ratio of their concentration in the feed (Karlsson and Tragardh, 1996). The permeate flux and separation coefficient are the two vital parameters that determine the transport and separation abilities of a pervaporation membrane (Kaminski *et al.*, 2008). When one factor increases, the other decreases and a good pervaporation membrane should have high permeate flux and high separation factor (Kalyani *et al.*, 2008).

Factors Affecting the Performance of Pervaporation Process

Operational temperature:

Changing the operating temperature may cause changes of membrane structures and mutual interaction between feed components, which can consequently contribute to the alteration of mass transport coefficient of each component (Peng*et al.*, 2003).

Downstream pressure:

It is widely agreed that increasing downstream pressure does not significantly alter pervaporation selectivity as long as it does not exceed the saturated vapor pressure. Beyond this limit, the transport selectivity may either increase or decrease depending on the respective volatility of the two feed component. If the permeable component is more volatile, the selectivity increases as the downstream pressure is raised (Peng *et al.*, 2003).

Feed concentration:
A change in feed concentration directly affects the sorption behavior at the liquid membrane interface and the diffusion of the component in the membrane. Sorption and diffusion of the feed components in membrane characterize the membrane separation properties. Therefore, the permeation characteristics are obviously dependent on the feed concentration. As reported by Kaminski *et al.* (2006) in their pervaporation experiment on the dehydration of ethanol, smallest effect on the permeation flux was observed for high ethanol concentration in the feed. Also, Smitha *et al.* (2004) carried out ethanol dehydration analysis and reported that permeation flux decreased with increase in ethanol concentration.

Merit of Pervaporation Technology over other Membrane Separation Techniques
Pervaporation is a membrane-based separation technique, which has a unique feature of phase change during separation. Hence, pervaporation is used for the separation of compounds having a low concentration in the feed mixture (Vane, 2005). It also separate azeotrope, heat sensitive mixtures, nonvolatile mixture and mixtures with relative volatility nearly equal to one, that are difficult to separate by other separation techniques (Chen *et al.*, 2010, Dobark *et al.*, 2010). Different separation techniques like adsorption, extractive distillation, distillation of azeotropic mixtures and liquid-liquid extraction are being used in food and pharmaceutical industries for the separation of mixtures (Pakkethati *et al.*, 2011). But all these separation techniques demand extensive amount of energy, extra care and downstream processing to recover key component. These techniques often cause product contamination and environmental pollution (Afonso and Crespo, 2005). In order to enhance the efficiency of separation process the advanced separation technique of pervaporation has been introduced. It is an economical, energy saving and safe membrane separation technique (Ding *et al.*, 2012, Liu *et al.*, 2012, Cai *et al.*, 2013). It provides efficient separation at normal operating conditions without using any external chemical separating agent or any other downstream processing (Nunes and Peinemann, 2006).

Developments in Pervaporation Technology in different Countries
In 1982-83 Gesellschaft fur Trenntechnik (GFT) Co., Germany, developed the first commercial pervaporation membrane for the dehydration of alcohol solutions. The membrane was prepared by depositing a thin layer of polyvinyl alcohol on an asymmetric polyacrylonitrile substrate using a proprietary technique (Neel, 1991; Bruschke 1989). The first commercial pervaporation plant was built in 1988 in Bethenville in the Champagne region of France. Here, the fermentation of sugar beets produced a fermentation broth containing approximately 14% alcohol content. The feed stream was first concentrated using conventional distillation columns up to 85% and then the pervaporation separation units were used to bring the alcohol content to 99.9%. The capacity of the plant ranged from150,000 litres/day of alcohols of various qualities to 400,000 litres/day. The plant was designed and built by GFT of Germany which has since been absorbed into Carbon Lorraine Engineering. Since 1987 Mitsui Zosen Co. of Japan has built many plants in Japan using the GFT membrane under license for various separation applications. This company has been instrumental in pioneering efforts to introduce pervaporation separation processes in the Japanese chemical industry and has already built some 10 pervaporation plants with applications in dehydration of ethanol, isopropanal and the separation of various types of organic aqueous systems (Asada, 1991). Between 1988 and 1989, Membrane Technology and Research (MTR) Inc., U.S.A. marketed a pervaporation system for the removal of small amounts of organic solvents from contaminated water. Pervaporation membranes for the dehydration of ethanol have recently been developed for Texaco by Zenon Inc. and the company has been contracted under license to build a spiral wound module based on these membranes. Kalsep, a subsidiary of British Petroleum, Great Britain, is developing a tubular, composite membrane which is claimed to be more efficient than the currently available membranes.

Pervaporation research was started in Canada in 1967 in the Chemical Engineering laboratory at the University of Waterloo. The early study concentrated on the pervaporation separation of organic-organic mixtures and the development of theoretical principles which govern the transport processes and diffusion through modified polyethylene membranes. The study eventually expanded to include the separation of aqueous organic mixtures (mainly ethanol-water and acetic acid-water systems using modified polyvinyl alcohol membranes). More recently, pervaporation research has been started at the Institute of Environmental Chemistry of the National Research Council of Canada and there is also a project involving the pervaporation separation of dilute organic contaminants from waste waters at the Department of Chemical Engineering, McMaster University, applications of pervaporation in the petroleum industry, EMR Canmet Laboratories, Ottawa (Slater and Hickey, 1989).

In Nigeria, no information appears to be available on research and application of membrane separation technology, especially the pervaporation technology in any industry including the food and pharmaceutical industries. Effort was made between 2013 and 2014 to apply the technology to the dehydration of bioethanol extracted from maize and red sorghum at the Department of Agricultural and Environmental Resources Engineering, University of Maiduguri, Maiduguri, but the success of the study was limited by the non-availability of appropriate vacuum pumps. The pervaporation set up employing a tubular module that was used is presented in Figure 18.

Figure 18: Set up of a pervaporation unit for bioethanol dehydration at the Dept. of Agricultural and Environmental Resources Engineering, University of Maiduguri, Maiduguri, Nigeria

Industrial Applications of Pervaporation Technology
Pervaporation has several industrial applications which are dependent on the feed composition and nature of membrane used. Industrial liquid separations can be broadly classified into two types: aqueous-organic and organic-organic separations. Figure 19 shows the wide and varied applications of pervaporation process with appropriate examples including dehydration of aqueous organic mixtures using hydrophilic membrane, extraction of trace organic compounds from aqueous mixtures (Aptel *et al.*, 1972) by hydrophobic and separation of organic-organic mixtures using organophilic membranes. Compared to conventional processes, pervaporation is often energy efficient, simpler to operate and yield a high quality product. The same is true for the isolation, concentration and purification of drugs and food products in pharmaceutical and food applications (Sunitha *et al.*, 2013). Integration of this process offers the advantage of operation at ambient temperature thus avoiding degradation of products. Very often a combination of conventional water treatment procedures with membrane processes result in reliable and cost-effective treatment combined with high product purity.

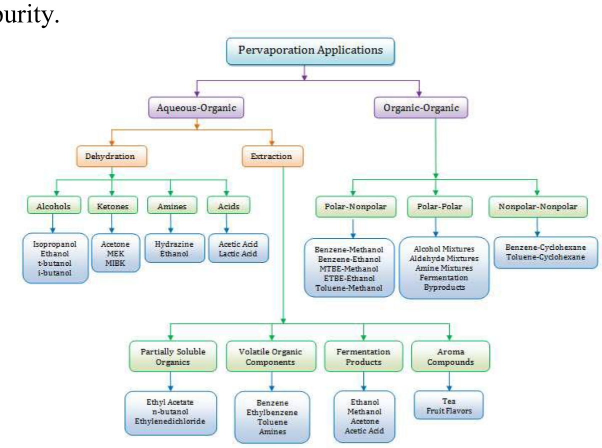


Figure 19: Chart of different liquid mixture systems separation by pervaporation process (*Source: Sunitha et al., 2013*)

Prospects of Pervaporation Technology Application in Nigerian Food and Pharmaceutical Industries

Pervaporation technology has great application potential in Nigerian food and pharmaceutical industries for liquid-liquid separations where the more conventional techniques such as distillation, adsorption and chromatography (which are the ones more frequently used in Nigerian food and pharmaceutical industries), are not possible to be realized or too expensive. This includes the separation of azeotropes of mixtures of components with only a slight difference in volatility, and of components that are pressure or temperature sensitive. These separations occur in the (petro) chemical and as well as the food industry and in waste water treatment.

Pervaporation technique can be used in Nigerian food and pharmaceutical industries to recover dissolved organics from water, concentrate milk and fruit juice (Kujawski *et al.*, 2008) and recover aroma, dealcoholize beverages (Karlsson and Tragardh, 1996), dehydrate edible vegetable oil, ethanol and drug syrups and in processing of heat sensitive and volatile foods. It can be used to deodorize food processing effluents (Pierre *et al.*, 2002) and it has the advantages of having less adverse effect on environment and less energy consumption over the most commonly used techniques.

Environmental pollution is a serious problem causing global warming and in turn affecting agricultural land close to industries in Nigeria. Pervaporation is regarded as "Green Separation Process" which is a universally accepted term being used worldwide only for those processes which are environment friendly. In the context of increasingly stringent legislation in environmental protection rules and regularities, there is an exponential increase in interest for the development of more environment friendly processes and techniques. Pervaporation process is an integral part of the Green Separation Processes as it does not need any hazardous or toxic chemicals for separation, but only a selective membrane. It does not discharge any hazardous effluent stream and no air, water or ground pollution is involved in the process, so, it does not make any contribution to global warming. The process is noise and with the above facts, pervaporation technique does not involve any factor relevant to environmental safety that limits its development or use (Afonso and Crespo, 2005; Usman *et al.*, 2009).

Power generation has being a serious problem in the country and the food and pharmaceutical industries are not immuned from the effect. High power requirements by these industries result from the methods of separation being used. The techniques involve phase changes that are generally energy-intensive and distillation is a notorious example of them. Pervaporation cleverly survives the challenge as it reduces the energy consumption compared with the distillation, because of the characteristics of pervaporation operation. It is essentially true that only the minor component in the feed consumes the latent heat.

Challenges of Pervaporation Technology Application in Nigerian Food and Pharmaceutical Industries

It is well known that pervaporation technology may possess many benefits over conventional techniques for biofuel production and purification. However, the pervaporation technology is not currently being extensively utilized in the Nigerian food and pharmaceutical industries. This may be due to the following reasons:

1. Lack of information on this method of liquid-liquid separation.
2. The long-term reliability of the technology is yet to be completely proven.
3. Most pervaporation membranes are tested under mild feed and bench-scale operating conditions. The separation performance of membranes for most industrial applications is still at the level of investigation.
4. Poor availability of investment capital and perceived risks associated with the process pose serious challenge.
5. Membranes are mechanically not very robust and can easily be destroyed by a malfunction in the operating procedure.
6. Pervaporation sometimes require excessive pretreatment due to its sensitivity to concentration polarization and chemical interaction between water and other constituents of mixture.
7. The high costs of membrane production and module fabrication and problems associated with membrane reliability and resistance to harsh environments is also a challenge.

These challenges are basically what could make the stakeholders in Nigerian food and pharmaceutical industries to find it difficult to invest in pervaporation technology.

CONCLUSION AND RECOMMEDATIONS

The pervaporation process description shows that it is a very convenient and highly efficient separation technique. Its areas of application are wide and its environmental impacts comparison with other competitive separation techniques is mild. Pervaporation therefore, proves an economic, efficient and green separation technique. It possesses great potentials for applications in the Nigerian food and pharmaceutical industries compared to the other conventional separation systems. Lack of information on the technique among other challenges, makes the stakeholders not to invest in this technology, and as a result, hinders its application. There is need for the stakeholders in the food and pharmaceutical industries in the country to encourage research in the field of fundamental and applied pervaporation technology. Conference should be organized on this important separation technique and laboratory outputs could be considered for scale up.

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APPLICATION OF COMPUTER VISION IN FOOD GRAIN QUALITY INSPECTION, EVALUATION AND CONTROL DURING BULK STORAGE

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ABSTRACT
This paper discusses the application of computer vision in quality evaluation and control of grains during such bulk storage as bags and bins. Though quality control begins at the farm and moves through collection and terminal points into the storage bin, controlling and sustaining the quality of the crop in the bin during storage is a meaningful step in ensuring that deterioration in stored grains is minimally reduced. The qualities that are controlled include soundness of gains, amount of admixtures, moisture content, odour and presence of insects or their eggs. Traditionally, quality control is usually carried out using human visual inspection which is usually associated with errors. Computer vision is a well-proven and useful method of quality inspection and evaluation which is a better substitute to human visual inspection. It is able to generate the needed data concerning the quality of the food grains from the images of the grains. Methods of image acquisition, analysis and interpretation are presented and the application of the method in food and agricultural industry in evaluating the quality of some crops is discussed. The paper noted that the technology can be successfully applied in the inspection and evaluation of grain quality during bulk storage using parametric sensors, automated sampling device and computer interface with such software as MATLAB with image analysis tool kit. Challenges, prospects and future trends of automated quality inspection and evaluation in Nigeria were highlighted.

Keywords: *Computer vision, Quality inspection, Quality evaluation, Quality control, crop, bulk storage*

INTRODUCTION
The quality of a crop can be defined as a series of physicochemical characteristics such as maturity, size, weight, shape, colour, presence of dirt and diseases, presence or absence of stem, presence of seeds, sugar content and so. These features cover all the factors that influence the appearance of a product and may eventually include nutritional and sensory qualities or properties related to its conservation. The qualities that are of interest in grain storage are variety of grains (inherited quality), soundness of gains, amount of admixtures, insect infestation and moisture content (Anderson, 1973).

Control is the process through which established standards are maintained (Pyle and Zaror, 1997). This process consists of observing activity performance, comparing the performance with some standards and then taking action if the observed performance is significantly different from the standards. The control process involves a universal sequence of steps as follows: choosing the control subject, choosing a unit of measure, setting a standard value and specifying the quality characteristics, choosing a sensing device which can measure, measuring actual performance, interpreting the difference between actual and standard, taking action, if any, on the difference (Niranjan *et al.*, 2006). Quality control can therefore be defined as that management technique by means of which product of uniform acceptable quality is produced. The aims of controlling quality are to decide on the standard of quality of a product that is easily acceptable to the customer, to check the variation during and after production, and to prevent the poor quality products reaching the customer. The locations where quality is controlled include farms, collection points and terminal points (Anderson, 1973). In recent time, the advancement of knowledge and technology in quality control, coupled with consumer's expectations for high-quality crops, has increased the need for improved production and quality monitoring in all the agricultural processes, especially in crops storage (Aguilera *et al.*, 2005).

One of the important steps in the quality control of grains is periodic inspection of the grains in order to detect and segregate varieties of different classes of grades at the farm and while on transit from the producer to the consumer or to predict possible future deterioration of the grains being stored (USDA, 2014). Inspection is the most common method of attaining standardisation, uniformity and quality of workmanship. It is the cost art of controlling the product quality after comparison with the established standards and specifications (USDA, 2014). If the said item does not fall within the zone of acceptability it will be rejected and corrective measure will be applied to see that the items in future conform to specified standards. Stages of inspection include inspection of the incoming materials, inspection of production process, and inspection of the finished goods which explain why inspection is done on the farm, collection points, and terminal points for the control of grain quality (Delwiche, 2010).

Traditionally, quality inspection of agricultural products has been performed by human graders. However, in most cases these manual inspections are time-consuming and labour intensive. Moreover the accuracy of the tests cannot be guaranteed (Park *et al.*, 1996) because, human perception can easily be fooled (Francis, 1980). It is pertinent to explore the possibilities of adopting faster systems, which will save time and more accurately detect any possible problem in stored grains. One of such reliable method is the automated computer vision system for inspection and quality control of grains (Mahendran *et al.*, 2012). It has been found that computer vision inspection of agricultural products was more consistent, efficient and cost effective (Lu *et al.*, 2000; Tao*et al.*, 1995) than the traditional method. Also, with the advantages of superior speed and accuracy, computer vision has attracted a significant amount of research aimed at replacing human inspection (Narendra and Hareesh, 2010).The quality inspection of stored produce in Nigeria is currently carried out manually and the procedure is not only difficult and labour intensive but also costly, time consuming and unreliable. This is so because human decision is inconsistent and subjective in identifying quality factors such as appearance, flavour, nutrient, texture, moisture, insect adults and larva, mould, bacteria and hot spots. Due to high expectation of food products with high quality and safety standards, the need for accurate, fast and objective quality determination of characteristics in food products has continued to grow (Mahendran *et al.*, 2012).The stated reasons above necessitate the replacement of traditional method of quality inspection with automatic inspection systems based on computer vision and image analysis (Du and Sun, 2006).

This paper discusses the application of computer vision in the food industry and noted that the application of the technology in food grain quality inspection, evaluation and control during bulk storage appears not to have been investigated. It highlights the technical requirement of the method for such application and opined that future trends of computer vision system application in which it would be directed towards grain quality control during bulk storage, could help in the detection of insect infection, grain defects, off odour, contamination and moisture build up in grains during storage.

AUTOMATED INSPECTION METHODS

Automated inspection can be defined as the use of mechanically or electronically controlled system to replace human labour in carrying out one or more of the activities involved in the inspection procedure. Aspects of automated inspection methods include neurobiology, signal processing, imaging, image processing, image analysis, machine vision, computer vision and pattern recognition. Image processing and image analysis tend to focus on two-dimensional images, and on how to transform one image to another. Examples of such operations are pixel-wise operations such as contrast enhancement, local operations such as edge extraction or noise removal and geometrical transformations such as rotating the image (Venkatesh *et al.*, 2015).

Machine vision is the process of applying a range of technologies and methods to provide imaging-based automatic inspection, process control and robot guidance (Turek, 2011) in industrial applications (Steger *et al.*, 2008). Machine vision tends to focus on applications, mainly in manufacturing, and examples are vision based autonomous robots and systems for vision based inspection or measurement. This implies that image sensor technologies and control theory often are integrated with the processing of image data to control a robot and that real-time processing is emphasized by means of efficient implementations in hardware and software. It also implies that the external conditions such as lighting can be and are often more controlled in machine vision than they are in general computer vision, which can enable the use of different algorithms (Oyeleye and Lehtihet, 1998).

Computer vision includes three-dimensional analysis from two-dimensional images. It analyzes the three-dimensional scene projected onto one or several images, and deals with how to reconstruct structure or other information about the three-dimensional scene from one or several images. Computer vision often relies on more or less complex assumptions about the scene depicted in an image (Riyadi *et al.*, 2007, Al-Ohali, 2011). Imaging primarily focus on the process of producing images, but sometimes also deals with processing and analysis of images (Riyadi *et al.,* 2007). Pattern recognition is a field which uses various methods to extract information from signals in general, mainly based on statistical approaches and artificial neural networks. A significant part of this field is devoted to applying these methods to image data (Riyadi *et al.*, 2007).

FUNDAMENTALS OF COMPUTER VISION

Computer vision is a field that includes methods for acquiring, processing, analyzing, and understanding images and, in general, multi-dimensional data from the real world in order to produce numerical or symbolic information that would inform the taking of decisions (Klette, 2014; Moris, 2004; Shapiro and Stockman, 2001). A theme in the development of this field has been to duplicate the abilities of human vision by electronically perceiving and understanding an image (Sonka *et al*, 2008). Understanding in this context means the transformation of visual images

(the input of retina) into descriptions of world that can interface with other thought processes and elicit appropriate action. This image understanding can be seen as the disentangling of symbolic information from image data using models constructed with the aid of geometry, physics, statistics, and learning theory (F*orsyth and Ponce*, 2003). Computer vision has also been described as the enterprise of automating and integrating a wide range of processes and representations for vision perception (Ballard and Brown, 1982).
As a scientific discipline, computer vision is concerned with the theory behind artificial systems that extract information from images. The image data can take many forms, such as video sequences, views from multiple cameras, or multi-dimensional data from a medical scanner. As a technological discipline, computer vision seeks to apply its theories and models to the construction of computer vision systems (Wikipedia, 2014).
The hardware configuration of the computer vision system generally consists of;

- A lighting device, which illuminates the sample under test as shown in Figure 1.
- Detector (A solid-state Charged Coupled Device (CCD) array camera to acquire an image).
- A personal computer monitor and a high-resolution colour device. The quality of the images to be captured is a direct function of two elements of the system: camera and illumination (lighting system) (Saldana *et al.*, 2013).

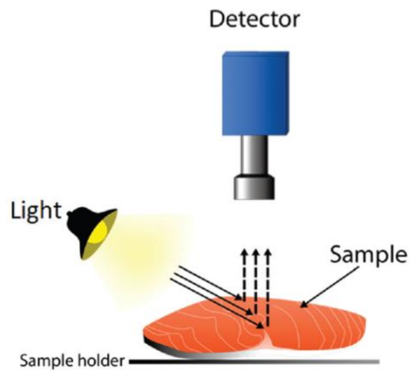

Figure 1: Schematic diagram of a typical Computer Vision System (*Saldana et al., 2013*)

Stages of Computer Vision System
Many functions are unique to the computer vision application and these include: image acquisition, image pre-processing, image feature extraction, image segmentation, image recognition and interpretation. As described in Figure 2 below, image acquisition and image pre-processing are categorized as low-level processing, the intermediate-level processing involves image segmentation, image representation and image description, while high level processing deals with image recognition and interpretation (Riyadi *et al.*, 2007).

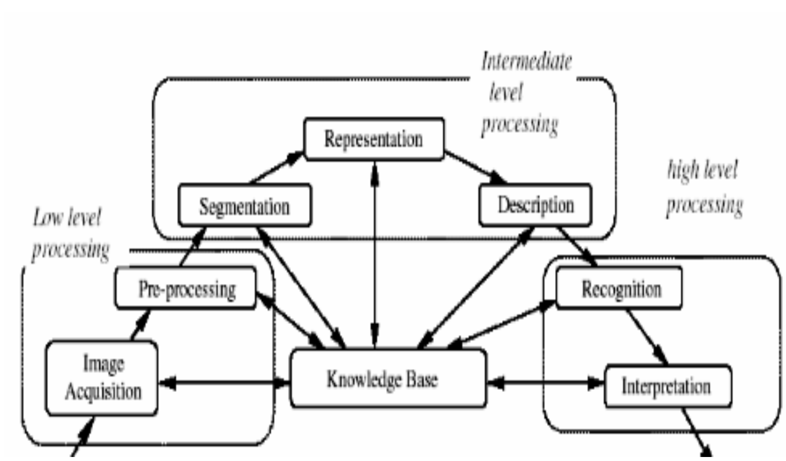

Figure 2: Techniques of Computer Vision *(Riyadi et al., 2007*)

Image acquisition

The stage of image acquisition consists of capturing a real image and transforming it into a digital image using devices such as cameras, scanners, videos, etc. A digital image is a numerical representation of an image that can be computationally processed. A Color Digital Camera (CDC), model used should be located vertically over the background at a distance of 30 cm. The angle between the camera lens and the lighting source axis was approximately 45º, since the diffuse reflections responsible for the color occur to this angle from the incident light (Francis and Clydesdale, 1975). Also, considering that ambient illumination is very critical for reproducible imaging (Shahin and Symons, 2001), sample illuminators and the CDC were covered with a black cloth to avoid the external light and reflections. As standard capture conditions, images were taken on a matte black background and using the following camera settings: manual mode with the lens aperture and speed, no zoom, no flash, intermediate resolution of the CDC pixels, and storage in JPEG format. The capture pictures should be then transferred to PC which is loaded with the image processing software (Rafiq *et al.*, 2013).

Image Pre-processing

Image pre-processing refers to the initial processing of the raw image. The images captured or taken are transferred onto a computer and are converted to digital images. Digital images though displayed on the screen as pictures, are digits, which are readable by the computer and are converted to tiny dots or picture elements representing the real objects. In some cases pre-processing is done to improve the image quality by suppressing undesired distortions referred to as "noise" or by the enhancement of important features of interest.

The images or pictures are transformed into computer digital readable format (i.e. digitized) if a digital camera did not take them by the image board digitizer. The digitized format is then transferred and used as the input data by the image processing software to carry out the necessary processes (Narendra and Hareesh, 2010).

Image Feature Extraction/Description

Image feature extraction involves the extraction of image features at various levels of complexity from the image data (Davies, 2005).Statistical procedures from basic image statistics such as mean, standard deviation, and variance to more complex measurement such as principle component analysis can be used to extract the features from digital images (Arivazhagan *et al.*, 2010). According to the diverse information stored in pixels, image features obtained can be categorized into four types - colour, size, shape, and texture (Du and Sun, 2004)

Image Segmentation

Image segmentation is a process of cutting, adding and feature analysis of images aimed at dividing an image into regions that have a strong correlation with objects or areas of interest using the principle of matrix analysis. Image segmentation is one of the most important steps in the entire image processing technique, as subsequent extracted data are highly dependent on the accuracy of this operation. Its main aim is to divide an image into regions that have a strong correlation with objects or areas of interest. If objects in image cannot be segmented correctly, it is difficult for object measurement; classification and recognition, hence impact interpreting and understanding that image. Earlier studies proposed the use of a 'flooding' algorithm to segment patch-like defects (russet patch, bruise, and also stalk or calyx area) (Yang, 1994). It was found that this method of feature identification is applicable to other types of produce with uniform skin colour. This technique was improved by Yang and Marchant (1995), who applied a 'snake' algorithm to closely surround the defects. Segmentation can be achieved by three different techniques: thresholding, edge-based segmentation and region-based segmentation (Sonka *et al.*, 1999; Sun, 2000). Thresholding is a simple and fast technique for characterising image regions based on constant reflectivity or light absorption of their surfaces. Edge-based segmentation relies on edge detection by edge operators. Edge operators detect discontinuities in grey level, colour, and texture. Region segmentation involves the grouping together of similar pixels to form regions representing single objects within the image (Mahendran *et al.*, 2012).

Image recognition and Interpretation

At this step the input is typically a small set of data, for example a set of points or an image region which is assumed to contain a specific object. It involves classifying a detected object into different categories (Davies, 2005). Image recognition and interpretation step is to meet the ultimate goal, the translation of image analysis data into information that is useful for further action such as process and/or machine control (Gunasekaran, 1996).

APPLICATION OF COMPUTER VISION IN FOOD AND GRAIN QUALITY INSPECTION AND CONTROL

Computer vision systems are being used increasingly in the food industry for quality assurance purpose. Computer vision has been proven successful in many areas of food processes; online measurement of several food products with applications ranging from routine inspection to the complex vision guided robotic control (Gunasekaran, 1996). The ultimate purpose in many computer vision based inspection systems is to estimate one or several features of interest of the products at a particular time, and relate them to the consumer who appreciates quality (Sun, 2000, Tan, 2004). Other systems are designed to determine the evolution of the product in time in order to determine whether one particular treatment or process is valid or not. In most of these applications, image analysis is used to evaluate characteristics such as colour, size, shape, texture or the presence of damage (Cubero, 2011).

Some of the researches in which computer vision has been applied for quality inspection of grains in order to segregate them into different classes of grades with the aim of achieving effective quality control, are as follows. An early study by Zayas *et al.* (1989) used machine vision to identify different varieties of wheat and to discriminate wheat from non-wheat components. In later research Zayas *et al.* (1996) found that wheat classification methods could be improved by combining morphometry (computer vision analysis) and hardness analysis. Hard and soft recognition rates of 94% were achieved for the seventeen varieties examined. Twenty-three morphological features were used for the discriminant analysis of different cereal grains using machine vision (Majumdar *et al.*, 1997). Classification accuracies of 98, 91, 97,100 and 91% were recorded for CWRS (Canada Western Red Spring) wheat, CWAD (Canada Western Amber Durum) wheat, barley, oats and rye, respectively. 25 kernels per image were captured from a total of 6000 for each grain type examined. The relationship between colour and texture features of wheat samples to scab infection rate was studied using a neural network method (Ruan *et al.*, 1997). It was found that the infection rates estimated by the system followed the actual ones with a correlation coefficient of 0.97 with human panel assessment and maximum and mean absolute errors of 5 and 2%, respectively. In this study machine vision-neural network based technique proved superior to the human panel.

A machine vision algorithm for corn kernel mechanical and mould damage measurement was developed by Ng *et al.* (1997). Result from 250 grains examined showed a standard deviation less than 5% of the mean value. They found that the developed method was more consistent than other methods available. Ni *et al.* (1997) performed automatic inspection of 600 corn kernels using machine vision. For whole and broken kernel identification on-line tests had successful classification rates of 91 and 94% for whole and broken kernels, respectively. Liu and Paulsen (1997) measured the whiteness of corn by an on-line computer vision approach. For the 63 samples (50-80 kernels per sample) tested the technique was found to be easy to perform with a speed of 3 kernels per second.

Shahin and Symons (2001) developed a machine vision system for colour grading of lentils, using a flatbed scanner as the image gathering device. Grain samples belonging to different grades of large green lentils were scanned and analysed over a two-crop season period. Image colour, colour distribution, and textural features were found to be good indicators of lentil grade. Linear discriminant analysis, k-nearest neighbours, and neural network based classifiers performed equally well in predicting sample grade. An online classification system was developed with a neural classifier that achieved an overall accuracy (agreement with the grain inspectors) of more than 90%. A digital image analysis method for measuring the degree of milling of rice was developed by Liu *et al*. (1997). The result obtained showed a coefficient of determination of R^2=0.9819 for the 680 samples tested and compared favourably with the conventional method of chemical analysis. Wan *et al.* (2000) developed an online automatic grain inspection system using machine vision. A total of 16 brown rice appearance characteristics related to kernel shape, colour and defects were employed to study the rice quality recognition performances of three classification techniques. Sound, cracked, chalky, broken, immature, dead, off-type, broken, paddy, and damaged brown rice kernels could be recognized by the system with an accuracy of 91% at a speed of over 1200 kernels/min. A modified dark field illumination technique was used for the computer vision inspection and estimation of the internal damage of rough rice (Cardarelli *et al.*, 1999). The machine vision system was 91.5% successful for correctly categorizing a test sample when compared to rice visually separated by trained plant pathologists. Panigrahia *et al.* (1998) also investigated quality characteristics of corn the by use of computer vision. The classification of germplasms (ear of corn) was performed by use of an algorithm developed to discriminate round-shaped samples based on two features. Two different approaches based on fractal geometry and higher order invariant moments were used for classification of non-round shaped germplasms. Piotr *et al.* (2008) used image processing to determine the utility of morphological features for classifying individual kernels of five varieties of barley. It was found, that the method using morphological features may be successfully employed in image analysis for a preliminary varietal identification of barley kernels. It was also shown that the data reduction considerably improved the results of the classification of barley kernels. Furthermore, linear discriminant analysis (LDA) was found to be the method which best separated different varieties of objects.

Digital image analysis was used to monitor baking process, in order to check and control quality of baked goods (Paquet *et al.*, 2011). The goal was the development of algorithms for distinction of baking goods and characterization of color saturation and shape, altogether resulting in an optical online process monitoring system. Raji and Alamutu (2005) discussed the prospects and challenges of applying computer vision to the automation of food grain sorting and grading systems in Nigeria and recommended the adoption of the technology in order to maintain the freshness and attractiveness of agricultural and food products for longer time duration. In the same vein, Mahendran *et al.* (2012) discussed the application of computer vision in the sorting and grading of fruits and vegetables and noted that the technology has been able to detect the occurrence of diseases, defects and contaminants on the produces with high speed and accuracy. Mogol and Gokmen (2014) discussed the monitoring of food quality and safety using computer vision and described the ways in which the technology can be used to detect browning ratio and relate it to acrylamide content of potato or cookies, and how porosity index as an important physical property of breadcrumb can be easily calculated., while in their discussion, Manickavasagan *et al.* (2015) highlighted the application and efficiency of the technology for variety identification, surface crack detection, texture and hardness detection in date palm fruits.

Abdullah *et al.* (2004) developed a machine-vision based automated oil palm inspection system that utilized colour assessment to classify palm nuts with accuracy that ranged from 84% to 92%. The system showed a 20% more consistent results compared to human grading. Tan (2004) applied computer vision to the evaluation of such meat quality characteristics as colour, marbling, maturity and texture, and used the quality indicators to measure cooked meat tenderness, while Jin *et al.* (2009) used the Adaptive Intensity Interception (AII) and Fixed Intensity Interception (FII) in computer imaging to detect such external defects on potatoes as bruises and degree of cell rupture. FII performed better than AII with correct inspection rate ranging from 92.1 to 100% for three potato cultivars examined. Al Ohali (2011) developed a computer vision based date fruit grading system. Results of tests conducted on pre-selected fruit samples showed that the system can sort the date with 80% accuracy. Golmohammadi *et al.* (2013) designed and developed a potato sorting machine based on computer vision that was able to sort pre-selected potato tubers to an accuracy of 97.4%, and Maheshwari (2013) used a computer vision system to detect level of breakage, colour changes and extent of stress cracking in rice with high precision. She further proposed steps that would enhance the application of the technology in rice grain quality inspection as follows:

(a) Selection of the region of the grain that is of interest and imaging it, (b) converting the RGB image to gray, (c) applying morphological operations, (d) calculating the parameters of interest, (e) finding the histograms of the same, (f) computing the threshold values based on the histograms, and (g) evaluating the quality indicators on the basis of the above process. Matiacevich *et al.* (2013) investigated the quality parameters of blueberry cultivars using computer vision. The parameters studied were shape, colour and fungal presence with time. The berries were stored in thin layers in desiccators and equilibrated under different relative humidity values at 4 and 15ºC for 21 days. Changes in colour, shape and level of fungal presence with storage duration were detected using the technology and the shelf life of all the cultivars studied was estimated to be 14 days. Similarly, Yimyam (2015) developed a system for agricultural produce grading by computer vision based on generic programming. The system was able to determine the shape and appearance of 3D objects reconstructed from 2D images taken by cameras in arbitrary positions. Gongal *et al.* (2016) applied computer vision to the development of a crop-load estimation system with over-the-row platform integrated to a tunnel structure. The equipment was able to acquire images from both sides of apple trees thereby minimizing the covering of apple fruits by branches, leaves and or other apples as well as variable outdoor lighting conditions. The dual side imaging of the over-the-row system achieved an accuracy of 82% on estimating apple fruit load on trees compared to 58% with single side imaging.

The application of computer vision in the agricultural and food industry show that the technology has mainly been used to inspect and evaluate the quality of seeds, fruits and vegetables, meat and fish products (Gunasekaran, 1996, Brosnan and Sun, 2004, Narendra and Hareesh, 2010, Kodagali and Balaji, 2012 and Saldana *et al.*, 2013). The closest approach to the inspection and evaluation of the quality of food grains during bulk storage using automation and machine vision was the development of a method that combined fuzzy clustering mean with spatial transformation to inspect the quality of red beans packaged in bags by Ngatchou *et al.* (2014). Even at that, the grains needed to be pre-selected and sampled out before the system could get it segregated by colour to separate the mixtures.

APPLICATION OF COMPUTER VISION IN GRAIN QUALITY INSPECTION AND EVALUATION DURING BULK STORAGE

Bulk storage of grains are usually carried out using either bags that are filled with grains and stacked on top of each other on a wooden platform in a warehouse (Figure 3) or battery of silos arranged as shown in Figure 4.

Figure 3: Bulk storage of grains in bags stacked on each other on wooden platforms in a warehouse

Figure 4: Battery of silos for bulk storage of food grains

Although, Computer vision has not really been applied to the inspection and monitoring of grains during bulk storage, a consideration of the advantages the technology offers, shows that it has the potential to automate the manual method that is presently practiced in bulk storage quality inspection, thus it can be used to reduce the drudgery and tediousness of the operation. This will enable the monitoring and evaluation of qualities such as variety of grains, soundness of gains, amount of admixtures, mould growth, presence of insect eggs, insect infestation and moisture content in bulk grains during storage to be carried out rapidly, economically, hygienically, consistently and objectively.

The application of computer vision in bulk grain quality inspection, evaluation and control during storage will require the following:

i. Sensors located at different points within the bag or silo holding the bulk grain, can be used to detect the occurrence of moisture accumulation, insect infestation, presence of foreign materials and off-odour.

ii. The above information in the form of signals would be transmitted to connected and automated sampling device (triers or probes) that would draw grain samples from designated points and pass them through an imaging system consisting of lighting devices and CCD cameras.

iii. The images obtained would then be sent into a PC system for digitalization, analysis and quantification of the target parameters using the Image Analysis Tool kit in MATLAB or any other image analysis software.

CHALLENGES TO THE APPLICATION OF COMPUTER VISION IN FOOD AND BULK GRAIN QUALITY INSPECTION AND EVALUATION IN NIGERIA

The major problem of automated method in quality inspection and control in Nigeria is one of socio-economic effects, which implies that it would tend to reduce employment since the number of operators required in the processing line would be reduced. It is not suitable in processes where manual skill is necessary or economically more attractive. It requires higher initial and maintenance cost and there may be the need for a precise understanding of the process for programming to achieve the required product quality. Equipment associated problem involving reliance on the accuracy of sensors to precisely measure process condition and the increased risk, delays and cost if the automatic system fails, may arise. In situ sensing and imaging of portions of bulk grains within the storage system may not be easily carried out using existing sensing devices. The farm layout and level of production, which remains at the peasant level is also a serious hindrance to the introduction of this technique. Most of the products found in the markets are owned by a number of individuals with each controlling not more than 4 to 5 baskets, which would be too small for the adoption of an automated technique. However, wholesalers and groups of retailers operating in cooperatives could be encouraged to pull their resources together and embark on the adoption of the technology.

PROSPECTS OF APPLYING COMPUTER VISION IN FOOD AND BULK GRAIN QUALITY INSPECTION, EVALUATION AND CONTROL IN NIGERIA

The adoption of the emerging technology of computer vision, by first putting more effort into researches on the appropriate methods and the ways of its application will be of immense benefit to this country as it will reduce the drudgery of the manual method that is presently being practiced and ensure more accurate assessment. Some of the other associated benefits include increased production rates (e.g. through optimization of equipment utilization), more efficient operation, production of more consistent product quality, greater product stability and safety. More complex systems are needed for the automated inspection and segregation of grains because of the greater range in variability of quality and grain orientation may influence results. With the idea of precision and more environmental friendly agriculture becoming more realistic the potential for computer vision system in this area is immense with the need in field crop monitoring, assessment and guidance systems.

The introduction of automated method of inspection will also encourage an improved quality as unsound grains will not be mixed with sound grains, damp grains will not be mixed with dry grains, grains with a lot of admixtures will not be mixed with clean grains in that regard and mould growth and insect infestation during bulk storage will be detected on time and curbed.

FUTURE TRENDS

Changing towards automation in the agricultural and food industry reflects the industry's goal of producing high quality food with relatively low cost. Computer vision technology is becoming an integral part of the industry's move towards automation. The presence of machine vision system on a production line has come to represent a visible demonstration of a company's commitment to quality. During the past few years, the food industry has made significant strides in computer vision-based food processing automation in the Western World.

However, it is expected that a number of important developments within the next decade will be seen in which there will be full application of computer vision technology in most of the food processing operations and especially in bulk grain storage. For instance, it is expected that widespread use of computer vision technology in the food industry for routine inspection and quality assurance tasks will be achieved. Also, research efforts are expected to continue to improve in all aspects of the vision system such as the use of better cameras, faster hardware and software, and more accurate algorithms. The focus will clearly be on adaptive learning and automatic controls using vision system data. Developments in color vision and three-dimensional image processing will continue at a rapid pace. Efficient techniques will be developed to handle real-time, three-dimensional image flow data to accommodate increased production rates and quality requirements. Totally automated production, processing, storage and quality assurance lines with robotic controls will be the long-range target for food manufacturers and combined efforts of every sector involved will be needed to accomplish this goal.

CONCLUSIONS

The technology of computer vision has great potential for application in food grain quality inspection, evaluation and control during bulk storage. The use of the technology will guarantee substantial improvements in quality inspection since it has the capability of overcoming the limitations of manual methods, allowing for a long-term evaluation of the processes objectively, rapidly, hygienically and economically. In addition, the online monitoring systems allow one to inspect and monitor food in storage even when nobody is physically present. Some challenges however, need to be overcome but the prospects of the technology for successful application are high. Future trends in the development of the technology will address the challenges

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PRODUCTION OF STOCKFISH FROM WHITING (*Merlangius merlangius)* USING NSPRI DEVELOPED SOLAR TENT DRYER

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ABSTRACT

Fish are processed to increase protein availability to people. Stockfish are usually imported into Nigeria at a huge cost and with little adherence to quality standards. A cost effective and environmental friendly solar tent dryer was developed for production of stockfish from Whiting (Merlangius merlangius) which would be free of contaminations, dust and insects. The dryer was able to dry 25kg of fresh Whiting with an average moisture content of 80.10% (wet basis) to a final weight of 5.42kg with average moisture content of 10.13% (wet basis) within a period of four days. The stockfish produced had over 75% score for overall acceptance. The tent dryer was effective in producing stockfish that can compete favourably with the imported stockfish in terms of nutritional quality, food safety and sensory attributes. The use of the technology in Nigeria would reduce the huge amount of money being spent on importation of stockfish.

KEYWORDS: *stockfish, dryer, sensory quality, solar, whiting*

INTRODUCTION

Fish supplies a good balance of proteins, vitamins and minerals. It has relatively 10% calories content; hence its role in nutrition is recognized (Akande and Tobor, 1992). Fish and fish products constitute more than 60% of the total protein intake in adults especially in the rural areas. They are widely accepted on the menu card and form a much cherished delicacy that cuts across socio-economic, age, religious and educational barriers (Adeleye, 1992). Fish flesh is tender due to bundles of muscle fibres which are held together by fibrous material when heated (Fagade, 1992). According to Adebayo-Tayo *et al.* (2008) it is better digested than beef or other types of protein.

Nigeria has the resource capacity (12 million ha inland water and aquaculture) to produce 2.4 million MT of fish every year, with an estimated demand at 1.4 million MT which currently exceeds supply. However, despite this great potential Nigeria is still a major importer of fish (about 648,000 MT of fish annually) with domestic fish production estimated at only 496,700 MT from all sources (Abba, 2007). However, Nigeria still remains a big importer of fish. Nigeria, Italy and Croatia are the biggest importer of stockfish (whiting) *merlangius merlangius* in the world. According to Junaid *et al.* (2010), Nigeria has been importing large quantities of high grade stockfish not available locally from all over the world in the last few decades. The annual export of dried cod heads from Iceland are about 15,000 tonnes, mainly to Nigeria, where they are used for human consumption (Sigurjón, 2003).Whiting fish (*Merlangius merlangius)* called *Okporoko* and *Panla* among Southern and Western Nigerians respectively, is not only a tasty delicacy but also a costly soup material.

Fish is an extremely perishable food. It begins to spoil as soon as it is caught perhaps even before it is taken out of the water. Spoilage proceeds as a series of complex enzymatic, bacteria and chemical changes that begin as soon as the fish dies. This is why the fish become soft and the smell becomes more noticeable (Carruthers, 1986). In Nigeria, fish is eaten fresh, preserved or processed (Adebayo – Tayo *et al.,* 2008). Fish processing and preservation is carried out to slow down or prevent the enzymatic, bacteria and chemical deterioration to maintain the fish flesh (Carruthers, 1986).

Food preservation can be achieved by the removal of water from the food items since the microbial deteriogens require moisture for active growth including enzymatic hydrolysis of the food components (Ogbonna, 1987). Water occurs naturally on the fish's body and so drying is one of the simplest ways to preserve fish. It works by removing water from the fish which prevents the growth of micro-organisms and decay. In other to prevent spoilage, the moisture content needs to be reduced to 25% or less. The percentage will depend on the oiliness of the fish or whether it has been salted (Facts, 2004).Drying food using the sun and wind to prevent spoilage has been known since ancient times, water is usually removed by evaporation (air drying, sun drying, smoking or wind drying) but in the case of freeze drying, food is first frozen and then water is removed by sublimation.

Drying and salt-curing of fish have been used as preservation methods since ancient times for the purpose of product storage stability (months or even years under the right conditions). Traditionally, fish drying is done by laying the fishes on open beaches, roadsides, mats or even on the ground in open sun drying. However, this method has a lot of disadvantages such as contaminations, infestation and slow drying which results in low quality products (Gopakumar, 2002).

Stockfish is usually processed from Cod (*Gadus* spp) which boasts remarkable nutritional properties. Cod has long been highly appreciated as dried and/or salted product due to its high nutritional value (high protein and low fat content) and specific sensory properties (colour, texture, aroma, and a characteristic taste) imparted by these preservation methods (Heredia *et al*., 2007). The production process is resource friendly and beyond all doubt the least energy-demanding food manufacturing procedure in the world. All the nutrition of fresh fish remains in the dried fish, only the water is removed (Kurlansky, 1997).

For centuries, it was preserved by drying as stockfish and clip fish and traded as a world commodity. During the drying, about 80% of the water in the fish disappears. The stockfish retained all the nutrients of the fresh fish only concentrated. It is best known to be one of the richest sources of protein with the important B vitamin, Iron and calcium. Cod is moist and flaky when cooked and is white in colour. It has a mild flavour, low fat content and a dense white flesh that flakes easily (Kurlansky, 1997). According to Helena *et* al. (2012), salted cod is still considered a highly popular product due to high demand and simplicity of processing. This important and traditional product is highly appreciated in many countries, is mainly produced in Norway and Iceland, and is primarily consumed in Mediterranean countries such as Spain and Portugal, and also in Nigeria. Although different types of processes and equipment have been developed in Nigeria for fish processing (Olayemi *et al*., 2013; Kolawole *et* al., 2010; Davies and Davies 2009), the processing of "stock fish" as well as appropriate drying equipment still remains an area with little research.

This research work was aimed at developing a solar tent dryer for processing high quality stockfish that will command high acceptability and good price especially in supermarkets and fish markets in Nigeria. If the product is fully developed to commercial level, it will drastically reduce stockfish importation and empower some citizens of Nigeria. The amount of money been spent on importation of stockfish could be diverted into other economic sector of the country if local fish species available within Nigerian territorial water is fully harnessed into stockfish production. In order to achieve this, technology input is required to develop a good quality stockfish product that is widely acceptable. NSPRI has indentified some fish that could be processed into stockfish using standard developed methods. Cost benefit analysis of the technology has shown that an investor of the venture when fully developed would make 35 % profit margin and can breakeven within 12 to 15 weeks of production.

MATERIALS AND METHODS

Study Area

This study was carried out in the premises of Nigerian Stored Products Research Institute (NSPRI) headquarters in Ilorin, North Central zone of Nigeria. The experiment was carried out in November 2014. The average ambient temperature and relative humidity of the location at the period of the experiment were 33^{o}C and 42% respectively (NSPRI Agro-meteorological Station).

Materials and Methods

i. **Dryer:** A solar tent dryer was developed for the purpose of the study. The dryer has capacity to hold 25 kg fresh fish per batch. It was mainly fabricated of steel and polythene sheet. The tent dryer has dimension of 245 cm x 184 cm (L x B). The frame was constructed of galvanized pipe of 2.54 cm diameter while the rack was made of 37.5 mm x 37.5 mm angle iron. The dryer has two sets of trays with an interspacing of 82.5 cm. The first sets has two (2) trays of dimension 120 cm x 109 cm situated 77 cm from the floor while the second set consists of two trays of dimension 120 cm x 45 cm positioned 42 cm from the top of the dryer. The frame was covered with 0.25 mm thick polyethylene sheet. It is collapsible for ease and comfort of transportation. Openings which are underlay with a thin pvc mesh were provided at the base end for fresh air intake and at the angular top sides of the dryer for moisture laden air exit. The pictorial view of the dryer is presented as Plate 1.
ii. **Fish:** Whiting fish (*Merlangius merlangius*) was used for the experiment. The fish was sourced from a reliable fish marketer located within Ilorin metropolis and transported to the processing centre of Nigerian Stored Products Research Institute. The average weight of fish used for experiment was 200 g.
iii. **Fish Preparation and Drying:** The fish was gutted and thoroughly washed. Thereafter, the washed fish was brined (200 grams of salt to 5 litres of water) to give the stockfish good taste. The fish was allowed to drain before it was arranged on the drying trays. Positioning of loaded trays in the dryer and covering of the dryer with

polythene followed immediately. The dryer was situated in location where there was no possible obstruction of solar energy. The drying operation commenced immediately after the covering of the dryer.

iv. **Sampling Procedures:** Samples were taken prior the drying for initial moisture content and microbial load. Initial weight of loaded fish was taken and recorded. Moisture content of the fish samples was determined by oven drying method as described by Adebayo-Tayo *et al.* (2008). Weight of the fish was also taken every day throughout the experiment. This was accomplished using a digital weighing balance with an accuracy of 0.01 g (Avery Berkel- Averyweigh-Tromix HL122). The drying temperature of the dryer was monitored using a data logger (Tinytag™ TV-4104). The rate of moisture removal (drying rate) was calculated from the data recorded during drying. The drying rate was calculated using equation 1.

$$R = \left(\frac{dM}{dt}\right) = \frac{m_i - m_f}{t} \qquad 1$$

where;

R is the drying rate in g/hr, dM is the change in mass (g), dt is the change in time (hr) and t is the total time (hr). m_i and m_f are the initial and final mass of fish samples respectively in gram.

v. **Microbial Analysis:** The methods used were of the Association of Official Analytical Chemists (AOAC 1995) and the Compendium of Methods for the Microbiological Examination of Foods (Downes and Ito, 2001). Identification of Enterobacteriaceae and other species was made by commercially available biochemical tests, while taxonomic identification of the different genea and species was made according to microscopic criteria in accordance with appropriate keys (Pitt and Hocking 1997).

vi. **Sensory Evaluation:** The following food sensory quality parameters were employed to assess the quality of the dried fish samples: appearance, colour, texture, taste, flavour and aroma. A palatability test template used by Oyewole *et al.* (2013) was adopted. The template gave the panellists opportunity to choose from a range of options, which covered 'like extremely' to 'dislike extremely'. The options include; like extremely, like very much, like moderately, like slightly, neither like nor dislike, dislike slightly, dislike moderately, dislike very much and dislike extremely; and they were allocated 9, 8, 7, 6, 5, 4, 3, 2 and 1 mark respectively. Each of the panellists was given a test template. After the test, the result was extracted by collating the allocated point for each option chosen by the panellists. Thereafter, the average of the awarded score out of 10 mark by all the panellists was calculated for all the sensory quality parameters considered.

RESULTS AND DISCUSSION

Evaluation of the Solar Tent Dryer

The solar tent dryer was able to maintain an average differential temperature of 12 °C (the average ambient temperature was 35 °C while that of the dryer was 47 °C) during the drying test. This is an indication that the initial condition for drying (i.e. an air temperature that is higher than that of ambient) was achieved by the dryer and as such the fish samples were dried to desired moisture content within four days (Table 1). The tent dryer was able to dry fresh samples of Whiting (*Merlangius merlangius*) of 25 kg from average moisture content of 80.10% (wet basis) to a final weight of 5.42 kg with average moisture content of 10.13% (wet basis) for four days. The drying rate was higher for the first day because of the high initial moisture content of the fish with about 50% moisture content removed while for the following days the rate gradually reduces. This is in consonance with the previous works reported by Chavan *et al*., 2011 and Bellagha *et al*., that considerably high draying rate can be achieved with high drying temperatures especially at the initial drying period when the moisture content of the fish if high.

There was a constant rate drying period for the first 10 hours of drying (Figure 1). This was due to the condition of the drying air (air temperature, relative humidity and the air velocity) which was the predominant factors influencing drying during this period (Omodara *et al., 2012*). As the drying progresses the drying rate fell drastically after the 10th hour of drying. This is because at this point, the internal movement of water is the predominant factor influencing drying. The drying rate as expected is lower than that of the artificial or mechanical dryers due to the fact that the maximum temperature obtainable in the solar dryer is lower compare to temperature output of mechanical dryer. This is in line with the result of Babarinsa *et al.* (2011). However, the condition obtained during drying is desirable as it was able to produce the stockfish of the desired quality.

Microbial Analysis of the Fish Dried in the Tent

The result of the microbial analysis carried out on both fresh and dried samples shows a reduction in bacteria count from 6.8 to 3.9 CFU x 10^2. There was also reduction in fungi count from initial 3.6 to 2.7 CFU x 10^5. See Table 2 for the microbial load of the fresh fish and the dried samples. The initial microbial load from the fresh fish sample for the total viable count was 6.8×10^2 CFU/g while that of the total fungal count was 3.6×10^5 CFU/g. The final total bacteria count obtained from the fish dried in the solar tent was 3.9×10^2 CFU/g while that of fungal count obtained for the dried stockfish was 2.7×10^5 CFU/g.

The result obtained showed that the microbial load of the samples dried with the dryer were below the acceptable limit of 6.0 log10 CFU/g as recommended by the International Commission on the Microbiological Specifications for Food (ICMSF 1998). This is expected because the drying temperature of the solar tent was lower with longer drying time. The presence of fungi above recommended level as noticed in stockfish and other food samples available in the market might probably make the consumption of the stockfish hazardous to health as reported by Adebayo – Tayo *et al.* (2008) because they might contain metabolites produced by the fungi. However, the process the stockfish went through was able to keep the fungi present in the stockfish below the safe limit.

Sensory Evaluation of the Stockfish

Presented in Table 3 is the average result of the sensory attributes of the fish samples dried in the solar tent dryer. The appearance attribute of the fish was scored the highest point of 8.6, followed by taste with 8.4; while the least score of 6.8 was recorded against flavour. The overall acceptability of the product was 7.5. The appearance is appealing coupled with its irresistible taste and aroma. The average score for overall acceptance of the product evidence why people were demanding for more in the course of the evaluation. Dried samples used for the test are shown in plate 2. . The analyses carried out so far prove that the stockfish is safe to take without further processing unlike the imported stockfish that lack most of these qualities, and is also highly contaminated as reported by Junaid *et al.* (2010).

CONCLUSION

The technology is capable of producing stockfish of good quality that could command higher economic value. The output (stockfish) of the solar tent can compete favourably with the imported stockfish in terms of food safety, nutritional and sensory qualities. This would reduce the huge amount of money been spent on importation of stockfish if not totally stopped. This is another means of job and wealth creation for the teeming populace while the lovers of stockfish now have access to freshly processed products that would not endanger their life.

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Table 1: Result of performance evaluation of the solar tent dryer

Day	1	2	3	4	Average
Average Drying Rate (Kg/hr)	1.39	0.32	0.29	0.17	0.54

Table 2: Avearge microbial load of fish dried in the solar tent dryer

Wet		Dried	
Bacteria CFU × 10^2	Fungi CFU × 10^5	Bacteria CFU × 10^2	Fungi CFU × 10^5
6.8	3.6	3.9	2.7

Table 3: Result of sensory evaluation of dried fish

Appearance	Colour	Texture	Taste	Flavour	Aroma	Overall Acceptability
8.6	8.3	7.0	8.4	6.8	7.0	7.5

Plate 1: Pictorial view of the solar tent dryer

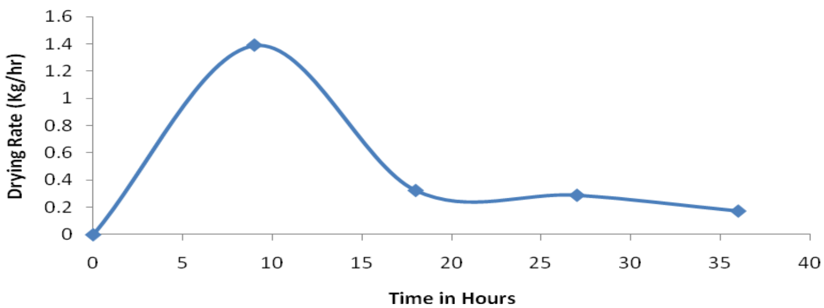

Figure 1: Drying rate curve of the fish dried in the solar tent dryer

ASSESEMENT OF QUALITY AND MASS LOSS OF SORGHUM (*Sorghum Bicolour L. Moench)* STORED IN METALLIC SILOS IN MINNA, NIGERIA

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ABSTRACT:

This research assessed the quality and mass loss of sorghum stored in metallic silo, in Minna, Nigeria for a period of eight months. The grain stock in the silo facility was managed using integrated grain management procedures (IGM) in metallic silos. A 2,500 metric tonnes capacity metallic silo out of 10 numbers assembled in a battery form was loaded with red coloured sorghum (*Sorghum bicolour*) SAMORG-14 variety. Samples were taken randomly from the bulk and analysed before binning which will serve as control and subsequently on monthly basis, at designated depth and locations. The samples were analysed using standard methods. The quality and mass characteristics assessed within the period, include moisture content (MC), bulk density (BD),carbohydrate (CHO), crude fat (F), ash (A), crude protein (CP), crude fibre (CF), germinability (G), and Energy value (EV). Data generated were analysed using Statistical package for social sciences (SPSS) and Duncan's multivariate test. Values obtained were compared with the control values. The result of this study shows that all the quality and mass characteristics evaluated are significant ($p<0.05$) with duration of storage. The following parameters depreciated from the control within the duration of storage, F (3.5%-1.4%), BD (98kg/m^3-91.3kg/m^3), CP (11.42%-6%), A (2%-1.15%), CF (4.76%-3.24%), MC (9.0%-6.98%), G (99%-86.4%) This may be due to fluctuations in storage conditions, grain respiration, age and shrinkage. The results also revealed that EV (366.6kcal-404.3kcal) and CHO (76.6% -79.2%) increased significantly ($p>0.05$) from the control within the 8 months duration of storage, probably due to continuous loss of moisture and the depreciation of other variables. The quality and mass characteristics of sorghum stored in metallic silos in Minna, Nigeria is significantly affected by duration of storage.

Keywords: *metallic silos, sorghum, storage losses, degenerating changes in storage, stored grain ecosystem*.

INTRODUCTION

Sorghum (*Sorghum bicolour L. Moench)* is a major cereal grain that is widely grown and stored in Europe, America, Asia and Africa. It is an integral member of grass family called (*Poaceae*). It is the fourth most important world cereal and the second most important cereal after maize in Sub-Saharan Africa (IITA, 2009; Nukenine, 2010). Sorghum (*Sorghum bicolour*) seems to have originated from the Sahel/dry lands of Sub-Saharan Africa, and diffused to other areas such as the Middle East, Asia, Europe and America through the slave traders. It ranks second to maize as the most popular cereal grain planted and stored in Nigeria (FAO, 2009). Nigeria is the second largest producer of sorghum in the world, and highest producer in Africa with 9 million metric tonnes per annum (IITA, 2009). The world sorghum economy and storage consist of two distinct sectors; a traditional, subsistent smallholder farming sector where most production are consumed as food (mainly in Africa, Middle East and Asia) and modern mechanized large scale sector where output is largely used for animal feeds in the developed countries (Iren, 2006). The grain consists of a naked caryopsis, made up of a pericap, endosperm and germ as shown in Plate 1, although there is a huge range of diversity. Sorghum is classified into four groups namely, grain sorghum, forage sorghum, grass sorghum, and Sudan sorghum. They are grouped using the colour of the pericap (white, yellow, or red). Sorghum is rich in protein and carbohydrate; other constituents include lipids, vitamins and minerals (Mc Kevith, 2013). As one of the grains with huge protein content, it is being relied upon as a cheap source of plant protein for human consumption especially in the developing countries where animal protein is increasingly becoming unaffordable (Vassal, 2000). In Savannah and the arid region of Africa, millions of people consume sorghum in their daily diets. It constitutes a staple food high in energy. It is an environmental friendly and water efficient plant; its ability to be grown in extremely harsh climates with little or no amount of fertilizer and pesticide makes it peasant farmers friendly.

Plate 1: Sorghum *bicolour*

Sorghum can be stored in a wide range of grain storage structures all over the world depending on, available resources, intended use of the grains, climate, storage duration, capacity, available technology and culture, but are stored in commercial quantity in metallic silos (Okolo, 2013). At farmers' level in Africa where output is low, it is mainly stored with traditional storage structures while in developed countries where individual output is high, modern storage structures are used (Adejumo and Raji, 2007). As a hygroscopic and biological active material, its interaction with the immediate environment during storage is ongoing. In bulk storage of sorghum in metallic silos, especially for long period in the tropics where moisture condensation and migration are imminent, certain degenerating changes are expected to occur that will certainly affect the quality and mass characteristics. Irrespective of the integrated bulk grain management strategies, the extent of the degeneration of the grains is largely dependent on the Grain storage factors such as physical, biological, and climatic. Climatic variables known to influence storability of cereal grains in metallic silos include temperature, humidity, rainfall or precipitation, solar radiation and wind (Ileleji, 2010).

The characteristics and behaviour of the structural materials used for the construction of any silo, in respect to solar radiation and thermal conductivity are also important factors towards successful storage. However, it is known that daily variation of ambient temperature determines the temperature gradient across the walls of the silo, the head space and inside the grain mass. Higher temperature will invariably result to more moisture condensation on the metallic silo walls (Alabadan, 2002). Humidity as a variable also affects the physiological response of stored grain and organism/pest in the storage bin. Wind speed and direction and size of ventilation openings also play an important role in the thermal state/regime and stability of metallic silo temperatures (Alabi, 2001). The rainfall pattern in any geo-ecological zone no doubt plays an important role in the thermal stability/regime of metallic silos, especially during the raining seasons, since rainfall affects relative humidity of the ambient air directly, and considering high thermal conductivity characteristics of metallic silos. If a metallic silo is porous, it will be even worse because moisture will the transmitted into the silos directly and as well as the grain mass. However, with proper monitoring and control of all these variables mentioned, enormous storage losses associated with sorghum storage in metallic silos can be minimized. Minna is located in the Northern Guinea Savannah agro-ecological zone of Nigeria. The dry season lasts between November and March with the on-set of rain usually around April. The average monthly temperature ranges between 28.5°C around the wet season of August to 38.9°C in the dry season of February and March giving a range of 10.4°C. The corresponding average monthly rainfall is usually about 409 mm in August and none in February and March. These climatic variables will encourage moisture migration and condensation as far as storage of grains in metallic silos is concerned but prolonged dry season observed will also ensure that grains are kept dry and at safe moisture content level (Alabi, 2001).

Integrated bulk grain management in metallic silos (IGM) includes the use of a wide range of grain management procedures to maintain the quality of stored grain in metallic silos (McNeil, 2010). The main objectives of IGM are basically using the most cost effective ways of maintaining the quality of grains in storage, without harming either the environment or the grains, and the grains still kept fit for human consumption. The procedures as mentioned above include, non-compromise of standards during grain reception, sanitation of the grain facility, record keeping, monitoring and control of stored grain ecosystem, integrated pest management (IPM), regular physical inspection and analysis of grains, grain turning and workers health and safety.

Monitoring and control of stored grain ecosystem, entails monitoring variables like temperature, humidity with industrial measuring devices and controlling them using aeration fans, dehumidifiers, and grain turning. However, IPM can be defined as the use of all available methods/knowledge to keep pest population below economical damaging levels in a manner that is profitable and causes no harm to human health and the environment (Opit, 2010). IPM is the most important aspect of grain management due to the complex nature of insect morbidity, development of resistance to chemicals, the emergence of new species, and chemical residues left on grains as they are treated with insecticides.

METHODOLOGY

The experiment was carried out in Strategic Food Reserve Silos Complex in Minna, Niger State Nigeria. Red coloured variety, SAMSORG-14 (*Sorghum bicolour*) used for this research was sourced within local markets in Niger State, by Government accredited suppliers. The grains are from the present harvest and have not undergone any form of storage before supply to the silo facility. Standard procedures were followed during the grain reception, which include sampling, analysis of the grains to check if it meets up to the FAO standard, for bulk grain reception, in which the consignment may be accepted or rejected. The accepted grains were cleaned and weighed using a set of cleaner, aspirator and a weighbridge. Online fumigation was carried out on the grains using a tablet dispenser before binning. The accepted grains were loaded in 2,500 metric tons metallic silo cells using grain handling equipment such as elevators, augers, conveyors chutes and sprouts. The silo cells were assembled in a battery form in an open space. Samples were taken at random, before loading (binning) to determine the initial properties of the red sorghum, which also served as control. Subsequent samples were taken on monthly basis for a period of eight months, with the aid of a sampling probe, 3 metres beneath the surface of the bulk, from 9 designated well-spaced positions/locations. The samples were mixed thoroughly to get a through representative sample. The experiment ran from January to August, 2015 spanning through the wet and dry season prevalent in Northern Guinea Savannah agro-ecological zone of Nigeria. Samples were analysed using standard methods and destructive method of analysis, in National Cereal Crop Research Institute, laboratory Badegi, Niger State. The temperature and relative humidity of the storage environment were also monitored within the period. The position of the silo cell used in the battery arrangement, the sampled position and the dimensions of the silos used are illustrated in Figures 1, 2a and b. Evaluation of data from was done using Statistical Package for Social Sciences (SPSS). Multiple Analysis of Variance (MANOVA), and Duncan's multivariate test was used to determine levels of significance of variables, and trends of deterioration or appreciation from the control, for all the values obtained in respect of duration of storage.

Immediately after bining, the grains inside the silo were levelled for easy access, performance of various tasks and silo inspection in accordance with IGM. The height of the grains in the metallic silo is 8 m from the silo base. Each silo cell has aeration facilities, temperature monitoring and control systems, inspection window/manhole, internal ladders and roof vents. Within the period of this research work, the grains were fumigated thrice and each time with methyl bromide fumigant (phostosin) and grain surface protectant (coopex dust) used to protect the grain surface from in-flight insects. The 2,500MT metallic silo is a product of Chief industries Nebraska USA installed in 1989, Aeration of the sorghum was carried with two non-mobile centrifugal aeration fan with air flow rate 0.03 cfm (cubic feet air per minute) installed in parallel position in a double (T) silos floor layout. The aeration was carried out at irregular intervals, especially whenever grains temperature reading indicates abrupt increase, but averagely twice in a week and for 30 minutes each time.

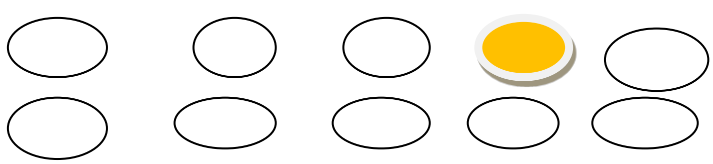
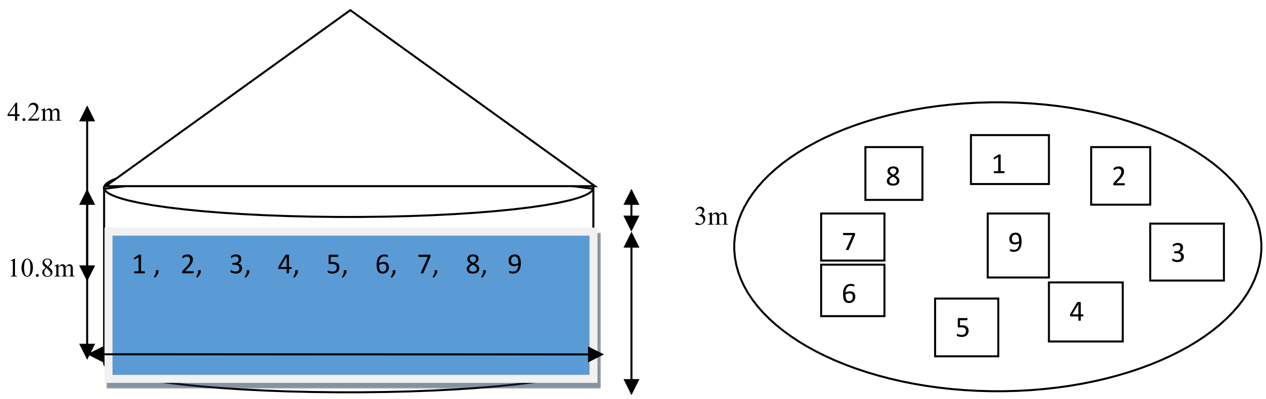


Figure 1: Position of the 10 silo cells in battery and the shaded one, used for the research



(2a) (b)

Figure: 2a Dimension of the silo used. (b) The sampling positions inside the metallic silo

Determination of quality and mass characteristics of the stored sorghum

Various samples analysed were carried out following detailed steps and the use of different customized laboratory equipment meant for each parameter/variable. However the final values were obtained using simple calculation meant for each of the variables, in accordance with (AOAC, 2006). Moisture content of the samples was determined using (oven method). The bulk density was determined by simple weighing of grains inside a known volume container in the laboratory, in accordance with the standard approved by (AOAC, 2006). The values were further confirmed using multi grain analyzer and hectolitre meter.

The Crude protein (CP) was estimated using standard Kjeldehl block digestion and steam distillation operation procedures. The ash and mineral contents was determined by simple weighing samples, incinerating the samples in a muffle furnace to about 550°C, cooling and re-weighing. The crude fibre content was determined using Erlenmeyer flask, while Crude fat content was determined by Soxtec extraction (ether extract/fat analysis) methods respectively. The germinability was determined using Napkin-dampen and wrap method. The carbohydrate and energy values were determined by simple calculation from other variables known, in accordance with (AOAC, 2006).

RESULT AND DISCUSSIONS

Within the period of this experiment, temperature and relative humidity of the immediate environment fluctuated due to prevailing unstable climatic conditions as presented in Table 1. At period of regular rainfall the humidity increases while temperature decreased significantly and the reverse was the case during extreme dry conditions. The monthly deviation of each variable from the control is presented in Table 2

Table 1: Average monthly temperature and relative humidity data within the period of the experiment from January to August 2015

MONTH	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
R.H	55	53	52	52	71	68	69.8	69
TEMP T(^{O}C)	34.5	34.2	34.2	34.7	32	30	29.0	30.0

The result of this research and the graphical illustration in Figures 3 and 4 shows that the following variables, CFAT, BD, CP, AC, CF, MC, Na and Mg decreased with duration of storage while EV and CHO increased with duration of storage. They are significantly dependent on the duration of storage with varying deviations from the control ($P < 0.05$) for all the values obtained for each variable. The Crude fat content had a downward progression which may be due to degradation of fatty acids during drying process. The direct implication is the reduction in baking quality. The Bulk density reduction has direct effect on the mass and weight of the grain, and this is due to the reduction of moisture content. BD is a critical factor especially when the basis of sales and grading of grains are done on weight basis. The Crude protein content also showed a significant decrease with the duration of storage. The high storage temperature inside the silo bin and the immediate environment may be responsible. This is also expected to facilitate the denaturation or degeneration of gluten which is responsible for visco elasticity (Gupta, *et al*., 2013).

Table 2: Monthly mean deviation of variables from the control

	MC	BD	CP	CA	EV	CHO	CFAT	CF	G	Na	Mg
Control	9	98	11.42	2	366.6	76.6	4.76	3.5	99	3.12	1.96
JAN	0.1	0	1.21	0.1	-17.4	0.5	0.09	0.3	0	0	0.36
FEB	1.8	1.5	2.22	0.2	-22.4	0.6	0.64	0.7	2	0.82	0.44
MAR	2.1	4.8	3.26	0.4	-22.6	-0.4	0.64	0.6	2.7	0.82	0.48
APR	2.08	5.2	1.72	0.5	-24.7	-1.2	0.95	2	7	0.97	0.58
MAY	2.5	7.2	2.62	0.75	-25.2	-1.2	0.85	1.5	8.8	0.97	0.56
JUN	2.2	7	4.72	0.7	-25.5	-1.3	0.76	1.9	8.6	0.97	0.56
JUL	2.08	6.4	4.71	0.75	-25.8	-1.9	0.76	2.02	8.9	1.01	0.56
AUG	2.02	6.7	5.42	0.85	-37.7	-2.6	1.52	2.1	12.6	1.01	0.55

Positive values means there a decrease from the control while Negative values means there is an increase from the control

However, FAO (2010) upheld that crude protein content of cereal grains stored under good condition, devoid of insect infestation and mould is not altered by seed respiration during long storage. The result of the statistical analysis also shows that crude ash content and germinability of the stored sorghum are significantly affected ($P < 0.05$) by duration of storage at (2.0%-1.15%) and (99%-86.4%). What could be responsible is insect infestation, in which appreciable percentage of the grains are eaten up by insects. The effect of higher temperature inside the silo bin and head space could also reduce thiamine content (important vitamin which acts as co-enzyme in various energy transfer biochemical reaction during metabolism) (Gupta, *et al*., 2013).

Crude fibre content reduction from 3.5% to 1.4% during the 8 months of storage is very significant, and may be attributed to lipid hydrolysis, due to oxidation, seed respiration and other enzymatic processes/actions; germinability could depreciate due to insect activity, mould activity and heat (Faure, 1988).

Energy value and Carbohydrate content are significantly affected by duration of storage, considering the difference between control value and the values of variables after 8 months of storage (366.6 kcal-404.3kcal) and (76.6%-79.2%) as shown in Figure 3. This may be due to the reduction of MC/shrinkage and other variables since they are expressed as percentage of the whole (Brooker, *et al*., 1995). The assessed mineral contents Na and Mg also evaluated also depreciated within the 8 months of storage as illustrated in Figures 3 and 4, and this could be due to high temperature, inside the bulk of grain and the head space.

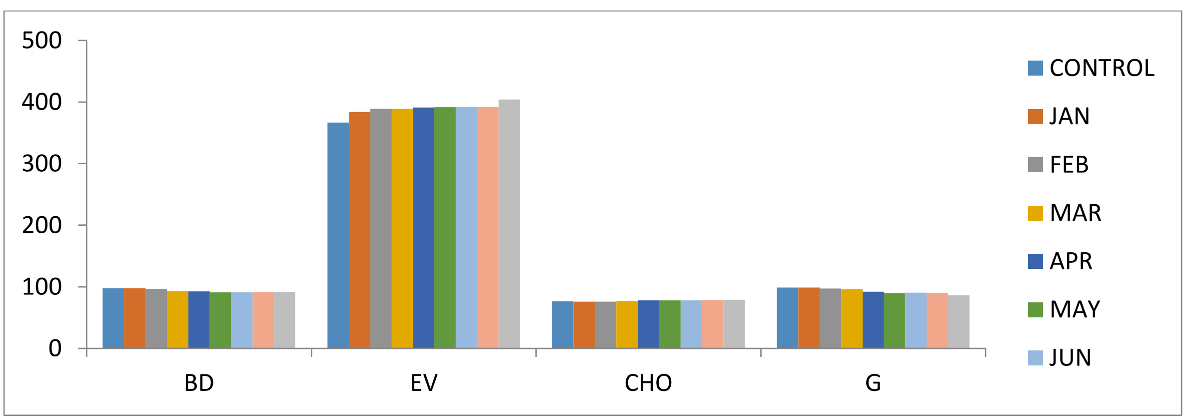


Figure 3: Average monthly percentage BD, EV, CHO, and G in respect to storage duration

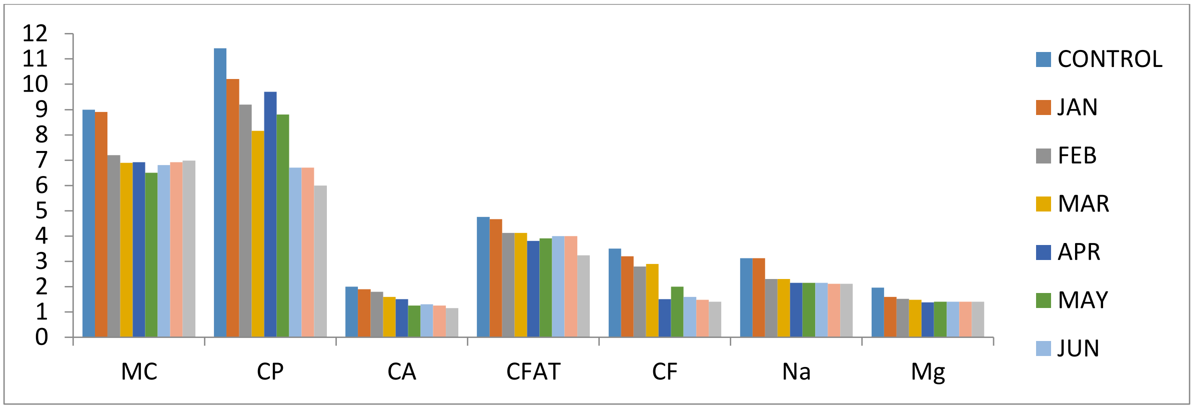


Figure 4: Average monthly percentage MC, CP, CA, CFAT, CF, Na, Mg, with respect to storage duration

CONCLUSION

The results of this research shows that quality and mass characteristics of sorghum stored in 2500 metric tonnes metallic silo, in Minna, Nigeria are significantly affected, by the duration of storage. Apart from the Carbohydrate and Energy value in which significant increase were recorded, all other mass and quality characteristics depreciated significantly within the 8 months duration of storage. The efficiency of metallic silos for bulk storage of sorghum in the tropics, as well as its impact in the quality and mass characteristics is largely dependent on storage conditions and its management, due to prevalent moisture migration and condensation issues. However with the provision of good storage conditions and management, the use of metallic silos for bulk storage will go a long way to aiding agricultural independence, storage of enormous paddy/cereal agro-raw material as well as enhancing food security in the developing countries.

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DETERMINATION OF PYSICO - MECHANICAL PROPERTIES OF THE AFRICAN OIL BEAN SEED (*PENTACLETHRA MACROPHYLLA)*

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ABSTRACT

Some Physical, and Mechanical properties of the African oil bean seed (pentaclethramacrophylla) were determined as a preliminary step towards the development of processing and handling equipment. These properties include physical size, arithmetic mean diameter, geometric mean diameter, volume, density, aspect ratio, surface area, sphericity, bio-yield and rupture force. Seeds were categorized into large, medium and small samples at a moisture content of 8.73% (d.b). From the results obtained, large samples had major, intermediate and minor diameters ranging from 58.50mm – 75.15mm, 38.50mm – 53.05mm and 8.25mm – 13.56mm respectively. For medium samples, the major, intermediate and minor diameters ranged from 42.05mm – 70.01mm, 30.91mm – 49.25mm and 8.00mm – 11.92mm respectively. Similarly, small samples had major, intermediate and minor diameters ranging from 32.00 – 62.45mm, 4.01mm – 13.95mm and 6.59mm – 32.28mm respectively. Furthermore, other properties were determined to be sphericity 0.3079mm – 0.6872mm; volume 7.01cm^3 – 21.07cm^3; density 0.353g/cm^3 – 1.928g/cm^3; aspect ratio 0.197 – 1.011 and weight of each seeds ranged from 9g – 26.7g; the rupture force was highest at 5,053.00N when the seed was loaded along its minor diameter (natural rest point) axis, 483.00N when loaded along its intermediate diameter (transverse) axis and 99.00N when the seed was loaded along its major diameter (longitudinal) axis. It was noted that the force required to initiate seed rupture decreased as moisture content increased, this can be attributed to the fact that at higher moisture content, the seeds were softer and required less force.

Keywords: Physical, Mechanical, Properties, African oil bean seed (*pentaclethramacrophylla*)

INTRODUCTION

African oil bean *(Pentaclethramacrophylla)* is locally referred to in South-Western Nigeria as *Apara* and *Agiri* in South-Eastern Nigeria. It is a leguminous tree (family *leguminosae*; sub-family *mimosoideae*) and recognized by peasant farmers in the South East of Nigeria for its soil improvement properties (Akindahunsi, 2004). Its tree grows to about 21m in height and up to 6m in girth. It has a characteristic low branching habit and an open crown, which allows substantial light under its canopy hence, it is used in combination with other food crops on farms and particularly in home gardens in South-eastern Nigeria. It has a crooked bole with low wide buttresses. African oil bean tree has a grayish to dark reddish-brown bark, thin flaking off in irregular patches. It has leaves with a stout angular common stalk about 20-45cm long and covered with rusty satellite hairs and consists of between 10 and 12 pairs of stout opposite pinnae. Its leaflets, are in the shape of a parallelogram and are practically glabrous. Its flowers are creamy-yellow or pinkish white and sweet smelling is crowded in narrow spikes and flowering occurs twice in a year: January-May and July-December. Its (fruits) pods are persistent, 35-45cm long and 5-10cm broad, widest at the upper end, rounded at the apex, blackish in colour, very hard, woody, splitting open explosively and valves curling up as well as containing between 5 and 8 flat glossy brown edible seeds up to 7cm long. The wood of the plant is reddish-brown and very hard. Many researchers have investigated and found that this oil seed contains 23-28% protein, the twenty (20) essential amino acids and essential fatty acids. Moreover, the seeds when cooked, processed and fermented can be used for the preparation of many delicious delicacies including African salad, soups and sausages. Also, the plant is used as salt substitute, charcoal, carvings, seed craft, dye, mild poison, medicine against convulsion, abortion, diarrhea, infertility, wound treatment, lactogenicity, for ornamental as well as fencing purposes and as timber. (Akindahunsi, 2004).

In spite of the economic importance of the African oil seed as enumerated above there is little knowledge about its physico-mechanical properties pertinent to design of machines required for processing the seed.

In order to design equipment for planting, processing, handling, harvesting, transportation, storage and oil extraction of African Oil Bean Seed (*Pentaclethramacrophylla*), it is necessary to know its physical and mechanical properties.

The knowledge of these properties of the seeds plays a vital role in the design and construction of any agricultural machinery either during preservation or processing. Therefore, there is a need for the study of physical and mechanical properties of agricultural materials. This research was limited to determination of the following physico-mechanical properties; shape, size, arithmetic mean, geometric mean, volume, density, aspect ratio, area, sphericity, bio-yield and rupture force.

METHODS AND MATERIALS

Material

Samples of African oil bean seeds were obtained from open markets in Kwara and Kogi States of Nigeria. The seeds were manually cleaned to remove defective ones and other foreign materials and then labeled before conducting the test. After the seeds were cleaned, it was observed that they differ in sizes. There was therefore the need to classify the seeds into three distinct categories; small, medium and large. Moisture content at purchase was determined on dry basis following International Seed Testing Association procedure and using the ASAE 1999 Standards.

Methods

Physical dimensions of seeds

One hundred seeds were randomly taken and each seed was measured for its length (major diameter), width (intermediate diameter) and thickness (minor diameter), using a Godmarchvernier caliper with 0.01mm accuracy.
Each seed was placed between the outside jaws of the caliper to measure the length along the major axis of the seed. Equatorial diameter was measured such that it was perpendicular to the length of the seed while the breadth was measured to be perpendicular to both the length and the equatorial diameter.

Arithmetic mean diameter

Arithmetic mean diameter of the African oil bean seeds was determined using the Sirisomboon *et al*. (2007) and Prandhan *et al*. (2009) methods.

$$D_a = \frac{a + b + c}{3} mm$$

where,
a is the major diameter, **b** is intermediate diameter and **c** is minor diameter of the seed.

Geometric mean diameter

The geometric mean diameter was also determined from the physical dimensions of the seeds. It was obtained from the (Sirisomboon *et al*., 2007; Prandhan *et al*., 2009) relationship:

$$D_g = (abc)^{1/3} mm$$

where
a is the major diameter, **b** is intermediate diameter and **c** is minor diameter of the seed.

Sphericity

Sphericity of the seeds was determined from the equation given below, which has been used by other researchers (Sirisomboon *et al*., 2007; Prandhan *et al*., 2009). It is defined as:

$$\text{Sphericity (S)} = \frac{(a.b.c)^{1/3}}{a} \quad (3)$$

where,
a is the major diameter, **b** is intermediate diameter and **c** is minor diameter of the seed.

Surface area

Surface area of the seeds and kernels were calculated using the following equations (Jain and Bal, 1997; Bart-Plange and Baryeh, 2003):

Surface area $= \frac{\pi \mathrm{da}^2}{(2a - \mathrm{d})} mm^2$ (4)

where,

a is the major diameter, **b** is intermediate diameter and **c** is minor diameter of the seed.

d = $(bc)^{0.5}$ (5)

Aspect Ratio

The aspect ratio, Ra, was computed using the following relationship (Altuntas *et al*., 2005; Sharma *et al*., 2011):

$$\mathrm{Ra} = \frac{\mathrm{b}}{\mathrm{a}} \quad (6)$$

where,

a is the major diameter, **b** is intermediate diameter of the seed.

Volume and Density

The volume of each seed was determined by the water displacement method. Each seed was immersed in a graduated measuring cylinder with water present in it. The volume of water displaced when the seed was immersed was taken to be the volume of each seed.

To determine the density, a weighing balance (Scout pro, OHAUS) was used to weigh each seed and the ratio of the weight to the volume gives the density.

Mechanical properties

Bio-yield and Rupture Point

139 seeds were randomly taken. The initial moisture content of seeds at purchase was noted and in order to achieve the desired moisture levels of 15.96, 19.91, and 34.50%, the rewetting formula was used. To allow the samples absorb moisture, they were placed in refrigerator.

$$Q = \frac{W_i(M_f - M_i)}{(100 - M_i)} \quad (7)$$

where,

Q is mass of added water; W_i is the mass of sample; M_f is the final moisture content; M_i is the initial moisture content The bio-yield and rupture point was determined by carrying out a compression test on the seeds using a Universal Testing Machine (UTM) at test speed of 10.00mm/min and individual seeds were loaded on their natural (rest), transverse and longitudinal orientation The UTM produced the force-deformation curve on each revolution of the force arm until the seed ruptures. The force at bio-yield and rupture point were recorded from the force-deformation curve.

RESULTS AND DISCUSSION

Physical properties

Results of physical properties determined are presented below.

Size

The largest category of the samples has the highest intermediate and major diameters ranging from 38.56mm to 53.05mm and 58.50mm to 75.15mm respectively with average values of 45.01±4.545mm and 67.23±5.302mm respectively followed by the medium sample which has its diameters with the range of 30.91 to 49.25mm and 42.05mm to 70.01mm respectively with average value of 39.92±4.34mm and 58.220±7.455 mm, then the small sample with range of 4.01mm to 13.95mm and 32.00mm to 62.45mm respectively with average value of 30.59±48.80mm respectively. These results show that the major diameter has the highest value followed by the intermediate and the minor diameter as shown in Table 1.

Shape and Sphericity

The sphericity of the seeds ranged from 0.417 to 0.534 for large seeds, 0.307 to 0.627 for medium seeds and 0.468 to 0.687 for small seeds with average values of 0.473±0.0343, 0.4929±0.056 and 0.557±0.0584. It was observed that sphericity varies with seed sizes. The shape of the African oil bean seed is irregular, elliptical and flattish with minor diameter about 20% of the major diameter and cannot roll. This is confirmed by the low values of sphericity as shown in Table 2.

Table.1: Physical properties of African oil bean seed

Properties	**Sample size**	**Mean value**	**Minimum value**	**Maximum value**	**Median value**	**Standard deviation**	**Variance**
Small samples							
Minor diameter	27	11.24	6.59	32.28	9.59	6.12	37.32
Intermediate	27	30.59	4.01	13.95	31.08	6.99	48.80
Major diameter	27	42.52	32.00	62.45	42.01	6.3928	40.87
Medium samples							
Minordiameter(mm)	59	10.174	8.00	11.92	10.35	1.986	3.947
Intermediate diameter	59	39.923	30.91	49.25	40.155	4.337	18.815
Majordiameter (mm)	59	58.220	42.05	70.01	59.00	7.455	55.586
Large samples							
Minor diameter	14	10.73	8.25	13.56	10.87	1.19	1.42
Intermediate	14	45.01	38.56	53.05	43.96	4.55	20.66
Major diameter	14	67.23	58.50	75.15	55.78	5.30	154.76

Table.2: Physical properties of African oil bean seed for sphericity

Sphericity	Sample size	Mean value	Minimum value	Maximum value	Median value	Standard deviation	Variance
Small samples	27	0.557	0.4683	0.6872	0.570	0.0584	0.0030
Medium sample	59	0.4929	0.3079	0.6273	0.4881	0.0565	0.0031
Large samples	14	0.473	0.4178	0.5341	0.470	0.0343	0.0011

Surface Area

Seed surface area ranged from 29.36cm^2 to 44.56cm^2 with about 79% having surface areas between 33.00cm^2 and 40.00 cm^2. Only about 6% of the seeds have surface area greater than 40.00 cm^2, most of them from the small size category. Small sized seeds have the largest surface areas and surface area increased with decrease in seed size as shown in Table 3.

Density

Seed density ranged from 0.814928g/cm^3 to 1.928g/cm^3 for the large seeds, 0.455928g/cm^3 to 1.792928g/cm^3 for medium seed and 0.352928g/cm^3 to 1.386928g/cm^3 for the small seeds with average values of 1.327±0.353928g/cm^3, 0.969±0.326928g/cm^3 and 0.691±0.234928g/cm^3, the large sized seeds had the highest seed densities ranging from 0.814928g/cm^3 to 1.928g/cm^3 respectively as shown in Table 3.

Volume

Large samples have the highest volume, displacing larger amount of water followed by the medium and then small samples with value ranges of 9.9cm^3 to 21.06cm^3, 7.24cm^3 to 19.09cm^3 and 7.01cm^3 to 12.87cm^3 with average values of 15.10±4.47cm^3, 14.67±3.36cm^3 and 10.68±1.95cm^3 respectively as shown in Table 3.

Weight

The weight of each seeds ranged from 8.13g to 14.15g with average value of 11.32±2.55g for small seeds, 9.14g to 20.54g with average value of 13.408±2.979g and 10.72g to 22.21g with average value of 18.821±3.378g as shown in Table 3.

Geometric mean diameters

Geometric mean diameter ranged from 29.479mm to 35.138mm with average value of 31.68±1.47mm for large seeds, 21.097mm to 32.810mm with average value of 28.36±2.36mm for medium seeds and 19.461mm to 30.888mm with average value of 23.29±2.39mm for small seeds respectively as shown in Table 3.

Arithmetic mean diameters

The arithmetic mean diameter ranged from 38.98mm to 46.15mm with average value of 40.99±2.14mm, 28.95mm to 41.33mm with average value of 36.10±3.25mm for medium seeds and 22.45mm to 38.12mm with average value of 27.93±3.06 for small seeds respectively as shown in Table 3.

Mechanical Properties

The mechanical properties are presented in Tables 4 to Table6. The mechanical properties include force at peak (the maximum force which the seed can withstand without cracking), force at break, deformation at break, force at yield (bio-yield point), deformation at yield and deformation at peak, The effect of moisture content on bio-yield point and rupture force of African oil bean seed under natural, transverse and longitudinal loading orientation for small, medium and large samples are as presented in Figures 1 – 6.

Bio-yield point

The bio-yield force of the seed was taken as the point on the deformation curve, at which the visible failure of the seed became initiated and the seed began to tear and the force to tear the seed for minor, intermediate and major values are 1,692.3N, 245.3N and 317.2N for small sample with 3,025.9N, 245.5N and 317.2N for medium samples and 1,692.3N, 245.3N and 317.2N for large samples respectively.

Fig.1 to Fig 3 show that as moisture content increased bio-yield point reduced. The variation of bio-yield force with moisture content when loading in its natural, transverse and longitudinal orientation which shows that the yield force decreased from 2,652.00N to 1,072.00 N, 445.00N to 85.00 N and 842.00N to 71.00N for small samples, 5,035.00N to 1244.00 N, 579.00N to 19.00 N and 602.00N to 89.00N for medium sample and 2,652.00N to 1,072.00 N, 445.00N to 85.00N and 842.00N to 71.00N for large samples respectively are shown in Fig. 1 to Fig 3.

Rupture point

The rupture point was taken as the point on the force-deformation curve, at which the compressed seed became completely broken and the force to break the seed for minor, intermediate and major average values are 1,703.8N, 238.0N and 299.8N for the small samples, 3,242.9N, 245.5N and 199.1N for the medium samples and 1,703.8N, 238.0N and 299.8N for the large samples, as observed from Table 4 to Table 6. Fig.4 to Fig. 6 similarly show that as moisture content increases, rupture force reduced. The force required to initiate seed rupture decreased from 2,635.00N to 1,062.00N, 441.00N to 13.00N and 842.00N to 16.00N for small sample, 5,035.00N to 1,244.00N, 483.00N to 34.00N and 473.00N to 74.00N for medium sample and 2,635.00N to 1,062.00N, 441.00N to 13.00N and 842.00N to 16.00N for large sample in the natural, transverse and longitudinal axis with increase in moisture content from 15.96 to 34.50% respectively. It was also observed from Fig. 7 that the rupture force was greater with value of 5,053.00N when loading the seed along its natural rest position (minor diameter).

A similar trend was reported by Saiedirad *et al* (2007) in their work on the mechanical properties of cumin seeds that the force required to initiate seed rupture decreased from 5.7 to 15 % and attributed this to the fact that at higher moisture content, the seeds were softer and require less force.

Table.3: Physical properties of African oil bean seed this caption is the same as for Table 1

	Sample	Mean	Minimum	Maximum	Median	Standard	Variance
Area (cm^2)							
Small samples	27	39.57	36.84	44.01	38.76	2.130	4.540
Medium sample	59	36.975	32.18	44.56	36.87	2.138	4.573
Large samples	14	33.022	29.36	37.04	32.37	2.703	7.309
Density(g/cm^3)							

Small samples	27	0.691	0.352	1.386	0.669	0.234	0.055
Large samples	14	1.327	0.814	1.928	1.348	0.353	0.124
Medium sample	59	0.969	0.455	1.792	0.920	0.326	0.106
Small samples	27	10.818	7.13	13.26	11.05	1.864	3.475
Medium sample	59	14.673	7.24	19.09	14.99	3.368	11.348
Large samples	14	15.102	9.90	21.06	14.745	4.473	20.008
Weight (g)							
Small samples	27	7.396	8.13	14.15	7.2	2.551	6.511
Medium sample	59	13.408	9.14	20.54	12.95	2.979	8.876
Large samples	14	18.821	10.72	22.21	18.35	3.378	11.415
Geometric mean diameters (mm)							
Small samples		23.298	19.461	30.888	23.458	2.390	5.716
Medium sample		28.367	21.097	32.810	28.537	2.361	5.577
Large samples		31.68	29.479	35.138	31.270	1.479	2.189
Arithmetic mean diameters (mm)							
Small samples		27.938	22.45	38.12	28.01	3.063	9.387
Medium sample		36.106	28.95	41.33	36.458	3.249	10.559
Large samples		40.991	38.98	46.15	40.231	2.149	4.622

Table.4: Mechanical properties of African oil bean seed for small samples

Loading orientation for small sample	Mechanical properties	Sample size	Minimum	Maximum	Mean	Standard deviation
Minor (natural)	Force @ peak (N)	139	1,072.00	2,652.00	1,726.38	536.91
	Force @ break (Rupture point) (N)	139	1,062.00	2,635.00	1,703.846	534.198
	Deformation @ break (mm)	139	0.834	3.052	1.692	0.657
	Force @ yield (Bio-yield point) (N)	139	1,072.00	2,652.00	1,692.385	535.45
	Deformation @ yield (mm)	139	0.834	3.047	1.609	0.560
	Deformation @ peak (mm)	139	0.834	3.047	1.670	0.629
Intermediate (transverse)	Force @ peak (N)	139	120.00	459.00	282.769	116.042
	Force @ break (Rupture point) (N)	139	13.00	441.00	238.08	139.103
	Deformation @ break (mm)	139	0.623	2.277	1.380	0.567
	Force @ yield (Bio-yield point) (N)	139	85.00	445.00	245.38	112.86
	Deformation @ yield (mm)	139	0.396	1.321	0.739	0.316

	Deformation @ peak (mm)	139	0.461	2.241	1.143	0.541
Major (longitudinal)	Force @ peak (N)	139	81.00	842.00	343.92	205.96
	Force @ break (Rupture point) (N)	139	16.00	842.00	299.84	231.45
	Deformation @ break (mm)	139	0.484	3.168	1.376	0.654
	Force @ yield (Bio-yield point) (N)	139	71.00	842.00	317.23	86.000
	Deformation @ yield (mm)	139	0.206	1.720	0.894	0.448
	Deformation @ peak (mm)	139	0.461	1.833	1.122	0.404

Table.5: Mechanical properties of African oil bean seed for medium samples

Loading orientation for medium sample	Mechanical properties	Sample size	Minimum	Maximum	Mean	Standard deviation
Minor (natural)	Force @ peak (N)	139	1,244.00	5,035.00	3,261.35	1,076.94
	Force @ break (Rupture point) (N)	139	1,244.00	5,035.00	3,242.95	1,069.92
	Deformation @ break (mm)	139	1.064	3.241	1.734	0.460
	Force @ yield (Bio-yield point) (N)	139	1,244.00	5,035.00	3,025.95	1,125.11
	Deformation @ yield (mm)	139	1.050	3.241	1.635	0.474
	Deformation @ peak (mm)	139	1.073	3.241	1.743	0.460
Intermediate (transverse)	Force @ peak (N)	139	19.00	584.00	291.00	119.88
	Force @ break (Rupture point) (N)	139	19.00	579.00	245.545	129.250
	Deformation @ break (mm)	139	0.050	2.064	0.986	0.484
	Force @ yield (Bio-yield point) (N)	139	19.00	579.00	245.545	129.25
	Deformation @ yield (mm)	139	0.050	1.337	0.585	0.343
	Deformation @ peak (mm)	139	0.687	2.769	1.243	0.503
	Force @ peak (N)	139	137.00	602.00	289.70	118.805

	Force @ break (Rupture point) (N)	139	-74.00	473.00	199.105	148.298
	Deformation @ break (mm)	139	0.642	3.535	1.376	0.608
Major (longitudinal)	Force @ yield (Bio-yield point) (N)	139	71.00	842.00	317.23	86.000
	Deformation @ yield (mm)	139	0.160	3.359	0.910	0.646
	Deformation @ peak (mm)	139	0.405	3.359	1.134	0.644

Table.6: Mechanical properties of African oil bean seed for large samples

Loading orientation for large sample	Mechanical properties	Sample size	Minimum	Maximum	Mean	Standard deviation
Minor (natural)	Force @ peak (N)	139	1,072.00	2,652.00	1,726.38	5,36.91
	Force @ break (Rupture point) (N)	139	1,062.00	2,635.00	1,703.846	5,34.20
	Deformation @ break (mm)	139	0.834	3.052	1.692	0.657
	Force @ yield (Bio-yield point) (N)	139	1072.00	2652.00	1692.385	535.45
	Deformation @ yield (mm)	139	0.834	3.047	1.609	0.560
	Deformation @ peak (mm)	139	0.834	3.047	1.670	0.629
Intermediate (transverse)	Force @ peak (N)	139	120.00	459.00	282.769	116.042
	Force @ break (Rupture point) (N)	139	13.00	441.00	238.08	139.103
	Deformation @ break (mm)	139	0.623	2.277	1.380	0.567
	Force @ yield (Bio-yield point) (N)	139	85.00	445.00	245.38	112.86
	Deformation @ yield (mm)	139	0.396	1.321	0.739	0.316
	Deformation @ peak (mm)	139	0.461	2.241	1.143	0.541
Major (longitudinal)	Force @ peak (N)	139	81.00	842.00	343.92	205.96
	Force @ break (Rupture point) (N)	139	16.00	842.00	299.84	231.45
	Deformation @ break (mm)	139	0.484	3.168	1.376	0.654
	Force @ yield (Bio-yield point) (N)	139	71.00	842.00	317.23	86.000

Deformation @ yield (mm)	139	0.206	1.720	0.894	0.448
Deformation @ peak (mm)	139	0.461	1.833	1.122	0.404

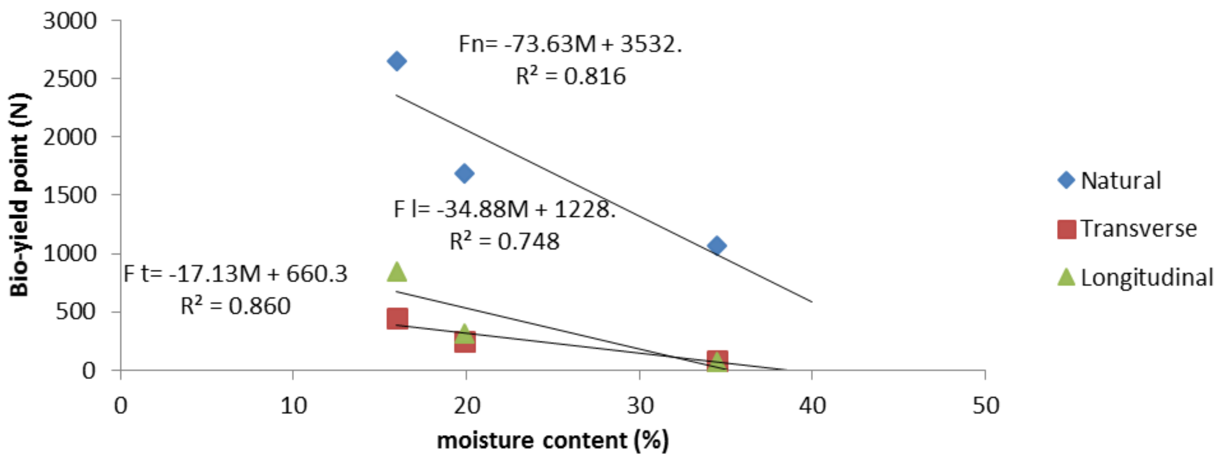

Fig.1: Effect of moisture content on bio-yield point of African oil bean seed under natural, transverse and longitudinal loading for small sample.

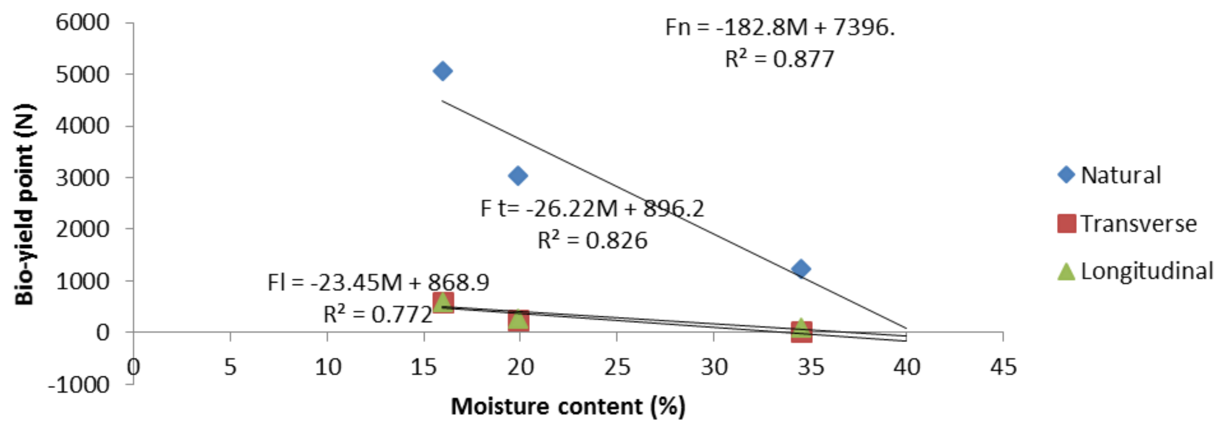

Fig.2: Effect of moisture content on bio-yield point of African oil bean seed under natural, transverse and longitudinal loading for medium sample.

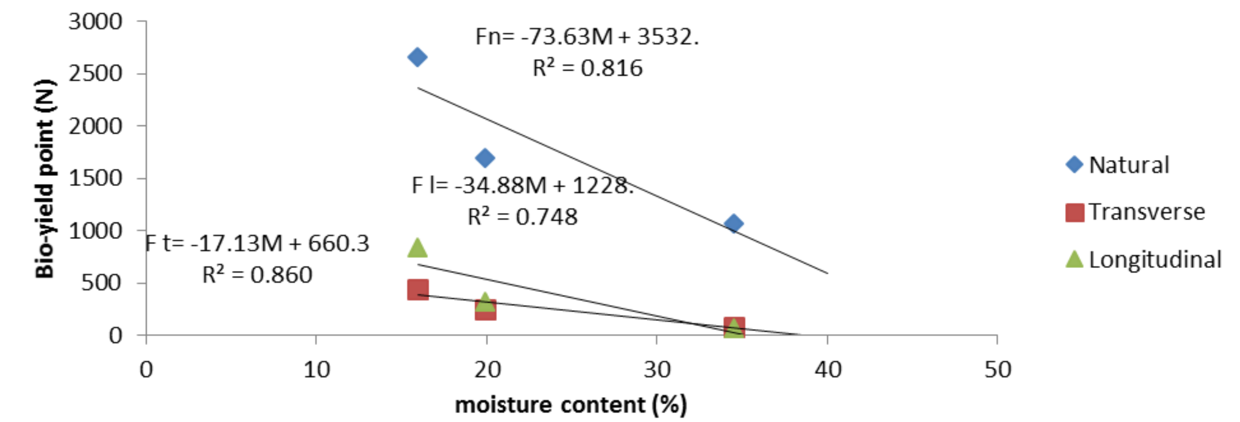

Fig.3: Effect of moisture content on bio-yield point of African oil bean seed under natural, transverse and longitudinal loading for large sample.

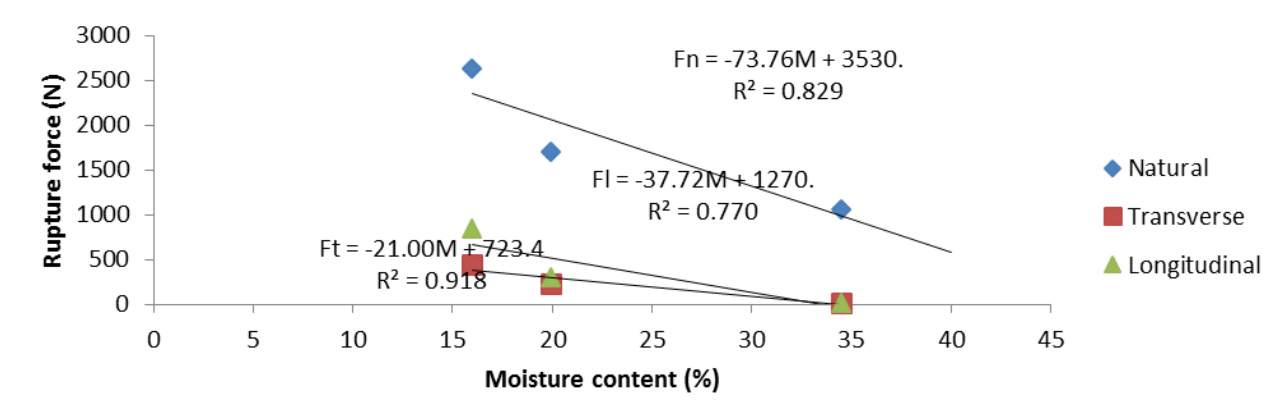

Fig.4: Effect of moisture content on rupture force of African oil bean seed under natural, transverse and longitudinal loading for small sample.

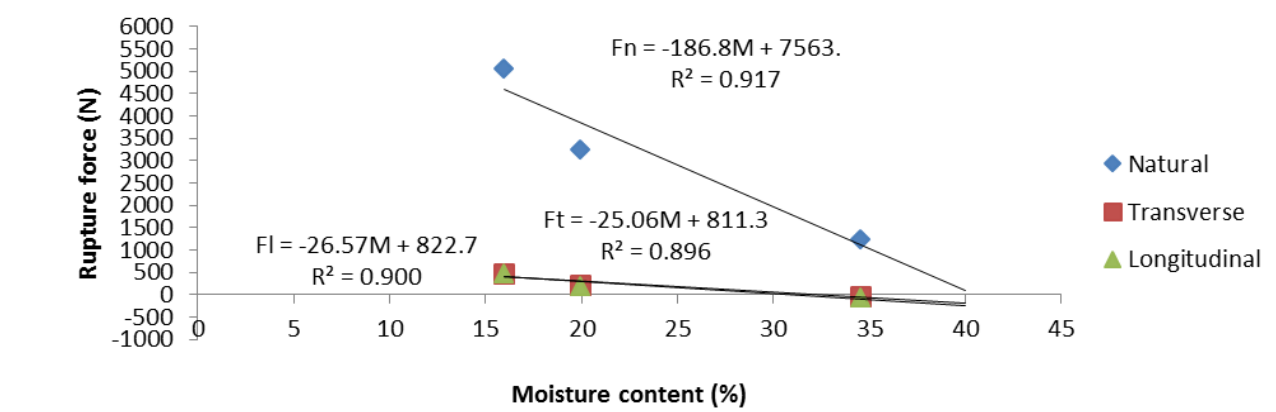

Fig.5: Effect of moisture content on rupture force of African oil bean seed under natural, transverse and longitudinal loading for medium sample.

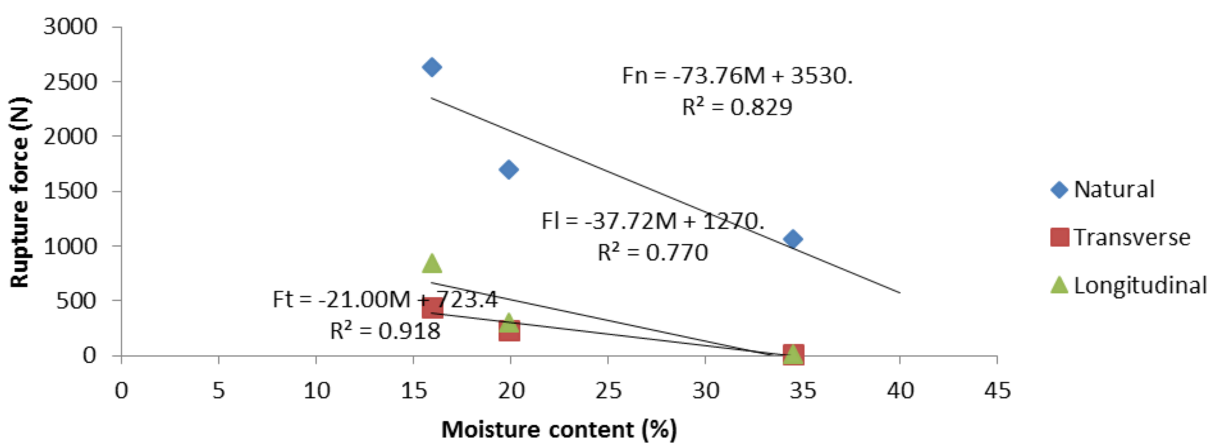

Fig.6: Effect of moisture content on rupture force of African oil bean seed under natural, transverse and longitudinal loading for large sample.

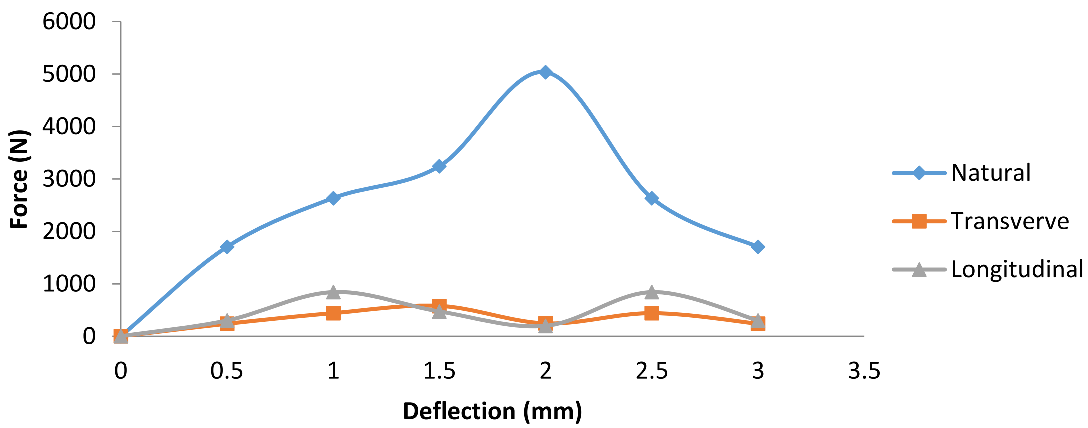

Fig.7: Typical force-deflection characteristic of African oil bean seed

CONCLUSION

The following observations and conclusions have been deduced from the determination of some physical and mechanical properties of African oil bean seeds.

The major, intermediate and minor diameters of African oil bean seed averaged 42.52mm, 30.59mm and 11.24mm for small samples, 58.22mm, 39.92mm and 10.17mm for medium sample and 67.23mm, 45.01mm and 10.73mm for large samples respectively and thus the seed is fairly larger than many other oil seeds.

The sphericity values of the seeds as measured averaged 0.557 for small samples, 0.492 for medium samples and 0.473 for large samples, the low sphericity value gotten shows why it is difficult for the seeds to roll on plane surfaces.

The seed density was higher than that of water showing that it can't float on water except the seed is skinny in nature, a property needed in separating processes.

The force required to break the seed was highest when the seed is loaded on its normal rest position, so the seed must be either broken through its intermediate (transverse) diameter or the major (longitudinal) diameter. This is needed in the dehulling or cracking processes.

The force required to initiate seed rupture decreased with an increase in moisture content.

It is recommended that further work should be carried out to design an appropriate equipment to be used in the dehulling, storing, processing and size reduction of African oil bean. Research should also be done on the thermal properties of the seed which could also be useful in developing processing machines for the seed.

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REVIEW OF BIODEGRADABLE NANOCOMPOSITE PACKAGING MATERIALS FOR FRUITS AND VEGETABLES

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ABSTRACT

The packaging of agricultural commodities is usually carried out to enhance the storability and promote the market value of the products. Many conventional materials have been designed for this purpose, yet because of their non biodegradable nature their application is usually thwarted in food packaging. This review was undertaken to access the various kinds of biodegradable packaging materials for fruits and vegetables. The biodegradable packaging materials reviewed include those made from starch, cellulose and polysaccharides together with their limitations. The production processes of the biodegradable materials and their application, especially of reference values to the consumers in Nigeria have also been reviewed. This information will undoubtedly assist the crop processing and storage engineer in decision making and planning of postharvest commodities to curtail huge potential loses.

Keywords: *Biodegradable, Nanocomposite, Packaging, Postharvest losses*

INTRODUCTION

The conventional packaging materials are the major source of environmental pollution when disposed in the open field because they are not biodegradable (Fadeyibi *et al.,* 2016). Fadeyibi *et al.* (2016) also reported that fossil fuel, which is the raw materials used in the production of the packaging materials, can be replaced by greener agricultural sources, such as starch and protein, so as to promote biodegradation. In the last seven years, the suppliers of packaging materials have been encouraging the use of biodegradable plastics for the packaging all forms of food products (Peterson *et al.,* 1999, Fadeyibi *et al.,* 2016). Based on the enormous benefits associated with the use of biodegradable materials, the market for packaging materials is fast growing. At the moment, some of this polymers are already reliable alternatives to conventional materials, especially polylactate (PLA) for food packaging (Haugard and Martensen, 2003; Yin *et al.,* 2007). A biodegradable packaging material undergoes degradation due to the activity of enzymes secreted by living micro-organisms such as bacteria, fungi or algae, according to the Biodegradable Products Institute (BPI) (2001) (Narayan, 2001).

The biodegradation process usually occurs via two stages. The first stage involves degradation or defragmentation, which is initiated by heat from ultraviolet radiation and moisture. The second stage is the biodegradation, where the cell walls of the living organisms are acted upon by a shorter carbon chain in the polymer to generate energy needed for their breakage (Chandra and Rustgi, 1998). In order to certify a packaging material as biodegradable nevertheless, it is important to subject the material to testing according to the internationally recognised standards (van de Velde and Kiekens, 2002; Rouilly and Rigal, 2002). Since the middle of 1990s, the capacity of the biodegradable packaging materials produced has increased in the Europian market. According to a survey conducted by the Europian Bioplastic Association in 2006, the demand for biodegradable packaging materials had almost double that of conventional polymers. The total production capacity of the available packaging materials in the market are accounted for 85% of

the renewable resource based biopolymers, such as starch and PLA with conventional polymers accounting for only 15% (Platt, 2006). Furthermore, four different categories of biodegradable polymers have been identified, depending on the method of preparation, with three of them obtained from renewable raw-materials (Fadeyibi *et al.,* 2016). The synthetic biodegradable, bio-based biodegradable and bio-based non-biodegradable are the three polymer categories obtained from renewable resources. The contributing share of the biodegradable polymers in the market is about 12 % of a total production capacity of 262000 tonnes in 2007, with almost 40 % of total capacity in 2011.
The biodegradable polymers have found application in the food packaging industry. This include biodegradable materials for fruit and vegetables packaging, shopping bags, bio-waste bags, mulch films, nets, cellulose, starch and protein based bio materials. Among all the available biodegradable packaging materials, PLA is the most widely utilised for packaging of fresh-food (Rouilly and Rigal, 2002). The compound annual growth rate of biodegradable materials, especially polyhydroxyalkanoate (PHA), for food packaging applications has been placed at around 22 %in 2013. The limitation of using biodegradable materials for packaging materials requiring longer shelf-life has been a center of discussion in the industry due to their poor barrier properties, with efforts made to improve them for such purpose (Chandra and Rustgi, 1998). This has prevented their wide acceptability and application until today (Fadeyibi *et al.,* 2016). The biodegradable PLA material developed by Hycail-Finland Limited has been found oven-able and microwavable and can withstand temperatures over 200 °C. There are also compostable PLA trays useful for improving the shelf life of food products by the absorbing exuded liquid during packaging. Particularly too, the high barrier properties biodegradable lidding film blended with PLA has been essential for packaging fresh fruits and vegetables.
The essence of this review was to provide information on the various categories of biodegradable packaging materials for fruits and vegetables packaging, and their limitations, especially against the non-biodegradable counterpart.

Starch based packaging materials

Starch is considered one of the most promising thermoplastic materials, among all natural polymers for food packaging, because of it is biodegradable, cheap and readily available (Mali and Grossmann, 2003). It is usually found as carbohydrate stored in plant such as corn, cassava, wheat, rice, potatoes and other cereals. The molecules of starch are made up of a combination of linear amylose, which consists of 200-20,000 glucose units which form a helix as a result of the bond angles between the glucose units, and a highly branched amylopectin, containing short side chains of 30 glucose units attached to the same number of glucose units along the branched chain. Amylopectin molecules may contain up to two million glucose units (Ray and Bousmina, 2005). This property exhibited by starch, can be utilised in the preparation of edible or biodegradable films and coatings. Modified and highly amylose starches have been prepared to form excellent self supporting films by casting from aqueous solution (Mali and Grossmann, 2003; Mali *et al.*, 2006). The disadvantages of these films however are their poor water barrier and mechanical properties, though they have moderate oxygen barrier property.
It is possible to use starch as a filler to produce reinforced plastic materials with excellent service performance (Mali *et al.,* 2006). To achieve this in most of the occasions, about 30 % of the starch is usually blended with plastic materials, thus improving the biodegradability of the product. Additionally, the thermoplastic characteristic of starch is usually enhanced by the addition of plasticiser such as glycerol, urea and sorbitol under heat and pressure and resulting product is called thermoplastic starch (TPS). Mohanty *et al.* (2005) prepared TPS products with different viscosity, water solubility, and water absorption capacity by moisture/plasticiser content, amylose/amylopectin ratio, temperature and pressure alterations. The plasticisation of starch using glycerol, sorbitol, formamide and dimethyl sulfoxide and low molecular weight sugars have been reported to increase the flexibility and processability of resulting biofilms (Gaudin *et al.,*1998; Ma *et al.,* 2004; Kalichevsky *et al.,*1993). Despite the potential of the thermoplastic starch application in food packaging, its sensitivity to humidity and poor mechanical properties has greatly limited its usefulness.

Cellulose based packaging materials

Cellulose, a linear polymer of anhydroglucose, is the most bountifully available natural polymer. The major source of cellulose is wood which contains 40 to 50 % cellulose by weight. Cellulose is unsuitable for film production because it is highly crystalline, fibrous, and insoluble in water. However, cellulose can be associated with a prepared solution of sodium hydroxide, carbon disulphide and sulphuric acid to produce cellophane film. Cellophane, coated with nitrocellulose wax or polyvinylidene chloride to improve barrier properties, especially water vapour permeability has good mechanical properties. Coated cellophane can be used for packaging fresh fruits and vegetables. Cellophane has good gas barrier properties at low relative humidity, but poor at intermediate and high relative humidity. Cellophane is not heat sealable owing to its non-thermoplastic nature (Peterson *et al.*, 1999; Ma *et al.,* 2004).
Alternatively, the esterification of the hydroxyl groups on the cellulose structure can form the derivative state of the polysaccharide. A number of derivatives such as cellulose acetate, ethyl cellulose, hydroxyl-ethyl cellulose, and hydroxyl-propyl cellulose are commercially available. Steps involved in making these thermoplastic materials include

producing cellulose ester biopolymers in powder form and extruding the ester powders in the presence of different plasticisers and additives. The phthalate plasticiser, used in commercial cellulose ester plastic, is now under scrutiny because of its health implications. Recently, efforts have been geared to replace the phthalate plasticiser by eco-friendly plasticiser such as citrate and blends of citrate and derivative oil (Ray and Bousmina, 2005; Peterson *et al.,* 1999). The gas and water vapour barrier properties of cellulose acetate are not optimal for food packaging. However, the film is excellent for high moisture products as it allows respiration and reduces fogging (Peterson *et al.,* 1999). Cellulose acetate is biodegradable for degrees of substitution up to 2.5. Mazzucchelli (Castiglione Olona, Italy) and Planet Polymer (CA, USA) manufacture biodegradable plastics based on cellulose acetate under the trade names of BioCeta and EnviroPlastic respectively. BioCeta is used for the manufacture of biodegradable packaging films, retractable films, and tubes (Mohanty *et al.,* 2005). Recently, there is an increased interest in reinforcing synthetic plastics with cellulose fibers rather than glass fibers because cellulose fibers can offer desired aspect ratio and increased biodegradability (Mwaikambo, 2007; Yin *et al.,* 2007).

Polysaccharide based packaging materials

Chitin is the second most bountifully available organic compound on earth after cellulose. Soluble chitin, known as chitosan, is a natural product obtained from de-acetylated chitin. Chitosan possesses repeating units of 1, 4 linked 2-deoxy-2-aminoglucose. The protonation of the amino group NH_2 to NH_3^+ can have electrostatic interactions with anionic groups in an acid environment. Clear, tough, and flexible chitosan films can be formed by film casting from aqueous solution. Studies on the effects of storage time, acid concentration, molecular weights of chitosan, plasticiser concentrations and the degree of de-acetylation of chitosan on the mechanical and barrier properties of chitosan films have already been undertaken. The greatest limitation of chitosan films is the lack of long term stability and higher water vapour permeability. Chitosan films can be used to protect foods from fungi decay and modify atmosphere of fresh fruits (Fadeyibi *et al.,* 2016; Peterson *et al.,* 1999).

Pectin is a family of heterogeneous branched polysaccharides consisting mostly of variably methylated galacturonan segments separated by rhamnose residues, some of which may be linked to short neutral sugar side chains. Pectin is a secondary product of fruit juice, sunflower oil, and sugar manufacture. As a food industry waste, pectin is suitable for producing eco-friendly biodegradable materials. Considerable attention has been given to pectin because it is widely available as waste material and is readily modified, through demethylation, to give preparations that can form edible films in the presence of calcium ions. However, WVP of pectin films is quite high, which limits its use in food packaging. Several studies on the combination of pectin with other biodegradable materials have been reported (Park *et al.,* 2004).

CONCLUSION

The packaging of fresh fruits and vegetables have often been made possible through conventional and traditional means, which include the use of paper boards, leaves, metals, glass, wooden boxes and plastics. This practice, however, is no longer tenable nowadays because of the inability of some the materials to be degraded or biodegraded by the actions of ultra violet radiation or enzymes secreted by living organisms (bacteria, yeast and fungi), respectively. The need to address this challenge, especially among practitioners in agricultural products processing and storage engineering, forms the essence of this review. The various kinds of biodegradable packaging materials for use fruits and vegetables packaging, together with their process of production and limitations have been highlighted. The information will form part of the data base for curtailing postharvest loss through green polymer technology.

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EFFECTS OF BLANCHING PARAMETERS ON THE NUTRITIONAL QUALITIES OF 'POUNDO' YAM

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ABSTRACT

This study was carried out to determine the effect of blanching parameters on 'poundo' yam nutritional quality. White yam (Dioscorea rotunda) was used to produce the 'poundo' yam. The drying aspect of the experiment was accomplished with the aid of an electrical agricultural produce dryer. The two blanching parameters studied are temperature (80ºC, 90ºC, 100ºC) and duration (10 minutes, 20 minutes, 30 minutes). The produced 'poundo' yam was subjected to proximate analysis (carbohydrate, protein, fat, ash, fibre and calorie). SPSS 16.0 statistical package was used for its statistical analysis. There was no significant difference ($p \leq 0.05$) in the proximate compositions of the 'poundo' yam under the different processing conditions. It was established that increase in the blanching duration led to reduction in the protein (4.10 to 3.75 %) and mineral content (1.42 to 0.98 %) of the processed 'poundo' yam. Also, blanching duration has effect on availability of fibre content as the samples blanched for 10 minutes had best fibre retention. Therefore, blanching duration is a dependable factor for mineral depletion and fibre availability in 'poundo' yam production.

KEYWORDS: *poundo yam, production, blanching, proximate, nutritional quality*

INTRODUCTION

Yam, *Dioscorea* (*spp.*) is a good and affordable source of carbohydrate for many people of the sub-Sahara region, especially in the yam zone of West Africa (Akissoe *et al*., 2003). One of the commonly found varieties of yam in Nigeria is *Dioscorea (D.) rotundata* (white yam). By dry weight white yam is composed of 80 % starch, 7 % protein, 7 % minerals, 3 % fibre and 1.7 % lipids; 100 g of the yam give 385 kcal energy and is made up of 67 % moisture (Egbe *et al*., 1984).

Processing in a number of ways can alter the content and nutritional quality of food carbohydrates. Boiling, cooking and heating of carbohydrates results in alteration of physical properties through gelatinization and retrogradation. Cooking increases the viscosity of carbohydrate and also splits the starch granules, thereby increasing the starch availability to amylase (Jimoh *et al*., 2008).

It is known that the more processed a food is, the higher the glycemic response it will produce (Thorne *et al*., 1983). This appears to be negated by the response to *amala* (Jimoh *et al*., 2008). During the process of boiling of yam in water, gelatinization of the starch molecule occurs, thus increasing the availability of starch for digestion by digestive enzymes. This is what occurs when boiled yam is eaten directly as well as in case of pounded yam without further processing (Jimoh *et al*., 2008). However, in the preparation of yam flour (Akingbala *et al*., 1995), the parboiled yam is sun-dried for about 3 days, losing almost all of its water content with a progressive re-association of the starch molecules (retrogradation). This re-association reduces the digestibility of the starch molecule. The processing undergone by the parboiled yam may also increase the fibre content since it is well known that the fibre content of tuber flour is generally higher than that of the fresh tuber (FAO/WHO, 1998). Various studies have shown the importance of viscosity (a property of the fibre content of food). Yam flour is usually sprinkled on boiled water and only very rarely it is boiled continuously as in other meals. This might also reduce its starch availability, as observed by Collins *et al.* (1981). Acrylamide could be lower in potato crisps compared to French fries, due to a more pronounced extraction of sugar from potato slices upon blanching (Mestdagh *et al., 2008*).

In a research undertaken by Akissoe *et al*. (2003) to study the kinetics of polyphenoloxidase (PPO), peroxidase (POD), and phenolic compounds during yam blanching at different temperatures and after drying, 45 % of PPO activity remained after 50 minutes of blanching at 60 and 65 °C; whereas the POD activity dropped sharply to less than 20 % of the initial activity after 10 minutes of blanching, irrespective of the blanching temperature considered. Adeola *et al.* (2012) investigated the potential of developing instant poundo yam flour from *D. alata*. According to the report, the production undergone peeling, dicing and immersion of yam tubers in sodium metabisulphite solution (800 ppm for 20 min). The tubers were thereafter blanched at 70 °C for 5minutes and 10 minutes before drying in a cabinet dryer at 60 °C for 72 hr.

FIIRO (2005) identified eight unit operations in the production of instant pounded yam. According to Nnamdi (2010) the process of producing instant yam flour is quite simple; it involves slicing, parboiling and milling of the product to yield flour and equipment required for production can be sourced locally. Instant yam, on addition of hot water and stirring, reconstitutes into dough with smooth consistency similar to pounded yam. The product is so popular that considerable quantities are exported to other parts of the world, especially Europe and North America, where there are sizable African populations (Olaoye and Oyewole, 2012).

According to Olaoye and Oyewole (2012), in order to run a well productive system of producing 'poundo' yam from white yam (*Dioscorea rotundata* Poir) and to give consumers of the product the best nutritional quality, the poundo yam production parameters must be investigated and the respective optimum values must be determined. However, it is equally necessary to study the trend of impact of blanching parameters at different level of application in processing of white yam into 'poundo' yam.

The objective of this study was to determine the effect of blanching parameters at different levels on 'poundo' yam nutritional qualities.

MATERIALS AND METHODS

Experimental Materials

The study was carried out on white yam (*Dioscorea rotundata* Poir). The choice of this species was based on the fact that it is preferred for pounded yam preparation and is readily available in Nigeria. The experiment was conducted at the Postharvest Engineering laboratory, while the laboratory analyses were carried out at biochemistry laboratory of Nigerian Stored Products Research Institute (NSPRI), Ilorin. The moisture content of the yam before processing was 59.5 % w.b. An agricultural produce dryer developed by Omodara *et al.* (2012) was used for the drying operation. It is an electric dryer, installed with a temperature regulator. The following instruments were used in conjunction with the dryer; weighing balance, thermo-hygrometer, mercury-in-glass thermometers, measuring cylinder and Polymix experimental hammer mill. Other items employed for the experiment include; stainless steel knife, plantain slicer, plastic bowls, electric water heater and plastic sieves (drain).

Experimental Method

The production process of 'poundo' yam used for this research exercise is as presented in Figure 1.

Blanching procedure

Three blanching temperature levels and duration levels were considered. One thousand five hundred (1500) cm^3 of water was measured with a measuring cylinder into a container, after which it was heated to 100 °C. The flaked yam was poured into the heated water and timed for the three levels of duration (10, 20 and 30 minutes) respectively. The exercise was subsequently repeated for 90 °C and 80 °C heated water respectively. The blanching water was then drained using plastic sieve; and the flakes was allowed to stay in the sieve for 10 minutes. The flakes were then spread on the trays in preparation for drying operation.

Drying procedure

The dryer was pre-heated to the desired temperature of 65 °C by the means of temperature regulator as recommended by Olaoye and Oyewole (2012) and Oyewole *et al.* (2013) while the samples were being prepared to ensure stability of the condition of the drying chamber when the yam flakes would be introduced. The samples were dried to 12 % w.b moisture content after seven hours of drying. The initial and final weight were taken using a top loading balance (Snowrex counting scale SRC 5001, product of Saint Engineering Ltd, Saint House, London) with an accuracy of 1g and measuring capacity of 5000 g, and the weights recorded.

Evaluation of the effect of blanching parameters on the nutritional quality of the 'poundo' yam

The effects of blanching parameters on the nutritional quality of the dried product were evaluated by subjecting the processed product to proximate analysis. Opara (1999) gave the quality assessment parameters for white yam and its processed products as: crude protein, ash content, crude fat (lipid), fibre content, carbohydrate and calorie. The protein, ash and fibre content were determined using the procedure of AOAC (1990), and AOAC (2005) was used to determine the fat content of the product. The carbohydrate content and the calorie were determined by using the method described by FAO/WHO (1998) and Oosthuizen *et al.* (2007) respectively. The results obtained from the nutritional analysis were subjected to Analysis of Variance (ANOVA) using SPSS 16.0 package.

RESULTS AND DISCUSSION

Nutritional Quality Evaluation

The Analysis of Variance (Table 1) shows that there is variation between and within groups of blanching temperature and blanching duration, but there was no significant difference at 5 % confidence level for fibre content of the 'poundo' yam. The analysis also revealed that there was no significant difference in the ash results obtained, but there were variations between and within the groups of blanching temperature, while variation due to blanching duration only exists between the groups. Variation was only experienced between the groups of both factors considered with no significant difference at 5 % confidence level for fat, protein, carbohydrate and calorie. There was no significant difference ($p \leq 0.05$) in the proximate composition of the instant poundo yam flour under this processing condition. This is in conformity with the outcome of study carried out by Adeola *et al.* (2012) on *Dioscorea alata.*

Results of the analysis on the protein content of 'poundo' yam showed that blanching duration has a pronounced effect on protein depletion in processed 'poundo' yam. Figure 2 shows that the more the blanching duration the more the protein loss. This is in line with the result of Olaoye and Oyewole (2012). The result of protein recorded is in the range of that reported by Adeola *et al.* (2012). The effects of blanching temperature and duration on fat content of the processed 'poundo' yam samples were presented in Figure 3. The result shows that both parameters have effect on fat availability in processed 'poundo' yam. Decrease in blanching temperature resulted to reduction in fat availability within the range considered. Likewise, extension of the blanching duration led to fat reduction.

Figure 4 shows that blanching duration has effect on availability of fibre content after processing of yam into 'poundo' yam flour. The samples blanched for 10 minutes have better fibre retention as compared to other blanching durations. This result is in conformity with the optimum value recommended by Olaoye and Oyewole (2012). The fat and fibre contents of the 'poundo' are higher than those reported by Udensi *et al.* (2008) and Adeola *et al.* (2012). This may be due to difference in yam species and processing methods. Figure 5 showed the effect of blanching parameters on mineral contents of the 'poundo' yam. The result obtained is lower in value than those reported by Udensi *et al.* (2008) and Adeola *et al.* (2012) as a result of difference in species, blanching temperature and blanching duration. Both blanching temperature and duration have considerable effect on minerals availability during poundo yam production. The samples blanched for 30 minutes had the least ash content as compared to other blanching durations. Therefore, blanching duration is a dependable factor for mineral depletion in 'poundo' yam processing. This shows that loss of minerals increases as the blanching duration increases, as equally reported by Olaoye and Oyewole (2012).

Yam being a good source of carbohydrate, it is very important to measure the effects of blanching parameters on the available carbohydrate in processed 'poundo' yam. The result of the analysis showed that samples blanched for 10 minutes performed low in terms of carbohydrate availability as compared to 20 and 30 minutes blanched samples (Figure 6). This effect suggests that water absorption in the cells increases with blanching time. This behaviour is normal since yams are rich in starch and blanching increases the proportion of water bound (Cheftel *et al.,* 1983, Leng *et al.,* 2011). Also, the effect of blanching temperature was felt, as the samples blanched at 80 ^{o}C had higher value of carbohydrate as compared to other treatments. This behaviour was expected since yams (Leng *et al*., 2011) are rich in starch and blanching at high temperature induces starch gelatinization. Mestdagh *et al. (2008*) equally reported that blanching temperature is a major factor influencing sugar extraction.

CONCLUSIONS

The two blanching parameters of poundo yam as considered in this research are blanching temperature and duration as it affects the nutritional qualities of the product.

It was established that increase in the blanching duration led to reduction in the protein content of processed 'poundo' yam. It is evident that extension of the blanching duration will cause more protein loss. The samples blanched at the highest temperature of 100 ^{o}C had the best protein retention.

The result also depicts that blanching duration has effect on availability of fibre content during processing of yam into 'poundo' yam as the samples blanched for 10 minutes had best fibre retention as compared to other blanching durations. The samples blanched for 30 minutes had the least ash content as compared to other blanching durations.

The blanching temperature must also be taken into cognisance, as the samples blanched at 80 ^{o}C had the highest values of carbohydrate as compared to other treatments. Consequently, optimum attention should be paid blanching parameters while processing yam into poundo yam for high quality maintenance.

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Table 1: Results of the Analysis of Variance for nutrition parameters

Nutrition Quality Parameters	Sources of Variation		Sum of Squares	df	Mean Square	F	Sig.
Fat	BD	Between Groups	1550.000	24	64.583	0.517	0.834
		Within Groups	250.000	2	125.000		
	BT	Between Groups	1800.000	24	75.000	-	-
		Within Groups	0.000	2	-		
Fibre	BD	Between Groups	1550.000	21	73.810	1.476	0.355
		Within Groups	250.000	5	50.000		
	BT	Between Groups	1450.000	21	69.048	0.986	0.566
		Within Groups	350.000	5	70.000		
Protein	BD	Between Groups	1750.000	24	72.917	2.917	0.287
		Within Groups	50.000	2	25.000		
	BT	Between Groups	1700.000	24	70.833	1.417	0.496
		Within Groups	100.000	2	50.000		
Ash	BD	Between Groups	1800.000	21	85.714	-	-
		Within Groups	0.000	5	-		
	BT	Between Groups	1500.000	21	71.429	1.190	0.464
		Within Groups	300.000	5	60.000		
Carbohydrate	BD	Between Groups	1800.000	26	69.231	-	-
		Within Groups	0.000	0	-		
	BT	Between Groups	1800.000	26	69.231	-	-
		Within Groups	0.000	0	-		
Calorie	BD	Between Groups	1800.000	26	69.231	-	-
		Within Groups	0.000	0	-		
	BT	Between Groups	1800.000	26	69.231	-	-
		Within Groups	0.000	0	-		

BD – Blanching Duration, BT – Blanching Temperature

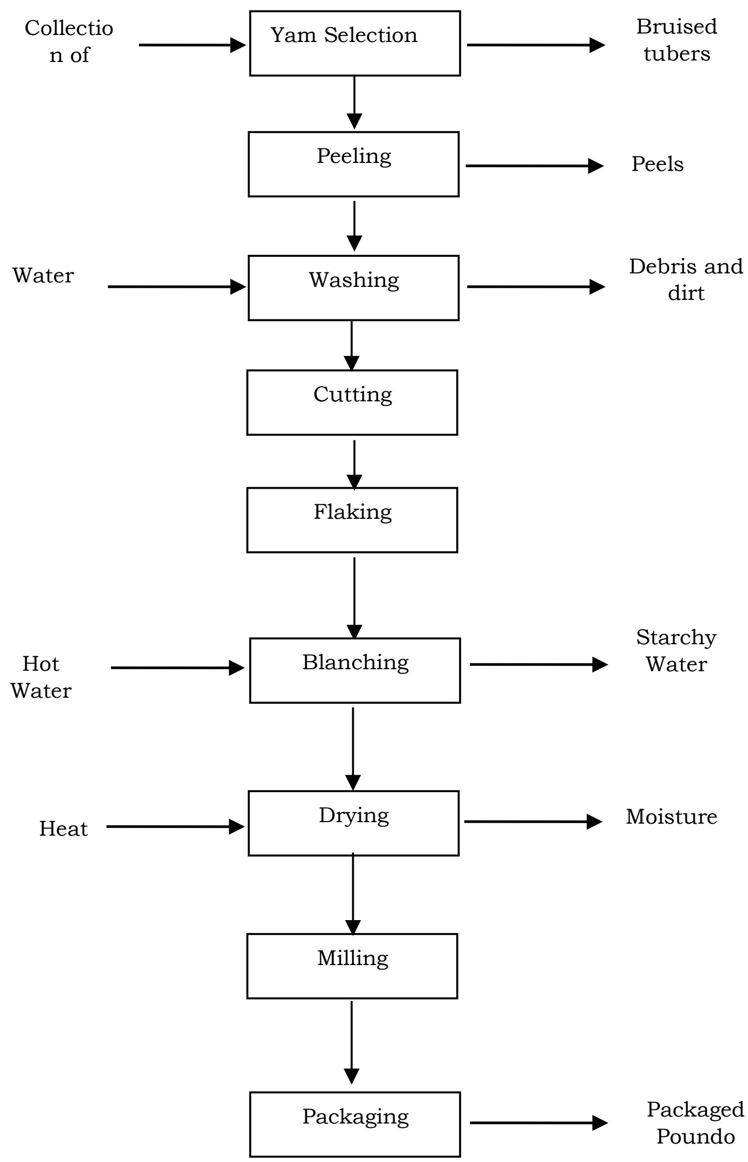

Figure 1: Flow diagram for 'poundo' yam flour production

(Source: Olaoye and Oyewole, 2012)

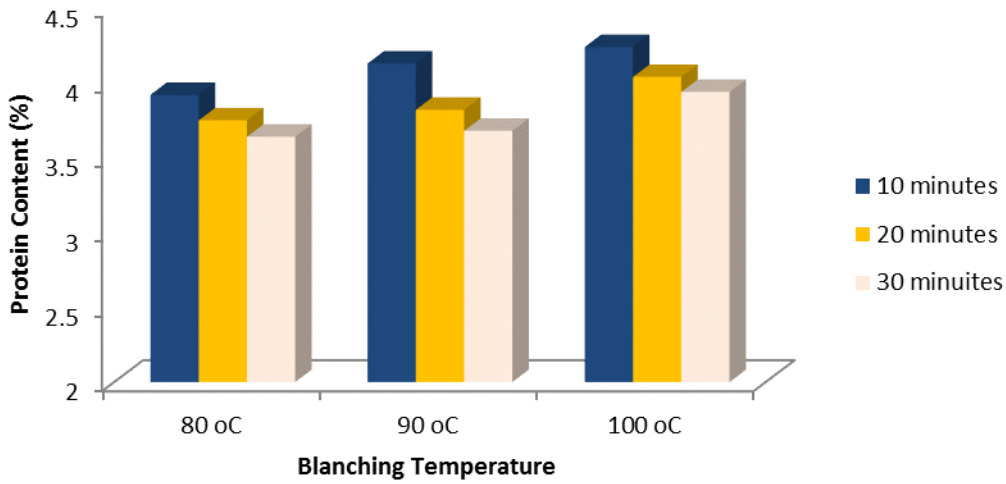

Figure 2: Effect of blanching parameters on protein content

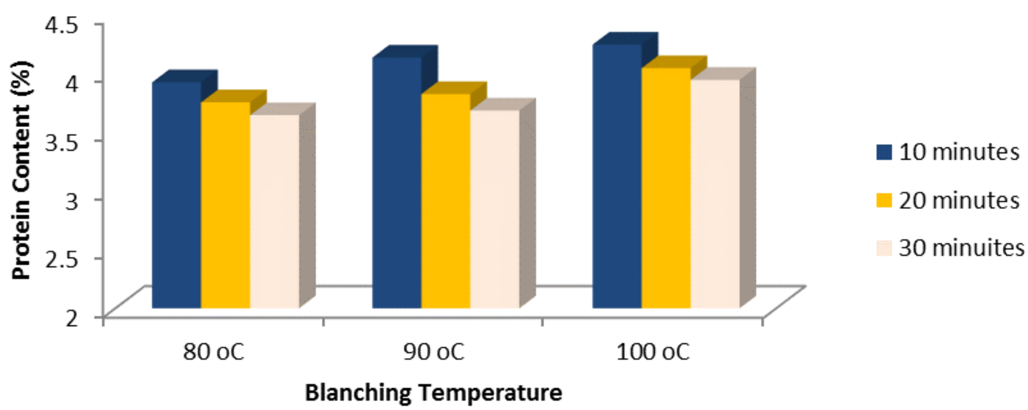

Figure 3: Effect of blanching parameters on fat content

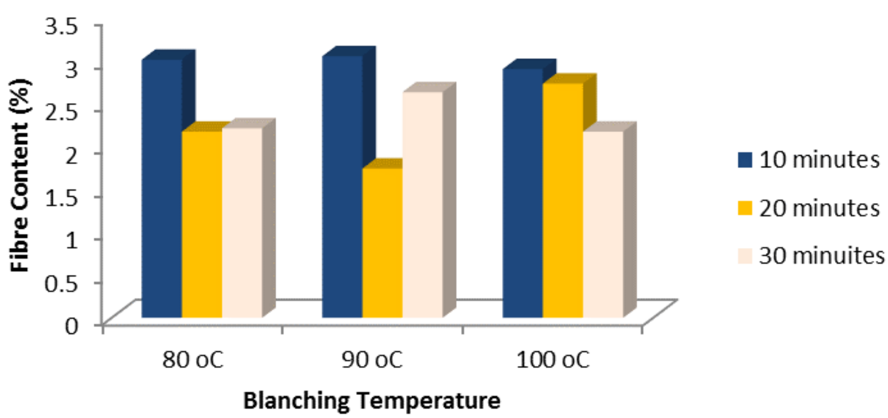

Figure 4: Effect of blanching parameters on fibre content

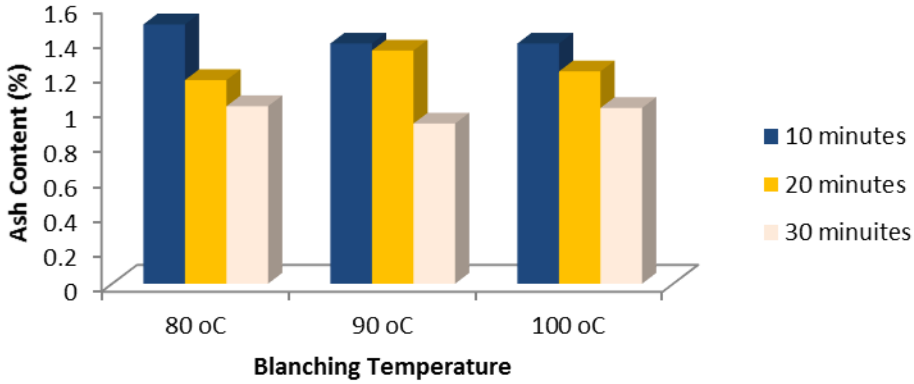

Figure 5: Effect of blanching parameters on ash content

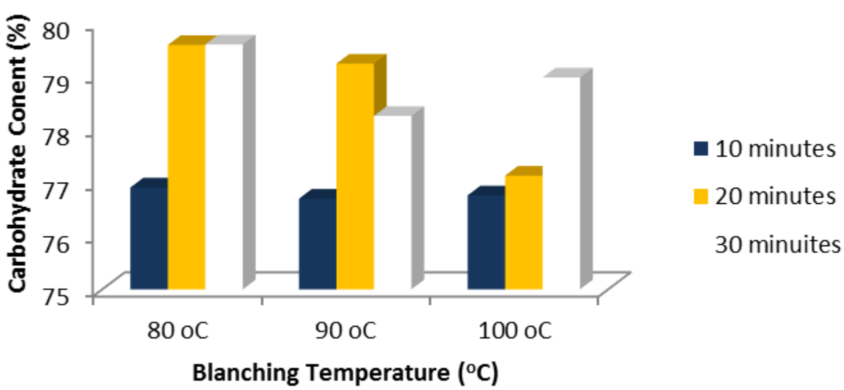

Figure 6: Effect of blanching parameters on carbohydrate content.

RHEOLOGICAL MODIFICATION OF DONKWA (GROUND CAKE SNACKS) USING FOOD GEL

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ABSTRACT

Donkwa is a common snack that is commonly taken in the northern part of Nigeria and it is prepared from roasted groundnut (peanut) mixed with roasted cereal (maize) flour and spiced with ginger and pepper, and sugar are added to taste. The mixture were pounded and moulded into balls that can be eaten without further processing. The need to optimize donkwa to meet the daily nutrient need of the malnourished were made by improvement of the textural and /or pasting properties of donkwa using food gels. The compositional effects of major ingredients on donkwa textural properties were also determined. Samples of groundnut, maize, and sorghum were obtained locally from Kure modern market, minna, Niger state. The groundnut were cleaned, sorted and roasted. The maize were cleaned, sorted and ground into powdered and sieved. The sorghum were cleaned, sorted and soaked in cleaned water for 24hours. The wet sorghum was milled to paste and 4litres of water were added to the paste and allowed to settled and sieved. The pastes were sun dried, and used as gelling agent (Binder). The roasted groundnut were mixed with the maize powder and milled to paste for the three ratio (G80-M20, G70-M30, G60-M40) with varied proportion of binder (food gel), 2%, 4%, and 6% respectively. These specified ratio of groundnut paste,(x_1) maize powder(x_2) and binder(x_3) were mixed accordingly. The mixture were constituted differently into a number of experimental treatments with 0.000053g of Sugar, 0.0000025g of Salt, and 0.0000012g of pepper as ingredients proportion for each run. The mixture were allowed to cool and settle, and moulded into various shapes and sizes. A three variables three levels factorial design matrix ($N=3^3$) were used to analysed the sensory data. The results were subjected to data analysis using SPSS 16.0, 2010 version. Analysis of variance was used to check if there were significant differences between the treatments and Student-Newman-Keuls Multiple range test (SNK) was used to separate means that were significantly different. The results showed that out of the 27 experimental treatments, treatment 2 with 70% groundnut, 20% maize and 2% binder gave the highest qualities in terms of adhesiveness, firmness, chewiness, textural hardness and cohesiveness. Therefore, it was recommended as the best formulation for high quality donkwa preparation.

Keywords: rheological, modification, donkwa, foodgels.

INTRODUCTION

The original constituent of donkwa is a combination of roasted maize and groundnut to form a paste. To improve the rheology, taste and flavor of the product, ginger, sugar, spices and paper in a given proportion were added to it. The mixture is pounded and moulded into balls that can be eaten without further processing (Abdurrahman *et al.*, 2003). A standard ratio for donkwa production has been reported to be either in the ratio of 40:60 of maize to groundnut or 50:50 of maize to groundnut because at these levels, the mineral content are significantly high (Ahmad, 2010).The need to optimize local food products to meet the daily nutrient need of the malnourished population in Africa has been advanced in different research activities, resulting in several high-energy-protein foods (Sanni, 1997; Gilbert, *et al*., 2000; Jideani*et al*., 2001). Concerted efforts were needed to achieve high quality, wholesome and safe products in the snacks food industry.

MATERIAL AND METHODS

Experimental materials;

Samples of groundnut, maize, and sorghum were obtained locally from kure modern market, minna, Niger state. The groundnut was cleaned, sorted and roasted. The maize was cleaned, sorted and ground into powdered and sieved. The sorghum was cleaned, sorted and soaked in cleaned water for 24hours. The wet sorghum was milled to paste and 4litres of water were added to the paste and allowed to settled and sieved. The sieved powdered were subjected to sun dried, and used as gelling effects (Binder).

Composite formulation

The roasted groundnut were mixed with the maize powder and milled to paste for the three ratio with varied proportion of binder (food gel), 2%, 4%, and 6% respectively. Specified percentages of groundnut paste, maize powder and binder were mixed as indicated in the Table of design matrix. The milled mixtures were pounded differently into a number of experimental treatments with 0.000053g of Sugar, 0.0000025g of Salt, and 0.0000012g of Pepper as ingredient proportion for each run. The Mixture was allowed to cool and settle, and moulded into various shapes and sizes.

***Experimental Design Method**:*

A three variables, three levels factorial design ($N=3^3$) provides the frame work for the experimental runs. Data were subjected to statistical analysis using SPSS 16.0, 2010 version. Analysis of variance was used to check if there were significant differences between the treatments and Student-Newman-Keuls Multiple range test (SNK) was used to separate means that were significantly different.

CONTROL SAMPLES

PLATE 1

IMPROVED SAMPLES

PLATE 2

RESULTS

Analysis Result of Donkwa Adhesiveness

The mean scores for adhesiveness of the 27 different donkwa treatments were as shown in table 3.1

Table 1: Analysis result of Donkwa Adhesiveness

Treatments	Mean	± standard deviation
Control	4.13^{ab}	1.48
1	3.96^{ab}	1.32
2	4.33^{ab}	0.89
3	4.50^{ab}	1.15
4	3.71^{ab}	0.58
5	3.79^{ab}	0.81
6	4.25^{ab}	0.40
7	3.54^{b}	0.86
8	3.71^{ab}	1.21
9	3.71^{ab}	0.86
10	4.00^{ab}	1.33
11	4.29^{ab}	0.92
12	3.92^{ab}	0.76
13	4.96^{a}	0.81
14	4.04^{ab}	0.72
15	3.67^{ab}	1.21
16	3.54^{b}	0.86
17	3.58^{ab}	0.93
18	4.04^{ab}	1.21
19	4.17^{ab}	0.44
20	4.50^{ab}	0.93
21	4.38^{ab}	0.48
22	3.58^{ab}	0.79
23	4.29^{ab}	0.66

24	4.38[ab]	0.43
25	4.03[ab]	0.68
26	4.75[ab]	0.78
27	4.25[ab]	0.89

Mean on the same column with different superscript are significantly different (P<0.05)
Range: 1.00 – 6.00

Analysis Result of Donkwa Chewiness

The mean scores for chewiness of the 27 different donkwa treatments were as shown in table 2.
Table 2: Analysis result of Donkwa chewiness

Treatments	Mean	±standard deviation
Control	3.75[a]	1.54
1	4.08[a]	1.08
2	4.58[a]	0.87
3	4.96[a]	0.81
4	4.96[a]	0.62
5	3.71[a]	1.64
6	4.63[a]	0.96
7	4.38[a]	1.13
8	4.08[a]	1.53
9	4.33[a]	1.25
10	4.13[a]	1.54
11	4.00[a]	1.35
12	3.92[a]	1.29
13	4.63[ac]	1.23
14	4.29[a]	1.37
15	4.33[a]	1.21
16	4.29[a]	1.16
17	4.46[a]	1.25
18	4.17[a]	1.45
19	4.08[a]	1.46
20	4.29[a]	1.18
21	4.67[a]	1.05
22	4.33[a]	1.21
23	4.50[a]	1.07
24	4.71[a]	0.89
25	4.63[a]	1.13
26	5.08[a]	0.36
27	5.25[a]	0.34

Means are not significantly different from each other (p > 0.05)
Range: 1.00 – 6.00

Analysis Result of Donkwa Firmness

The mean scores for firmness of the 27 different donkwa treatments were as shown in table 3.

Table 3: Analysis result of Donkwa firmness

Treatments	Mean	± standard deviation
Control	3.25[ab]	1.60
1	3.83[ab]	1.34
2	3.96[ab]	1.36
3	3.17[ab]	1.34
4	4.83[a]	0.94

5	4.13^{ab}	1.42
6	3.38^{ab}	1.11
7	3.42^{ab}	0.97
8	3.13^{ab}	0.80
9	3.08^{ab}	1.24
10	3.25^{ab}	1.60
11	4.04^{ab}	0.72
12	4.00^{ab}	1.11
13	4.17^{ab}	1.56
14	3.13^{ab}	1.23
15	3.13^{ab}	0.64
16	2.58^{b}	0.87
17	3.63^{ab}	0.43
18	3.04^{b}	0.69
19	3.42^{ab}	1.04
20	3.00^{b}	0.93
21	3.25^{ab}	1.39
22	2.83^{b}	1.05
23	3.46^{ab}	0.86
24	3.25^{ab}	1.54
25	3.2^{ab}	0.78
26	3.17^{ab}	1.53
27	4.33^{ab}	1.68

Mean on the same column with different superscript are significantly different ($P<0.05$)
Range: 1.00 – 6.00

Analysis Result of Donkwa Textural Hardness

The mean scores for textural hardness of the 27 different donkwa treatments were as shown in table 4.

Table 4: Analysis result of Donkwa textural hardness.

Treatments	Mean	±standard deviation
Control	3.67^{abc}	1.25
1	3.91^{abc}	1.62
2	5.08^{ab}	0.56
3	2.91^{d}	1.51
4	4.67^{ab}	0.65
5	4.58^{abc}	1.49
6	4.54^{abc}	1.41
7	4.29^{abc}	1.57
8	4.54^{abc}	1.53
9	4.46^{abc}	1.10
10	4.33^{abc}	0.89
11	3.33^{cd}	1.60
12	4.75^{ab}	0.66
13	3.42^{cd}	1.83
14	4.50^{abc}	1.00
15	4.41^{abc}	0.93
16	4.75^{ab}	0.62
17	5.25^{a}	0.45
18	4.92^{ab}	0.70
19	4.46^{abc}	0.84
20	4.71^{ab}	0.45
21	4.21^{abc}	1.27
22	4.75^{ab}	0.45

23	4.00^{abc}	1.40
24	4.42^{abc}	0.90
25	4.13^{abc}	1.19
26	4.50^{abc}	1.07
27	3.88^{abc}	1.68

Mean on the same column with different superscript are significantly (P<0.05)
Range: 2.00 – 6.00

Analysis Result of Donkwa Cohesiveness

The mean scores for cohesiveness of the 27 different donkwa treatments were as shown in table 5.

Table 5: Analysis result of donkwa textural cohesiveness

Treatments	Mean	±standard deviation
Control	3.58^{abcdef}	1.73
1	3.92^{abcde}	1.16
2	4.68^{a}	.84
3	3.71^{abcdef}	1.25
4	3.63^{abcdef}	1.19
5	3.79^{abcdef}	1.20
6	2.29^{f}	1.23
7	3.75^{abcdef}	1.12
8	3.38^{abcdef}	1.23
9	3.82^{abcdef}	0.90
10	3.46^{abcdef}	1.05
11	4.29^{abc}	1.03
12	3.79^{abcdef}	0.81
13	4.13^{abcd}	1.30
14	3.58^{abcdef}	1.29
15	2.67^{def}	0.78
16	3.50^{abcdef}	1.04
17	2.92^{bcdef}	0.97
18	2.50^{ef}	0.56
19	2.79^{cdef}	0.86
20	2.88^{bcdef}	0.88
21	3.54^{abcdef}	0.89
22	2.71^{def}	0.92
23	3.50^{abcdef}	1.22
24	4.38^{ab}	0.48
25	3.58^{abcdef}	0.36
26	3.71^{abcdef}	0.94
27	3.79^{abcdef}	0.58

Mean on the same column with different superscript are significantly different (P<0.05)
Range: 1.00 – 6.00

DISCUSSION

Result of donkwa sensory attributes

The adhesiveness of donkwa of experimental treatments 7, 13 and 16 are insignificantly different from each other but significantly different from the control, while the remaining treatments were not significantly different from each other and the controlat (p<0.05). There were no significant difference in the chewiness of the 27 experimental treatments with the exception of treatment 13 which is significantly different from the control and other experimental treatmentsat (p< 0.05). The experimental treatments 4,16,18,20 and 22 showed significant difference in firmness from the control, but the experimental treatment 4 was significantly different from both the control and othersat (p< 0.05). The treatments

2, 4, 12, 16, 18, 20 and 22 were not significantly different from each other but significantly different from the control in hardness at ($p < 0.05$). The experimental treatments 11 and 13 were not significantly different from each other in textural hardness at ($p < 0.05$). The experimental treatments 3 and 17 were significantly different from each other, from the control and from other treatments ($p < 0.05$). The treatments 1,5, 6, 7, 8, 9, 10, 14, 15, 19, 23, 24, 25, 26 and 27 were not significantly different from each other and the control at ($p < 0.05$).The experimental treatments of 3, 4, 5, 7, 8, 9, 10, 12, 14, 16, 21, 23, 25, 26 and 27 were not significantly different from each other and from the control at($p < 0.05$). The treatments 17 and 20 were not significantly different from one another but significantly different from the control at ($p < 0.05$).

CONCLUSION

The 27 experimental treatments showed that treatment 13 had quality characteristics in terms of adhesiveness, chewiness, firmness and cohesiveness than the control. However, it has lower textural quality characteristics than the control.

The treatment 27 recorded the highest chewiness, high firmness, moderately high textural hardness, high cohesiveness and adhesiveness in comparison with the control. The treatment 7 recorded the highest firmness, high textural hardness, moderately high cohesiveness, low adhesiveness and high chewiness in comparison with the control.

The treatment 2 recorded the highest textural hardness, high cohesiveness, high adhesiveness, high chewiness and high firmness in comparison with the control. The treatment 13 recorded the highest cohesiveness, high adhesiveness, moderately high firmness and low textural hardness in comparison with the control.

RECOMMENDATION

From the 27 experimental treatments, the products of treatment 2 recorded the highest of all the five sensory quality characteristics under consideration that is adhesiveness, cohesiveness, textural hardness, firmness and chewiness. Therefore, it was recommended as the best formulation for high quality donkwa preparation.

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COMPARATIVE ANALYSIS OF ESSENTIAL OIL FROM NIGERIAN GINGER (*ZINGIBER OFFICINALE ROSCE*) AND OTHERS

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ABSTRACT

Ginger essential oil was extracted and analysed from a locally grown ginger using steam distillation and gas chromatography –mass spectrometer methods respectively. The proximate composition of the ginger rhizome used was determined. The results obtained were compared to an available data on Thailand and China ginger proximate compositions as well as their respective essential oils. The oil yield was 1.7% which consisted of α-Pinene 0.22%, α-Phallendrene 0.04%, β-Phellandrene 1.00%, β-Pinene 0.65%, δ-Terpinene 0.04%, β-Sesquiphellandrene 18.45%, Farnesene 6.48%, Germacrene D 3.58% and Zingibrene 30.1%, having α-Pinene, α-Phallandrene and Zingibrene in common with Thailand and China ginger essential oils. The proximate composition of the ginger rhizome used was found to be Moisture content 88.53%, Ash content 2.47%, Lipids content 16.67%, Crude Fibre content 8.53%, Crude Protein 9.50% and Carbohydrates 62.50%. The ginger used was found to contain percentage lipids of 16.67% which is significantly higher compared to 7.78% and 9.00% Lipids content of Thailand and China gingers respectively, making it a good choice for oil extraction.

Keywords: *Ginger, Essential Oil, Gas Chromatography, Steam Distillation, Proximate Composition.*

Introduction

Essential oil refers to any concentrated, hydrophobic (immiscible with water), typically lipophilic (oil or fat soluble) liquid of plants that contains highly volatile aroma compounds and carries a distinctive scent, flavor, or essence of the plant. This large and diverse class of oils is also referred to as volatile oils, ethereal oils, aetherolea, or simply as the "oil of" the plant from which they were extracted (Ranitha *et al.,* (2013). Wide applications of ginger essential oil in medicine, food and cosmetics industries as well as the existence of different varieties, grown under different conditions have led to different studies of the essential oil. Although the variety and the age of the rhizome at harvest and distillation affect the composition and the yield of the essential oil and hence its flavor, the major factor that determines its value in the international market is its origin.

West African gingers, known for their stronger, more pungent and coarser flavors, of which Nigeria ginger is one, are the least studied among the varieties. Because of the applications of ginger essential oil in medicine and food industries and the compositional differences due to origin, there is the need for extraction and better understanding of the composition of West African ginger, which is the least studied so far. Currently, local production of essential oils is insignificant; nearly 100 per cent of the essential oils used by the local industries in Nigeria are imported. Research statistics from the Raw Materials Research and Development Council (RMRDC) indicates that a local demand of over 100,000kg annually is made, a figure that could be met through local production efforts.

Reports have it that Nigeria spent about $14m on importation of Essential oils between June and December 1994 alone. The export potential of essential oils is also very high as the market is presently dominated by the Chinese and Australians who are making significant income from this product in the international market. According to the United Nation's commodity trade figures, world trade in essential oils stood at $2bn in 2005. Apart from the numerous uses of essential oils, essential oils production also offer wide business opportunities to small-scale industrialists to invest in a viable area that guarantees speedy return on investments (Abraham, 2014).

MATERIALS AND METHODS.

Locally grown freshly harvested ginger rhizomes were obtained from Mr Kissinger's farm at Gidan sani village, Jaba local government area of Kaduna state, the ginger rhizomes were graded, sorted, split and sundried to reduce the moisture content to about 30%. The sample was then crushed using mortar and pestle.

Essential Oil Extraction Procedure

200g of the graded, cleaned, sundried and crushed ginger with the moisture content of about 30% was poured into the round bottom flask. 300ml of water was measured using a beaker and was poured carefully into the round bottom flask containing the crushed ginger sample, the mixture was properly mixed so as to allow for easy reaction. After which the other soxhlet extractor components (extraction chamber and condenser) were assembled, the valves that control the flow of cool water into the condenser were opened, the pressure pump was turned on and the heating mantle was turned on to a temperature of 90^0C. The setup was observed until the mixture began to boil. The boiling was allowed to continue, the vapour now containing the essential oil was condensed in the condenser and kept dropping into the extraction chamber until it got to a level that it was about to flush back into the round bottom flask then the heating mantle was turned off . The condensate now containing water (hydrosol) at the bottom and a small layer of the essential oil was collected into the separating funnel, after some time the water (hydrosol) was allowed out and the essential oil was collected into an air-tight bottle. The process was repeated until essential oil was no more realized.

Essential Oil Yield

A petri-dish was washed thoroughly and carefully then dried in an oven for a few seconds after which it was removed and placed in a dessicator to cool for a while. The weight of the petri-dish was taken using the electric weighing balance and was recorded as W_1. A 200g of the crushed ginger sample that was to be used for the extraction was added to the petri-dish, the new weight (weight of sample + weight of container) was taken using the electric weighing balance and was recorded as W_2 The air-tight bottle that was to be used for the collection of the essential oil to be extracted was weighed using the electric weighing balance and the weight was recorded as $W_{3.}$ After the extracted essential oil was collected into the bottle, the new weight (weight of bottle + weight of essential oil) was taken and recorded as $W_{4.}$

Finally the percentage of the essential oil yield was computed as according to the relation reported by Pin *et al*; (2009):

$$\text{\% Essential Oil Yield} = \frac{Weight\ of\ Essential\ Oil}{\text{Weight of Ginger}} \times 100 \qquad (1)$$

$$= \frac{W_4 - W_3}{W_2 - W_1} \times 100$$

Analysis of the Essential Oil

The chemical analysis of the extracted ginger essential oil was carried out using Gas chromatography- mass spectrometer. The read out of the peaks and the retention time where compared to known substances readout and the compounds were identified.

Proximate Composition

The proximate analysis of the ginger rhizomes used was carried out using the Standard methods as described by Onwuka (2005).

Proximate/Essential Oil Composition of Thailand and China Gingers

The proximate composition of Thailand and China ginger rhizomes as well as their respective essential oil composition was obtained from Misbah *et al.,* (2005).

RESULTS

From equation (1) the percentage essential oil yield was 1.7%. Table 1 shows the chemical compounds that were identified from the locally grown ginger.

Table 1: Composition of the extracted essential oil

S/No	Identified compounds	Concentration (%)
1	α-pinene	0.22
2	α-phallendrene	0.04
3	β-Phellandrene	1.00
4	β-pinene	0.65
5	δ-Terpinene	0.04
6	β- Sesquiphellandrene	18.45
7	Farnesene	6.48
8	Germacrene D	3.58
9	Zingibrene	30.10

The composition of ginger essential oil extracted from the Thailand and China ginger rhizomes are shown in Tables 2 and 3 respectively.

Table 2: Thailand Ginger Essential Oil Composition

Peak No	Identified compounds	Concentration (%)
5	α-pinene	3.59
6	α-phallendrene	2.84
7	Myrecene	4.58
8	β-pinene	0.74
9	γ-Terpinene	2.49
12	1,8-Cineol	3.87
13	Citral	5.39
15	Zingibrene	30.81

Table 3: China Ginger Essential Oil Composition

Peak No	Identified compounds	Concentration (%)
5	α-pinene	0.305
6	α-phallendrene	1.02

7	Myrecene	4.82
8	γ-Terpinene	2.88
9	1,8-Cineol	2.40
12	Citral	4.50
13	α-Terpinene	6.50
15	Zingibrene	8.00

The proximate composition of Thailand and China ginger rhizomes are shown on Table 4.

Table 4: Proximate compositions of Thailand and China gingers

Contents	Thailand ginger (%)	China ginger (%)
Moisture	89.20	88.00
Protein	12.25	6.67
Crude Fiber	6.00	15.00
Fat	7.78	9.00

The proximate composition of the locally grown ginger is shown in Table 5.

Table 5: Proximate Composition of the Ginger Used

Nutrients		Composition		Mean ± S.D
	Replicate 1	Replicate 2	Replicate 3	
Moisture	88.40%	88.70%	88.50%	88.53% ± 0.13
Ash	2.40%	2.10%	2.90%	2.47% ± 0.33
Lipids	19.00%	14.00%	17.00%	16.67% ± 2.06
Crude Fibre	8.70%	8.80%	8.10%	8.53% ± 0.31
Crude Protein	9.80%	9.20%	9.50%	9.50% ± 0.25
Carbohydrates	60.10%	65.90%	62.50%	62.80% ± 2.38

Discussion of Results

Comparative Analysis of Thailand, China and the Nigerian Ginger based on their Proximate Compositions

Comparing the moisture contents of the Thailand, China and Nigerian ginger which are; 89.2%, 88.00% and 88.53% respectively, shows that they all have approximately the same moisture contents but with the Thailand ginger having slightly higher moisture content. Looking at the protein contents which are; 12.25%, 6.67% and 9.50% for the Thailand, China and Nigerian ginger respectively shows that the Thailand ginger contains more protein followed by

Nigerian ginger and then the China ginger.

Considering the crude fibre contents of the Thailand, China and the Nigerian gingers which are; 6.00%, 15.00% and 8.53% respectively, the result shows that the Chinese ginger contains more crude fibre than both the Thai and Nigerian gingers. The result obtained for the lipid contents are; 7.78%, 9.00% and 16.67% for the Thai, Chinese and the Nigerian ginger respectively, thereby indicating that the Nigerian ginger rhizome is by far richer in lipids content which makes it the best choice for Oleorisin extraction.

The essential oil yield of 1.7% obtained in this study is lower than the value of 4.7% reported by Awang *et al*; (2014).

The ash and carbohydrate content of the Nigerian ginger used in the experiment as obtained in the analysis are; 2.47% and 62.80% respectively. The proximate composition of Thailand, China and Nigerian ginger are illustrated in Fig 1.

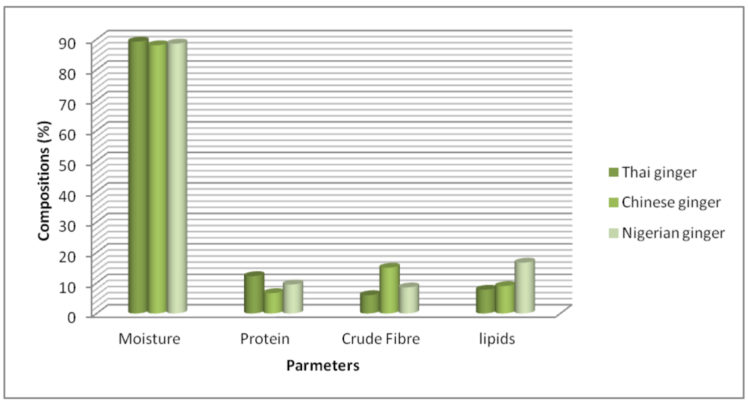

Fig 1: Bar Chart showing the Proximate Compositions of Thai, Chinese and Nigerian ginger

Comparative Analysis of the Essential Oils Composition

The result showed that the percentage composition of the identified compounds in Thailand ginger essential oil were α-Pinene 3.59, α-Phallandrene 2.84, Myrecene 4.58, β-Pinene 0.74, γ-Terpinene 2.49, 1,8-Cineol 3.87, Citral 5.39 and Zingibrene 30.81%. The percentage composition of the major compounds that were identified in the essential oil extracted from China ginger were α-Pinene 0.305, α-Phallandrene 1.02, Myrecene 4.82, γ-Terpinene 2.88, 1,8-cineol 2.4, α-Terpinene 6.5, Citral 4.5, and Zingibrene 8.0%. The percentage composition of the major compounds that were identified in the essential oil extracted from Nigerian ginger were α-Pinene 0.22, α-Phallendrene 0.04, β-Phellandrene 1.00, β-Pinene 0.65 δ-Terpinene 0.04 β-Sesquiphellandrene 18.45, Farnesene 6.48, Germacrene D 3.58, and Zingibrene 30.1%. The result showed that the essential oil extracted from the Thailand, china and Nigerian ginger have the following compounds in common α-pinene, α-phallandrene and Zingibrene. Thailand and Nigerian ginger essential oils have β-pinene in common. The following major compounds were also identified in Nigerian ginger essential oil only; β-Phellandrene, δ-Terpinene, β-Sesquiphellandrene, Farnesene and Germacrene D. The result obtained shows that Zingibrene is the predominant constituent of ginger essential oil (Ranitha, *et al.,* (2013).

The percentage composition of the compounds that are present in both the Thailand ginger essential oil, China ginger essential oil and Nigerian ginger essential oil are illustrated in Fig 2.

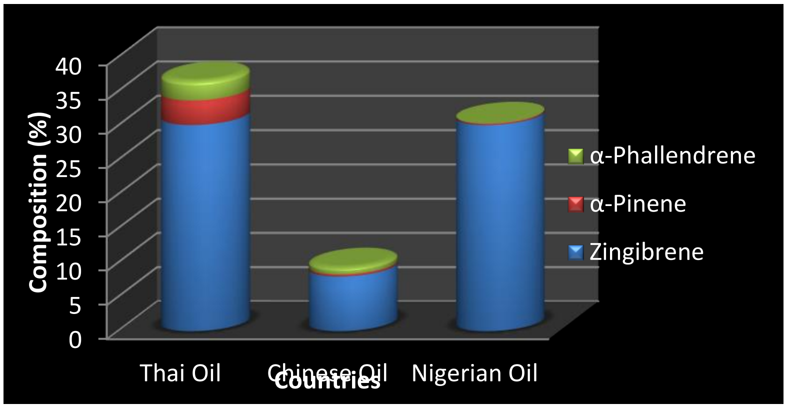

Fig 2: Bar Chart showing the compounds present in Thailand, China and Nigerian ginger essential oils.

Conclusion

This study has shown that Nigerian ginger essential oil contains a very good percentage of Zingibrene which is the compound responsible for flavouring, thereby making it a very good choice for aromatherapy and other applications. A good percentage of essential oil can be extracted from Nigerian ginger which makes it a good choice for essential oil extraction.

The study also revealed that ginger rhizomes contain a very high percentage of moisture, therefore for longtime storage the moisture content of ginger rhizomes should be reduced. Nigerian ginger contains a higher percentage of lipids, thus making it a very good choice for Oleorisin production.

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ASSESSMENT OF HANDLING LOSSES OF SOME MAJOR FRUITS AND VEGETABLES GROWN IN ADAMAWA STATE, NIGERIA

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ABSTRACT

The aim of the study was to assess handling losses in some fruits and vegetables in Adamawa State, in order to provide relevant information for formulation of policy and strategies for losses reduction in the areas. A sample of 280 farmers and traders were selected randomly from fourteen local government areas spread across the three Senatorial Zones of the state. A self – study questionnaire was designed and used to collect data; copies of the questionnaire were distributed and returned by hand. The data collected were analysed by percentages and other appropriate tools, the result interpreted at 5% level of significance. The study revealed that losses ranged from 21 – 37% in various fresh products, with a mean loss of 28%; while mean loss in dry products is 4%. Losses occurred in form of spoilage, wilting and mechanical damage. The causes of losses are poor harvesting practices, exposure of the products to the sun during transportation and storage under non - ideal conditions. Recommendations were made that could lead to reduction in these losses.

Keywords; *Assessment, Handling losses, Fruits, Vegetables.*

INTRODUCTION

Fruits such as mango and orange are juicy seed bearing structures of flowery plants that may be eaten as supplement to a meal or alone usually in raw form, while vegetables like sorrel and spinach are soft edible portions of plants which can be eaten alone or as part of a meal in cooked form (Tehinse, 1985).Vegetable production forms a substantial percentage (about 25%) of the major food crops cultivated in the tropics and so it is the source of livelihood for a considerable section of the population (Kra and Bani, 1988). In terms of value of production, vegetables rank even higher than all cereals except rice, all root crops, and all grain legumes. Fruit and vegetable production, marketing, processing, transport and export contribute significantly to employment and income. The importance of fruits and vegetables cannot be overemphasized due to the role they play in supplementing the important nutrients in our diet and also the health benefits derived from them. Fruits and vegetables can provide widely accessible sources of essential vitamins (particularly A, C, niacin, riboflavin and thiamine), and minerals (such as calcium and iron), as well as supplementary protein and calories. (F.A.O1990). Some vegetables, according to Asian Vegetable Research and Development Centre (1971), such as roots, tubers and leafy greens, are capable of producing protein and calories comparable to those of the most efficient staple cereal crops. Fruits and vegetables promote intake of essential nutrients from other foods by making them palatable. They also provide dietary fibre to improve digestion and health, and they are essential for properly balanced diets. In Nigeria, enormous quantities of fruits and vegetables are produced and staggering figures are sometimes given as estimated annual production. For example, figures like 3.8 million tonnes of onion, 6 million tonnes of tomatoes and 35 million tonnes of citrus have been quoted as annual production levels (Oyeniran, 1988). However, it is the amount of produce available to the consumer rather than the level of production that is more important. Fresh fruits and vegetables are inherently perishable. During the process of distribution and marketing, substantial losses are incurred which range from light loss of quality to total spoilage. Most fruits and vegetables are highly perishable and are often harvested and sold on the same day. Where they have been transported for some distance, however, it is essential that they be kept cool and moist. The use of containers which will protect them from damage and overheating is therefore essential (Rice *et al,* 1993). A reliable form of transportation to the market is necessary if market supplies are to be maintained, but this is often difficult to achieve unless the grower also has the means of transporting his produce directly to market. In this situation, he is able to control all the essential operations of harvesting, washing, grading or trimming and packing in containers to the final presentation in the market. The marketing chain for fruits and vegetables in Nigeria typically consists of the farm gate buyers (or what you may call dealers) who buy the produce from the farmers, the wholesalers who buy from the dealers, and the retailers who buy from the wholesalers and sell to the consumers. In the case of the leafy vegetables the chain is shorter, the farmer in many cases selling directly to the retailers. With virtually no industries to process the fruits and vegetables in Nigeria, the farmers rely on the chain to dispose of their produce. There are daily surpluses, especially during the peak harvesting period, both at the farmer's end and at the retailer's end of the chain. These surpluses mostly go bad as a result of poor handling and lack of effective preservation method. When fruits and vegetables are transported over long distances, poor handling, poor packaging as well as bad roads cause considerable damage to the produce. These damages lead to spoilage. The aggregate spoilage from these sources could be substantial, and constitutes a considerable financial loss to the farmers and traders, as well as reduce the availability of the produce in the market. Such losses also represent a waste of human effort, farm inputs, investments and scarce resources such as water. The objective of this paper is to present a study conducted on losses assessment in some major fruit (mango, guava, pawpaw and orange) and vegetables (sorrel, tomato, pepper and spinach) in Adamawa State of Nigeria.

MATERIALS AND METHODS

The Study Area

Adamawa State is in the North-eastern zone of Nigeria, lying between latitude 8^0N and 11^0N and longitude 11.5^0E and 13.5^0E. It is bounded on the north by Borno state, on the south by Taraba state, on the west by Gombe and Taraba states and on the east by Cameroun Republic. It has an area of 39,742 square km. with a population of 3,106,585 (2006 census), the majority of whom are farmers. There are two notable vegetation zones within the state, the sub-Sudan zone, marked by short grasses and trees (in the north) and the northern Guinea Savannah with tall grasses and trees (in the south).The state tropical climate is marked by dry and wet seasons. The rainy season commences in April and ends in late October, with annual rainfall of 79mm in the northern part and 197mm in the southern part. The dry season runs from November to April.

Population of the Study Area

Sampling

A total of two hundred and eighty farmers and traders were selected for the study. Twenty respondents were selected from each of the fourteen local government areas, where Ten (10) farmers and Ten (10) traders were considered using simple random sampling technique. The local government areas selected from the three senatorial zones of the state (North, Central and South), were Demsa, Fufore, Ganye, Hong, Madagali, Maiha, Mayo-Belwa, Michika, Mubi North, Mubi South, Numan, Shelleng, Yola North and Yola South. .

Data Collection

Data collection in this study was by means of a self-study questionnaire. Copies of the questionnaire were administered by hand in some areas through intermediaries. Out of the 280 copies sent out. Five questionnaires were distributed for fruit farmers, five for vegetable farmers and ten questionnaires goes to the traders. 213 copies were returned, giving a return rate of 76 percent.

Data Analysis

The data collected were analysed by percentages to study the percentage losses of the fruits and vegetables by the farmers and the traders. and t-test for the comparison of the losses for farmers and traders, as well as the losses incurred by respondents due to various educational levels. The results were interpreted at 5% significance level which produced a t-value of 0.83.

RESULTS

The data collated and collected from the questionnaires were presented in the tables 1 - 15

Table 1: Stages of Harvesting

Stage of Harvesting	Number of Farmers	Percentage
Ripe	64	76
Unripe	0	0
Ripe and Unripe	20	24
Total	**84**	**100**

Table 2: Time of Harvesting

	FRUITS		VEGETABLES	
Time of Harvesting	No. of Farmers	Percentage	No. of Farmers	Percentage
Morning	33	79	60	97
Afternoon	0	0	0	0
Evening	9	21	2	3
Total	**42**	**100**	**62**	**100**

Table 3: Harvesting Methods for Fruits

Methods	Number of Farmers	Percentage
Sharking the tree	11	26
Plucking with pole/hook	21	50
Hand picking into container	10	24
Total	42	100

Table 4: Distance Travelled During Transportation

Distance in (Km)	No. of respondents	Percentage
Very close (1-30)	22	10
Close (31-60)	38	18
Fairly far (61-90)	102	48
Far((91-120)	22	10
Very far (Above 120)	29	14
Total	213	100

Table 5: Condition of Road travelled

Condition	No. of respondents	Percentage
Very good	26	12
Good	19	9
Fairly good	27	13
Poor	98	46
Very poor	43	20
Total	213	100

Table 6: Type of Vehicle used for transportation

Type of Vehicle	No. of Respondents	Percentage
Refrigerated van	0	0
Trailer/lorry	102	48
Pick-up van	66	31
Bus	30	14
Station wagon	15	7
Total	213	100

Table 7: Packaging Materials used for Transportation of Produce

Material	No. of Respondents	Percentage
Basket	147	69
Cardboard box	155	73
Wooden box	1`3	6
Plastic case	0	0
Sack	183	86
Total	213 *	100

* Respondents use more than one material; hence sum of numbers is more than 213 and sum of percentages is more than 100.

Table 8: Preservation Methods Used

Method	No. of Respondents	Percentage
Cold room	0	0
Refrigeration	0	0
Sprinkling of water	175	82
No preservation	38	18
Total	213	100

Table 9: Average Storage Periods for Fresh Produce

Produce	Storage Period (days)
Mango	7
Orange	7
Guava	3
Pawpaw	4
Tomato	4
Pepper	7
Spinach	2
Sorrel	1

Table 10: Respondents that Dry Produce

Produce	No. of Respondents	Percentage
Tomato	31	24
Pepper	22	36
Sorrel	17	23
Mean	-	28

Table 11: Respondents Using Preservatives

Response	No. of Respondents	Percentage
Using preservative	12	23
Not using preservative	41	77
Total	53	100

Table 12: Average Storage Periods for Dry Produce

Produce	Storage Period (Months)
Tomato	6 months
Pepper	6 months
Sorrel	6 months

Table 13: Losses encountered in Fresh and Dry Fruits and Vegetables

Produce	Loss (%)	
	Fresh	Dry
Mango	32	N.A
Orange	26	N.A
Guava	30	N.A
Pawpaw	31	N.A
Tomato	37	8
Pepper	22	4
Spinach	21	N.A
Sorrel	28	*
Mean	28	4

Key:

N.A = Not applicable

* = Negligible

Table 14: Nature of Losses in Fresh Fruits and Vegetables

Produce	No. and Percentage of Respondents			
	Spoilage	Wilting	Mechanical Damage	Pest Damage
Mango	21 (32)	12 (18)	30 (46)	6 (9)
Orange	20 (22)	9 (10)	16 (18)	0 (0)
Guava	16 (42)	9 (24)	7 (18)	3 (8)
Pawpaw	13 (57)	7 (30)	7 (30)	2 (9)
Tomato	95 (74)	70 (55)	46 (36)	19 (15)
Pepper	56 (47)	40 (33)	14 (12)	6 (5)
Spinach	3 (5)	20 (32)	5 (8)	3 (5)
Sorrel	6 (8)	34 (46)	4 (5)	2 (3)

Table 15: Nature of Losses in Dry Fruits and Vegetables

Produce	No. and Percentage of Respondents	
	Spoilage	Pest Damage
Tomato	7 (17)	5 (12)
Pepper	2 (5)	1 (3)
Sorrel	0 (0)	2 (3)

DISCUSSION

The data collected showed that 76% of the respondent farmers harvest their produce ripe, while 24% harvest their produce either ripe or unripe. Most of the farmers harvest their fruits either in the morning or in the evening and their vegetables in the morning. No harvesting is done in the afternoon. Majority of the farmers allow their harvested fruits to fall to the ground from the tree. Among the remaining who harvests their fruits into containers, half pile the harvested fruits on the ground before eventual evacuation.Harvesting in the morning or evening when the ambient temperature is low is good practice, as this leads to low moisture loss from the produce. However, most of the farmers either allow their fruits to fall on the ground or pile them on the ground, or both. These practices are likely to cause mechanical damage, especially on the bulk of the produce which is harvested ripe. Thus the farmers harvest their produce at the proper time, but engage in some poor harvesting practices.

Transportation

The produces are transported over distances that are generally fairly long on roads that are generally in poor condition. The types of vehicle used for transportation are Lorries, pick-up vans, buses and station wagons. No one uses refrigerated van.

The packaging materials mainly used for transportation of the produce are sack, cardboard box and basket. The poor condition of the roads on which the fruits and vegetables are transported very likely causes vibration of the vehicles which causes mechanical damage on the produce. With respect to packaging, it is not only the material that determines damage but also how the material is handled. However, the study could not gather information on the handling of the packages, particularly during loading and unloading, and their stacking in the vehicles.

Preservation

About 82% of the respondents apply evaporative cooling on the fresh produce in storage (by sprinkling water on it), while 18% do not apply any preservation method. No one uses refrigeration or cold room. The average storage periods for fresh produce are 1 day for sorrel, 2 days for spinach, 3 days for guava, 4 days for pawpaw and tomato and 7 days for mango and pepper. About 28% of farmers and traders who deal on tomato, pepper and sorrel dry part of these products. Only 23% of those who dry their products use preservatives in storing the dry products. The dried products are stored for up to 6 months. Without the use of cold storage, fruits and vegetables in the study area are stored under less than ideal conditions (Table 2.1), and these conditions favour deterioration. Drying, which elongates the shelf life of the produce, is not practiced by majority of respondents, possibly due to the task involved and the consumers' preference for fresh products.

Loss Levels

Table 4.13 shows that the losses encountered in fresh produce range from 21% for spinach to 37% in tomato, with a mean of 28%; these values are within the range of values quoted for Nigeria and developing countries in general. The values are within the lower half of the range quoted (20 – 70%) possibly partly due to the fact that the fruits and vegetables are not kept for too long in storage. The losses in the dry products are only 0 – 8%, with a mean of 4%. These low values confirm the effectiveness of drying method of preservation, even with the much longer storage period.

Nature of Losses

Table 4.14 shows that spoilage (rottening) is the most important form of loss in all the products except mango and the leafy vegetables (spinach and sorrel), although for mango it is also an important form of loss. Wilting is an important form of loss in guava, pawpaw and all the vegetables. Mechanical damage is high in mango, pawpaw and tomato. Pest damage is not an important form of loss in any of the products, although it is highest in tomato. The prominence of spoilage is likely due to the less than ideal condition under which the products are stored. Wilting is probably due to the fact that majority of the vehicles used in transportation of the produce are open vehicles (Lorries and Pick-up vans) which expose the products (if not covered) to the sun. Mechanical damage is likely due to the poor harvested practices among majority of the farmers, and probably compression during transportation The spoilage of dried tomato is probably due to improper drying. However, there is no important form of loss in the dry products.

Influence of Social Factors on Loss

(a) ***Occupation***

The t value is not significant, implying that the two groups incur the same loss. The farmers harvest their produce; they handle, and are therefore in a position to control what happens to the produce all through from harvesting to sale. On the other hand, the trader has control over the produce from the point it is delivered to him. It was therefore thought that the farmers would incur lower loss than the traders. However, this was not supported by the result.

(b)***Education Level***

This study reveals that educational level does not influence loss. Since education is known to sharpen behaviour, further studies would bring more ideas and appropriate handling devices leading to lower losses.

CONCLUSION

The study was carried out in Adamawa state to determine the level and causes of handling losses in mango, orange, guava, pawpaw, tomato, pepper, spinach and sorrel. The study revealed that losses in the fresh fruits and vegetables range from 21% in spinach to 37% in mango, the average loss in all produce being 28%. The loss in dry produce (tomato, pepper and sorrel) is 4%, confirming the effectiveness of drying in controlling losses in these products. The losses incurred are in form of spoilage (rottening), wilting and mechanical damage, with spoilage being the most serious form generally. In the leafy vegetables wilting is the most serious. The causes of loss are poor harvesting practices of allowing the fruits to fall on the ground from the tree, exposing the produce to the sun during transportation and storage under condition that are not ideal. Neither the occupation of the handlers of fruits and vegetables (farmer or trader) nor their educational level influences loss, contrary to expectation.

RECOMMENDATIONS

1) The farmers who grow fruits should be discouraged from allowing the produce to fall on the ground from the tree during harvesting. Hand plucking into containers should be encouraged. This task can be carried out by an appropriate government agency responsible for agricultural extension.
2) Produce transported in open vehicles should be covered to provide protection from the sun, in order to control moisture loss.
3) An evaporative cooling system for transportation of fruits and vegetables should be developed. Such system, placed in an open van, will have a small water pump drawing power from the electrical system of the vehicle. A wind breaking device will be necessary to reduce the air speed when the vehicle is in motion to a level appropriate to the water supply rate. A system of this nature will reduce spoilage and moisture loss during transportation.
4) More of the tomatoes, pepper and sorrel should be dried to reduce loss in storage.
5) Government should pay greater attention to road maintenance. Good roads will prevent mechanical damage of the produce through vibration.

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FARM POWER AND MACHINERY

PERFORMANCE OF A SINGLE CHAMBER SOIL MICROBIAL FUEL CELL ACROSS VARIED EXTERNAL LOADS FOR POWER GENERATION.

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ABSTRACT

The soil is beginning to receive attention as suitable inoculums for Microbial Fuel Cells (MFCs) designed for remediation and for electricity generation because of its high microbial load. However, not much has been done in this aspect beyond laboratory based experiment. This study is aimed at generating electricity from agricultural soil, utilizing the microorganisms already present and the soil nutrients as the sole substrates and to investigate the performance of the soil Microbial Fuel Cell (MFC) across varied external loads. The study used the mud watt MFC kit inoculated with mud prepared from topsoil, collected from a garden where crops have been cultivated over the years. The electrodes (anode and cathode, 7cm diameter each), made of carbon felt material with conducting wires made of graphite, were housed in the same chamber and placed 4 cm apart. Voltage drop across seven external resistances 4670 Ω, 2190 Ω, 1000 Ω, 470 Ω, 220 Ω, 100 Ω and 47 Ω, were measured every 24 hours, with a digital multi-meter, for 40 days. The maximum open circuit voltage from this study was 731 mV, whereas the maximum power density was 65.40 mW/m^2 at a current density of 190.1 mAm^{-2}. The optimum performance of the MFC was achieved with the 470 Ω which is an indication that the internal resistance of the soil MFC of this present study is close to 470 Ω. This study revealed that MFCs constructed from agricultural topsoil are capable of producing electrical power continuously, across different external loads, without addition of any substrate.

Keywords: *Microorganisms, metabolism, performance, soil, external loads*

INTRODUCTION

The focus of global interest has been persistently directed towards alternative energy sources as, perhaps, one viable solution to the growing problem of fossil fuel depletion (Ieropoulos *et al*., 2012). Besides promising technologies such as photovoltaic, wind-turbines and hydropower, Microbial Fuel Cell (MFC) technology has been receiving increased attention as a potential part of this field of natural energy. The possibility of generating electricity from bacteria has been well established for almost one hundred years. But only in the past few years this capability had become more than a laboratory based experiment. It has been known that electricity can be generated using any biodegradable material, even wastewater, and that there is no need to add any special chemicals if bacteria is already present in the wastewater. While some iron-reducing bacteria, such as *Shewanella putrefaciens* and *Geobacter metallireducens* can be used to generate electricity, there are many other bacteria already present in wastewater that can do this (Logan and Regan, 2006).

Microbial Fuel Cell (MFC) technology is a new form of renewable energy technology that can generate electricity from what would otherwise be considered waste. It is a bio-electrochemical system that harnesses the natural metabolisms of microbes to produce electrical power. Within the MFC, microbes consume or degrade the nutrients in their surrounding environment and release a portion of the energy contained in the food in the form of electrons (Li, 2013). The electrons are then transferred to a terminal electron acceptor (TEA) which is reduced by the electrons. TEAs such as oxygen, nitrate and sulphate can diffuse into the cell and accept electrons to form new products that can then leave the cell. However, some bacteria can transfer their electrons outside the cell (exogenously) to the awaiting TEA. It is these bacteria that can produce power within an MFC system (Logan, 2008; Jenna, 2010).

Materials with abundance of microorganisms and high content of organic matter have been utilized in MFCs to generate electricity. These materials include, among others, industrial/domestic waste-water (Rabaey and Verstraete, 2005) marine sediment (Bond *et al*., 2002; Scott *et al*., 2008), sewage sludge (Zhang *et al*., 2012), garden compost (Parot *et al*., 2008) and animal waste (Yokoyama *et al*., 2006).

Results from several studies have demonstrated that the soil is suitable inoculums for MFCs designed for remediation and for electricity generation because of its high microbial load (Li, 2013; Samuel *et al.*, 2013; Deng *et al.*, 2014). It has been estimated that soil generally has a bacterial population of approximately 10^9

cells/g (Whitman *et al.*, 1998) and organic matter content of within 100 mg/g (Bot and Benites, 2005). Soils are naturally teeming with a diverse consortium of microbes, including the electrogenic microbes needed for MFCs, and are full of complex sugars and other nutrients that have accumulated over millions of years of plant and animal material decay. Soil-based MFCs (Fig. 1) adhere to the same basic principles of MFC operation. In this case, soil acts as the nutrient-rich anodic media, the inoculums, and the Proton Exchange Membrane (PEM). The anode is placed at a certain depth within the soil, while the cathode rests on top of the soil and is exposed to the oxygen in the air above it (Science Budies Staff, 2014).

Deng *et al*. (2014) noted that soil MFC without the carbon addition may generate power by using its own organic matter as fuel. The only natural components needed for a soil-based MFC to run are nutrient-rich soil and combining the soil with water to form mud. By implication, the soil MFCs can endlessly produce electricity if it does not run out of its nutrient-rich characteristics as long as conditions remain favorable for current production by the anode-associated microbes (Ashley and Kenny, 2010).This makes them very attractive for applications that only require low power but where replacing batteries may be time consuming and expensive. MFCs can possibly be used to power sensors particularly in the river and deep water environments where it is difficult to replace batteries. Powered by MFCs, the sensors can be left alone in remote areas for many years without maintenance (Li, 2013).

The influence of external resistance on the performance of MFCs has been studied by many researchers. Krishna *et al*. (2011) reported that the external resistance applied to MFCs during formation of the bacterial communities from sewage wastewater had no significant effect on power performance of the MFCs nor a significant influence on their anodic activity with both glucose and brewery wastewater as fuel. However, current generation, COD removal and the biomass yield were all directly influenced by the external load. Large differences in external resistance have been reported to affect both power production and microbial community structure.

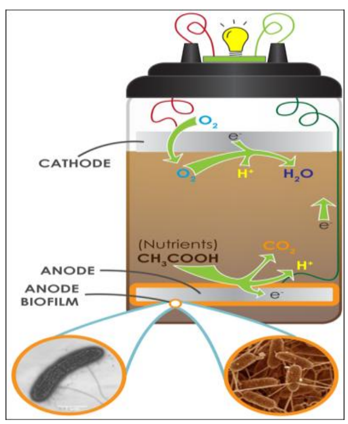

Fig. 1. A diagram of a Soil-based MFC. Source: (Wikimedia Commons, 2010)

Similarly, change in external resistance can change the anodic microbial community structure after the establishment of anodic microbial community. MFCs systems are flexible permitting different microbial community structures, established under different external resistances, to result in similar power production (Lyon *et al*., 2010). The flexibility of MFCs accounts for their ability to perform across a wide range of external loads. However, Maximum power point or optimum performance can only be achieved when external load is equal to the MFC's internal resistance (Logan *et al*., 2006). Output maximization is not possible if experiments with varying external loads are not performed.

Major researches in MFCs have been focused on waste water probably due to the dual advantage of wastewater treatment as well as electricity generation. No serious attention has, hitherto, been given to the soil-based MFCs for electricity generation, despite the large population of microbes present in the soil. Besides, the performance of the soil-based Membrane-less Single Chamber Microbial Fuel Cell (MSCMFC) across varied external loads has, hitherto, not been investigated. Therefore, this study is aimed at generating electricity from agricultural soil utilizing the microorganisms already present and the soil organic contents and nutrients as the sole substrates and to investigate the performance of the soil MSCMFC across varied external loads.

METHODOLOGY

Soil Sampling

Topsoil was collected from the vegetable garden at Appleton Junction adjacent U&I restaurant of the University of Ibadan (7°23′47″N 3°55′0″E), Nigeria. Soil sample was collected at a depth of 0-20 cm. The climate of this location is tropical wet and dry climate, with a lengthy wet season and relatively constant temperatures throughout the year. The mean total rainfall for Ibadan is 1420.06 mm. The mean maximum temperature is 26.46 °C, minimum 21.42 °C and the relative humidity is 74.55 %. This location was chosen because it is a rich farmland where crops have been cultivated over the years.

Preparation of Mud from Topsoil and MSCMFC Setup

After sampling, soil was thoroughly strained to remove any small hard particles (such as pebbles, rocks and twigs) the fine soil obtained after straining and mixed thoroughly until it was well prepared into mud. An MSCMFC kit designed by Keego Technologies LLC and assembled in the USA was used. It was set up according to the method described by Science Buddies Staff (2014). The electrodes (7 cm diameter) were assembled by carefully inserting the anode wire into the anode felt (carbon cloth), and the cathode wire into the cathode felt. Both wires were bent 90° at the points where the wires insulators end. A layer of mud was packed into the bottom of the fuel vessel up to the 1cm mark and it was pat down to obtain a smooth layer (Plate 1). The anode was placed in the mud by pressing it down firmly to squeeze out air bubbles after which the vessel was filled with more mud up to the 5 cm mark making the total volume of soil (mud) in the vessel 192 ml. Then, the cathode was gently placed on top of the mud but not covered with it. Finally, the lid of the MFC vessel was used to cover it, with the electrodes passed through the appropriate holes on the lid.

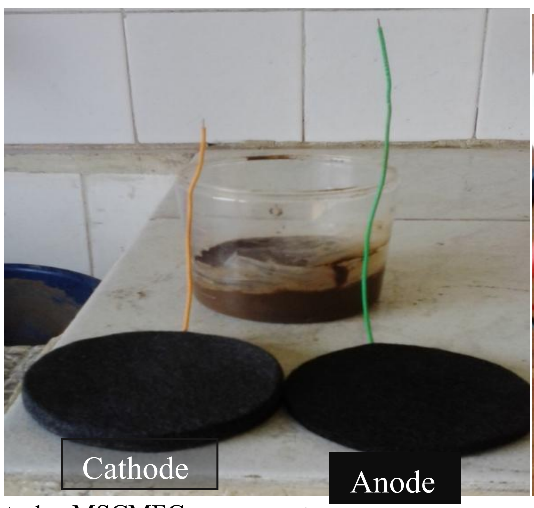

Plate 1. : MSCMFC components

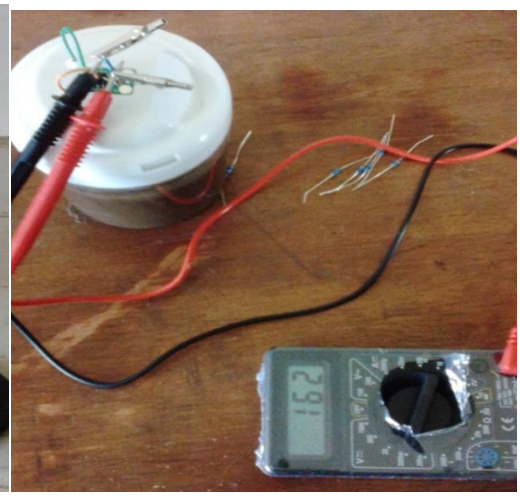

Plate 2: Multi-meter connected for voltage measurement

Data Acquisition and Calculations

The daily Open Circuit Voltage (OCV) was read with a digital multi-meter (Kelvin 50LE) after which crocodile clips were used to clip a multi-meter's probes and the resistor's lead to the cell's electrodes for voltage measurement (as shown on Plate 2). The voltage drops of the MFC across seven external resistances (4700 Ω, 2200 Ω, 1000 Ω, 470 Ω, 220 Ω, 100 Ω and 47 Ω) were noted after stabilization (5 to 10 minutes intervals). This measurement was repeated every 24hour, for the whole duration of the experiment. With the measured values of voltage, the current was determined from Equation 1, according to Ohm's law.

$$I = V/R \qquad (1)$$

V = voltage across each resistor in Volts

R = resistance of each external load (Ω).

Current densities were obtained by normalizing the calculated currents to the anode surface area (0.00385 m^2). In order to assess maximum power, polarization and power density curves were obtained by varying external resistance between

4.7 kΩ and 47 Ω according to the method described by Deng *et al*. (2014). The power density (P) for each external load was calculated and normalized to the anode surface area (A_{an}) using equation (2) (Logan *et al.*, 2006).

$$P = \frac{V^2}{A_{an}R} \qquad 2$$

RESULTS AND DISCUSSION

Results

The soil MFC was successfully operated without any outside source of inoculation. Fig. 2 presents the OCVs of the MFC over the 40-days operational period. The performances of the MFC at the seven external resistances are presented in fig. 3. Polarization and power density curves obtained after 15 days of operation of the MFC are presented in fig. 4.

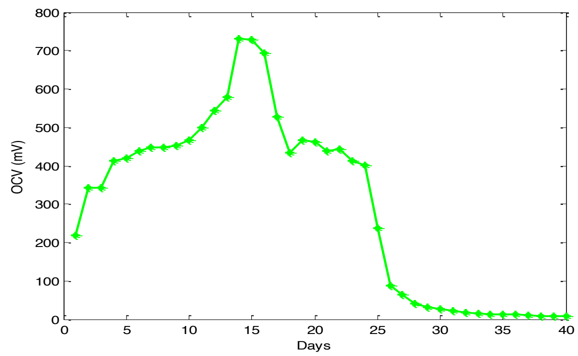

Fig 2: MFC Open Circuit Voltage

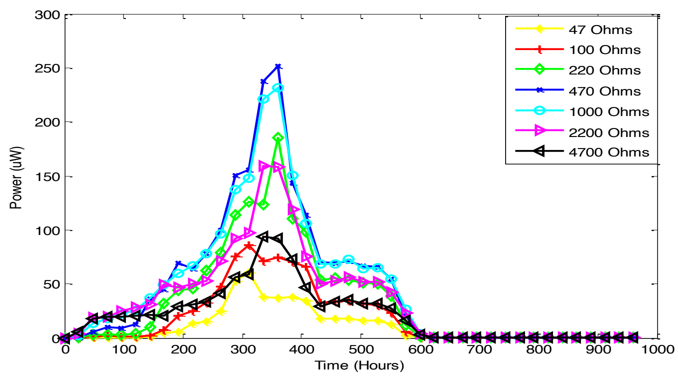

Fig 3: Power versus time plot of the soil MFC across set 3 external loads

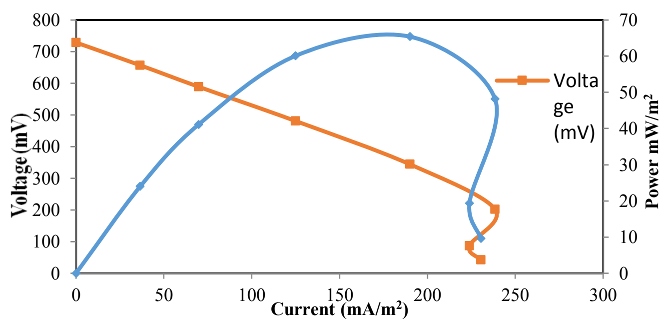

Fig. 4: Polarization and Power Density curves of the soil MFC

Internal Resistance

The daily internal resistance was calculated by linear regression of voltage against current according to Min *et al.* (2013). Figure 5 presents the MFC's internal resistance variation with days of operation.

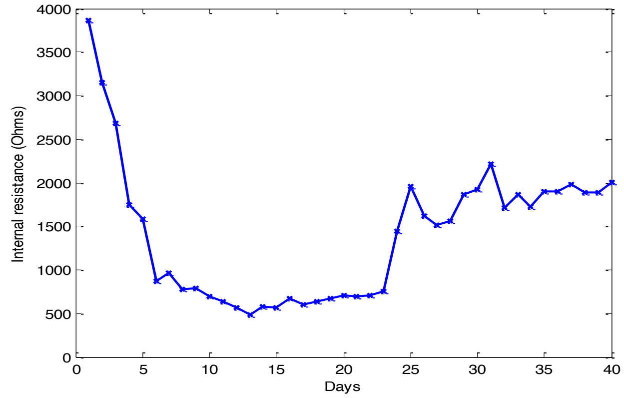

Fig 5: MSCMFC internal resistance variation with days

DISCUSSION

Opened circuit voltage (OCV) of a cell is the voltage measured across the terminals of the cell at infinite resistance where no current is flowing. It does not take into account internal losses (Logan *et al*., 2006). In MFCs, OCV reflects the ability of the biofilm to accumulate charge (Jenna, 2010). The maximum OCV achieved from this present study was 731 mV (Fig. 2). This size of voltage can be amplified for practical application if it is sustained. The present value is comparable to the value reported by Samuel *et al*. (2013) from a Membrane-less single chamber MFC inoculated with agricultural soil. Li (2013), however, studied the performance of a double chamber MFC, under similar conditions, with top soil as the anode inoculums and a cathode of conductive saltwater solution, and reported a maximum OCV which is 85.35 % lower than the maximum value from this present study. The performance of the MFC reported by Li (2013) also showed a negative gradient trend and could only generate electricity for 9 days. This is a clear demonstration that the absence of a membrane improves power densities. It is also an indication that the double chamber configurations may not be suitable for soil-based MFCs.

The maximum powers obtained from operating the MFC at the external resistances of 4700 Ω, 2200 Ω, 1000 Ω, 470 Ω, 220 Ω, 100 Ω and 47 Ω are 93.56 µW, 123.75 µW, 231.36 µW, 251.78 µW, 185.45 µW, 85.56 µW and 60 µW respectively (Fig. 3). For most MFC treating wastewater, it has been predicted that anodophilic microorganisms' proliferation is only possible when the MFCs are operated at external resistances close to their internal resistances (Lyon *et al*., 2010). A low external resistance promotes growth and metabolic activity of the anodophilic microorganisms since electron transport to the cathode is fascinated. However, when the external resistance is lower than the MFC's internal resistance, power output is reduced (Pinto *et al*., 2011). The results of the soil MFC of this present study concord with this prediction. As can be seen from Fig. 3, the soil MFC of this present study exhibited a better performance with the 470 Ω and 1000 Ω. The overall optimum performance of the MFC was achieved with the 470 Ω. This is an indication that the internal resistance of the MFC of this study lies between 470 Ω and 1000 Ω. This result conforms to the results of prior (UNH) research (Microcellutions, 2007). In a similar study, Jenna (2010) reported optimum performance at the same external load.

The maximum power density achieved from this MFC is 65.40 mW/m^2 at a current density of 190.1 mA/m2 (Fig. 4). The rapid voltage drop that is noticed from the polarization curve is a clear indication that Ohmic losses and concentration losses were dominant and thus the main limitation of the MFC's performance.

The power versus time plots (Fig. 3) mimic the phases that are typical in bacterial growth. The growth process begins with a lag phase as bacteria become accustomed to the environmental conditions and little growth is observed. This phase is followed by exponential growth of the microbial population and then the stationary phase where little growth is seen, but living cells are maintained. Lastly, a negative growth phase occurs if no new nutrients and carbon source are supplied to the bacteria (Jenna, 2010). These four phases are established in figure 3. These results proved that microorganisms present in the soil were actually responsible for the electricity generated.

The performance of the MFC improved with time for 360 Hours of continuous operation, as clearly indicated in the power versus time plots (Fig. 3) and the OCV plot (Fig. 4). A rapid drop was experienced between Day 15 and 18, then a constant phase. No improvement in performance was recorded after the first drop until the power output was reduced to near zero probably due to increased mass transfer, activation and Ohmic losses. The initial increase in performance with time of the soil MFC of this study can be attributed to enhancement of microbial metabolism due to availability of substrate in the form of soil organic contents. The exponential decrease in electricity generation may be attributed to a long period of starvation to which the microbes were subjected, which may have led to the death of some of the participating species, owing to the depletion of the soil organic contents with time. The biomass and activity of microorganisms is typically thought to be constrained by the availability and quality of carbon source (Wardle, 1992). Apart from the soil lacking the required moisture for the normal metabolism of the soil microbes, the carbon source and/or nutrients needed to activate them was also exhausted. This affected the activation energy needed for electrons generation and transfer from or to the compound reacting at the electrode surface and thus reduced the redox reaction at the cathode (Logan *et al*., 2006).

The soil MFC of this study is characterized by very high initial internal resistance (Fig. 5). There was an initial decrease in internal resistance from 3870.7 **Ω** to a minimum value of 484.14 **Ω**, the point at which the MFC exhibited optimum performance. The internal resistance remains fairly constant after which there was a non-linear increase. The initial reduction in internal resistance could be due to enhanced conductivity as a result of proliferation of the microorganisms with time. The increased values recorded after the optimum performance is obviously due to depletion of the soil biodegradable organic content needed for microbial metabolism. Thus, the MFC exhibited poor performance at this point probably due to higher anode over-potentials at the same working current (Watson and Logan, 2010).

CONCLUSION

This study revealed that agricultural topsoil is rich in active, highly electrogenic microbial community that can be used in membrane-less single chamber MFCs to generate electricity. MFCs utilizing agricultural topsoil need no outside source of inoculation due to the presence of the appropriate mixed bacterial community. Findings from this study also established that MFCs constructed from agricultural topsoil are capable of producing electric power continuously, across different external loads, for more than 960 hours without addition of any substrate. As it has been established for other types of MFCs, optimum performance of the soil MFC is achieved at external loads close to its internal resistance.

The major limitation of the soil MFC in this study was high internal resistance when the soil nutrient or carbon available for microbial metabolism was exhausted. This led to a rapid drop in power output after the optimum performance. Thus with a supply of appropriate substrate such as urine, septage or leachate from landfill, to enrich the soil; coupled with the right power management system (such as the use of micro-chips, converters or current boosters and capacitors), electricity may be cheaply harnessed from the soil for practical applications.

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EFFECTS OF SEED CONDITION, OPERATION AND DESIGN PARAMETERS ON OUT-TURN OF MORINGA KERNEL

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ABSTRACT

A moringa seed shelling machine is a machine used in breaking or cracking the endocarp of moringa seed to bring out the kernel without any form of damage. In this study, the optimum seed condition, operation and design parameters for Moringa oleifera seed shelling process were determined using Response Surface Methodology (RSM) by applying central composite design approach. The independent factors were moisture content, feed rate, cylinder speed, cylinder-concave clearance and cylinder bar inclination. The response factors were percentage whole kernel recovered, percentage broken kernel recovered and percentage total kernel recovered. The percentage whole and broken kernels recovered with the percentage total kernel were found to have optimum values of 39.08%, 24.69% and 68.2% respectively. The variation of the seed condition, operation and design factors were found to influence the responses significantly (p<0.05). The desirability of the optimization process was 0.68; this indicated the nearness of the response values to the predicted values and adjudged to be acceptable.

Keywords: *Percentage Whole Kernel, Percentage Broken Kernel, Total Percentage Kernel, Seed Condition, Design and Operation Parameters***.**

INTRODUCTION

Moringa oleifera is a monogenic shrub which belongs to moringaceae family, with provenance from Agra and Oudh in North Western region of India to South of the Himalayan Mountains. It is commonly known as horseradish tree or drumstick tree in English, and zogele in Hausa, ewe ile in Yoruba and ikwe oyibo in Igbo (Fadele and Aremu, 2016). *Moringa oleifera* seed has been discovered to contain flocculants which could be used for water treatment. Moringa kernels are known to remove lead, iron and cadmium ions from contaminated water; it is also a good source of protein and cooking oil. The seed oil is used as a raw material in the cosmetic industry and as lubricant for machineries. (Rashid *et al*., 2011; Tende *et al*., 2011; Fadele and Aremu, 2016; Aviara *et al.,*2013). Moreover, Moringa seed and oil are also used in the treatment of ailments such as arthritis, rheumatism, sexually transmitted diseases, hypertension and boils (Eilert *et al*., 1981). Moringa shell has been discovered to be an excellent feedstuff for animals. Moreover, moringa shell could also be used in production of composite materials such as ceiling boards and roofing sheets. The utilization of moringa kernel and shell for divers purposes could be achieved by shelling the seed. Shelling is a process which involves breakage and removal of the enclosing structure (epicarp) of the seed in order to bring out the kernel in a whole form without any damage. In most cases agricultural material shelling is associated with damage resulting from force impact being received by the agricultural material. Agricultural material damage includes abrasion, bruise, cracks, cuts, puncture, splitting, and distortion. Sitkei (1986) showed that damage to agricultural materials is generally followed by infections caused by various fungi. Damage exposes the torn skin of kernel to microorganisms such as fungi and bacteria; consequently leading to deterioration and spoilage of the kernel. The damaged parts are in direct contact with the air, and so the rate of oxidation is increased. This latter phenomenon occurs mainly in the case of cereals and other agricultural materials. In order to maximize the industrial utilization of moringa products such as moringa kernel and shell, processing machines with high performance have to be developed. Moringa seeds shelling machine is very important in moringa seed processing; this will make both moringa kernel and shell to be available to users. However, most agricultural materials are stored temporarily before they are used; therefore damage in these materials must be minimized or eliminated for extended shelf life. Consequently, optimization of shelling process of moringa seed is necessary in order to minimize kernel damage. Response Surface Methodoloy is mostly applied in the optimization of unit operation in food and crop processing. Response surface methodology (RSM) is a collection of mathematical and statistical techniques that are useful for modeling and analyzing situations in which a response of interest is influenced by several variables, and the objective is to optimize this response (Montgomery, 2001). Research on process optimization of moringa seed shelling is very scarce; therefore the objective of this work is to determine the effects of moisture content, feed rate, cylinder/concave clearance, cylinder speed and cylinder bar inclination on the out-turn of moringa kernels applying response surface method approach.

MATERIALS AND METHODS

Sample Preparation

Some moringa seeds were purchased from the Moringa Farmers Association, Oyo State Chapter and stored in polythene sack at the room temperature (28.0 ± 2.0ºC). The seeds were cleaned manually to get rid of foreign materials such as stone, pods remnant, infected seeds, leaves and so on. The initial moisture content of the moringa seed was found to be 10.75% (w.b.). Samples of moringa seeds were conditioned to five moisture levels (10.75, 11.75, 12.75, 13.75 and 14.75 %) by adding calculated quantity of water using the expression in Equation 1. The seeds were sealed in a polythene bag and stored in a refrigerator for a minimum period of three hours so as to enhance moisture stability and uniform distribution of moisture within the seeds (Sharma *et al*., 2013; Fadele and Aremu, 2016).

$$Q = A\,(b - a)/(100 - b) \quad (1)$$

Process Optimization

The process optimization of the moringa seed shelling was carried with the moringa seed shelling machine shown in Figure 1. Using Response Surface Methodology by applying central composite random design approach. One hundred grams of moringa seeds was used for each test (CIGR, 1999).

Figure 1: *Moringa oleifera* seed shelling machine

Percentage Whole Kernel Recovered

The percentage whole kernel recovered is a parameter which indicates the effectiveness of the Tangential Impact Shelling Device (TISD) in removing the outermost cover of the seed without any form of damage such as bruises, cuts, punctures, cracks, splitting and distortion to obtain the kernel in intact (Fadele and Aremu, 2016). This was also evaluated after the shelling process using Equation 2.

$$PWK = \frac{M_1}{M_a} \times 100 \quad (2)$$

Percentage Broken Kernel Recovered

The percentage broken kernel recovered was determined after the shelling process. The broken kernel was separated from the whole kernel by hand picking immediately after the shelling process was completed. This was evaluated using Equation 3 (Fadele and Aremu, 2016).

$$PBK = \frac{M_2}{M_a} \times 100 \quad (3)$$

Percentage Total Kernel Recovered

The percentage total kernel recovered is the proportion of both broken and whole moringa kernel recovered to the actual moringa kernel present in the seeds introduced into the machine. This was determined after the shelling process using Equation 4.

$$PTK = \frac{M_1 + M_2}{M_a} \times 100 \quad (4)$$

Experimental Design

The experimental design adopted was 5 × 5 × 5 × 5 × 5 central composite random design of Response Surface Methodology (RSM) as shown in Tables 1 and 2. The experimentation was based on preliminary study and work by other researchers (Fadele and Aremu, 2016; Figueiredo *et al*., 2014; Akinoso *et al*., 2012). The dependent factors considered for this research included percentage whole kernel recovered, percentage broken kernel recovered and percentage total kernel recovered while the independent parameters were moisture content, cylinder bar inclination, cylinder speed, feed rate and clearance. The optimization of the shelling process of moringa seed was achieved by maximizing percentage whole kernel recovered and percentage total kernel recovered while percentage broken kernel recovered was minimized. The results obtained were analyzed statistically using a commercial statistical package (Design-Expert 6.0.6, Stat-Ease Inc., Minneapolis, USA).

Table 1: Experimental Design for Moringa Seed Shelling Using Tangential Impact Shelling Device

Factors	Levels				
	1	2	3	4	5
Moisture Content (%)	10.75	11.75	12.75	13.75	14.75
Cylinder Bar Inclination (°)	30	40	50	60	70
Cylinder Speed (rpm)	200	240	280	320	360
Clearance (mm)	5	6	7	8	9
Feed Rate (kg/hr)	12	18	24	30	36

Table 2: Experimental Plan for Responses as Influenced by the Independent Factors

						Responses		
Runs	FR	CS (rpm)	MC (%)	CBI	C (mm)	PWKR (%)	PBKR (%)	PTK (%)
1	18	240	9.17		6	24.27	43.04	67.31
2	24	280	10.17		5	26.53	33.58	60.11
3	24	360	10.17		7	21.02	41.63	62.65
4	30	240	9.17		8	40.36	13.83	54.18
5	24	280	10.17		7	26.39	37.67	64.06
6	24	280	10.17		7	24.27	42.33	66.60
7	24	280	10.17		7	31.61	41.91	73.51
8	24	280	10.17		7	41.77	28.93	70.69
9	24	200	10.17		7	42.75	27.94	70.69
10	24	280	12.17		7	33.44	25.68	59.12
11	18	240	11.17		6	39.65	24.98	64.63
12	24	280	10.17		7	38.94	22.15	61.10
13	18	320	9.17		6	15.94	37.53	53.48
14	30	320	9.17		6	29.77	31.18	60.96
15	30	240	9.17		6	28.36	24.83	53.20
16	18	240	11.17		8	31.75	31.89	63.64
17	30	320	11.17		6	30.48	25.96	56.44
18	30	320	9.17		8	18.77	30.06	48.82
19	24	280	8.17		7	24.83	40.36	65.19
20	18	320	9.17		8	20.88	32.45	53.34
21	12	280	10.17		7	25.12	37.53	62.65
22	18	320	11.17		8	28.50	30.76	59.26

23	18	320	11.17	6	23.14	21.31	44.45
24	24	280	10.17	7	24.83	30.48	55.31
25	24	280	10.17	9	41.06	27.52	68.58
26	30	240	11.17	8	25.96	9.74	35.70
27	18	240	9.17	8	27.23	29.77	57.01
28	36	280	10.17	7	30.34	28.08	58.42
29	30	320	11.17	8	23.00	25.82	48.82
30	24	280	10.17	7	38.94	22.01	60.96
31	24	280	10.17	7	26.25	27.94	54.18
32	30	240	11.17	6	40.36	25.12	65.47

RESULTS AND DISCUSSION

Optimization

The optimization of the moringa seed shelling machine was evaluated based on relationship between dependent factors such as percentage whole kernel recovered, percentage broken kernel recovered, percentage total kernel and independent factor such as moisture content, cylinder speed, clearance, feed rate and cylinder bar inclination. The information obtained for each of the response factor was as a result of the effects of variation in the moisture content of moringa seeds, cylinder speed, clearance, feed rate and the cylinder bar inclination. In the optimization of the moringa seed shelling dependent factors such as percentage whole kernel and percentage total kernel recovered were maximized while percentage broken kernel recovered was minimized. Table 3 shows the level of significance of moisture content, cylinder speed, clearance, feed rate and cylinder bar inclination with respect to the dependent factors. The desirability of the optimization process was 0.68. The desirability of the response approaches 1 when the response values get close to the predicted values for both dependent and independent parameters. However, if the response value far is from the predicted value, the desirability approaches 0. The desirability of the process optimization tends toward 1 which indicates that models generated could be used to navigate the design space. Table 3 shows the F- Values for the Optimization of *Moringa oleifera* Seed Shelling.

Table 3: F-Values for Moringa Kernel Out-turn during Shelling Process

Parameters	Percentage Whole Kernel Recovered	Percentage Broken Kernel Recovered	Percentage Total Kernel Recovered
MC	*0.4055*	*0.0176*	*0.0269*
CS	*0.0012*	*0.0622*	*0.1472*
C	*0.3052*	*0.3093*	*0.3053*
FR	*0.6451*	*0.0104*	*0.0157*
CBI	*0.0251*	*0.3691*	*0.0287*
Interaction			
*C*MC*	*NA*	*NA*	*0.1315*
*C*CS*	*NA*	*NA*	*0.2752*
*C*FR*	*NA*	*NA*	*0.0127*
*C*CBI*	*NA*	*NA*	*0.0088*
*MC*CS*	*NA*	*NA*	*0.5849*
*MC*FR*	*NA*	*NA*	*0.1637*
*MC*CBI*	*NA*	*NA*	*0.4035*
*CS*FR*	*NA*	*NA*	*0.0124*
*CS*CBI*	*NA*	*NA*	*0.8888*
*FR*CBI*	*NA*	*NA*	*0.1743*

**Significant at 5% level; *Not significant at 5% level; MC is Moisture Content; CBI is Cylinder Bar Inclination; CS is cylinder speed; C is clearance and FR is Feed Rate; NA is not available.

Percentage Whole Kernel Recovered

The variation of seed condition (moisture content), operation parameters (feed rate, clearance and cylinder speed) and design factor (cylinder bar inclination) during the shelling process showed influence on out-turn of percentage whole moringa kernel recovered. Table 3 shows that percentage whole kernel recovered was significantly affected by cylinder speed and cylinder bar inclination (p≤5 %). The effects of moisture content, feed rate and clearance have lesser impact on percentage whole kernel recovered as shown in Table 3. The relationships between percentage whole kernel recovered and the independent factors (cylinder speed and cylinder bar inclination) is shown in Figure 4. The optimum value obtained for the percentage whole kernel recovered was found to be 39.08% at cylinder speed and cylinder bar inclination values of 240 rpm and 40.0° respectively, with standard error mean value of 2.44. The optimum value obtained for percentage whole kernel recovered follow the a decreasing trend for both cylinder speed and cylinder bar inclination, similar to that of Ojolo *et al* (2010) for cashew nut shelling and Pradhan *et al* (2010) for jatropha fruit decortications. The percentage whole kernel recovered tends to decrease with both increase in cylinder speed and cylinder bar inclination (Figures 2 and 3). The decrease in percentage whole kernel recovered with cylinder speed might be due to high force of impact on moringa seed during shelling as the cylinder speed increased. Moreover, percentage whole kernel recovered decreased with increase in cylinder bar inclination; this might be due to reduced contact area of the cylinder flat bar which brought about more compressive stress on the moringa seed as the cylinder bar inclination increased, thus resulting to kernel deformation which eventually affect the wholeness of the kernel.

$$PWK = 76.51 - 0.105CS - 0.353CBI \quad (5)$$

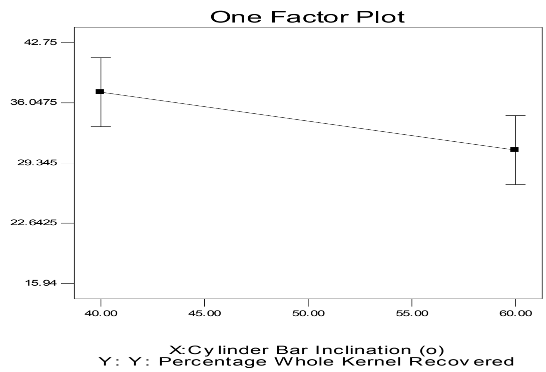

Figure 2 : Plot of percentage whole kernel against the cylinder bar inclination

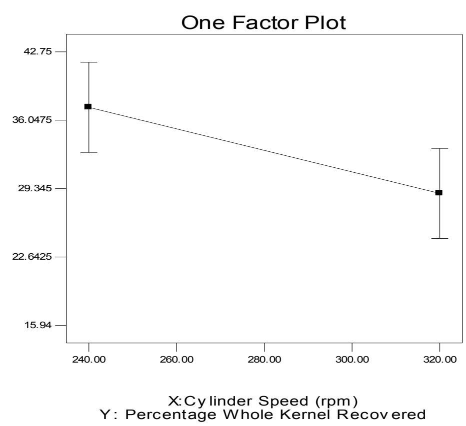

Figure 3: Plot of percentage whole kernel against the cylinder speed

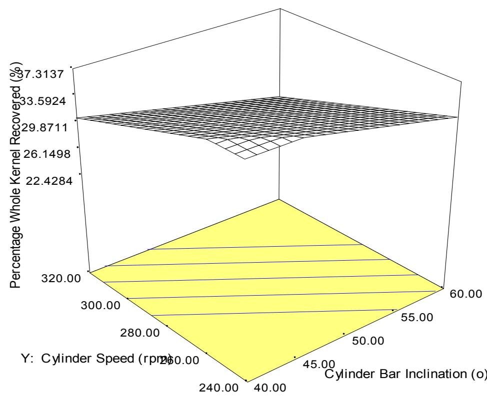

Figure 4: Effects of cylinder speed and cylinder bar inclination on percentage whole kernel recovered

Percentage Broken Kernel Recovered

The percentage of broken kernel recovered during the shelling process was significantly affected by moisture content and feed rate (p≤ 5%) as shown in Table 3. The relationships between percentage broken kernel recovered and the independent factors (moisture content and feed rate) are shown in Figures 5 and 7 and Equation 6. The optimum value obtained for the percentage broken kernel recovered was found to be 24.69% at moisture content and feed rate values of 13.71% (w.b.) and 22.30 kg/hr respectively, with standard error mean value of 2.91. This trend is similar to what Shittu and Ndrika (2012) obtained as seed damaged for melon seed shelling. Sitkei (1986) also showed that the condition for avoiding damage in agricultural materials is that the maximum stress arising during impact should not exceed the permissible value. In addition, percentage broken kernel tends to decrease as the feed rate increased; this is as a result of large quantity of moringa kernel being forced through the screen at the same time thus resulting to less rupturing and deformation of the moringa kernel. The percentage broken kernel recovered followed a decreasing trend with moisture content and feed rate which is similar to that of Oluwole *et al*. (2004); Gupta and Das (1999).

$$PBK = 84.45 - 3.19 (MC) - 0.583 (FR) \quad (6)$$

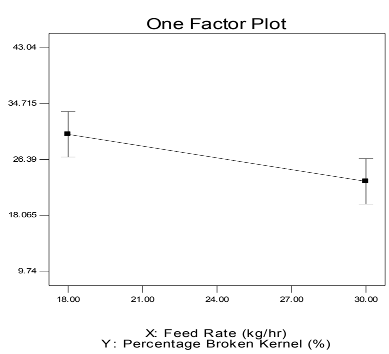

Figure 5: Plot of percentage broken kernel against the feed rate

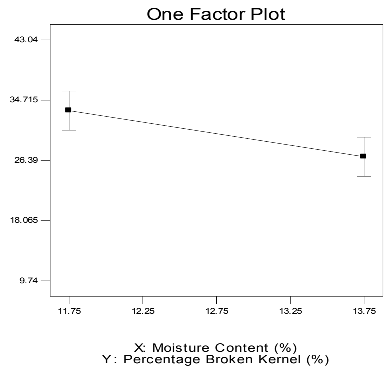

Figure 6: Plot of percentage broken kernel against the moisture content

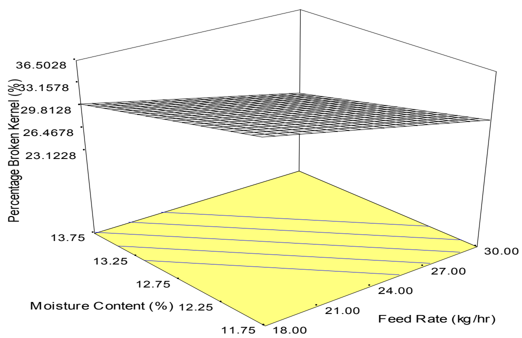

Figure 7: Effects of moisture content and feed rate on percentage broken kernel recovered

Percentage Total Kernel Recovered

The percentage total kernel recovered during the shelling process was significantly affected by all the parameters (viz. moisture content, cylinder speed, clearance, feed rate and cylinder bar inclination) ($p \leq 5\%$) as shown in Table 3. The relationship between percentage total kernel recovered and the independent factors is shown Equation 7. The optimum value obtained for the percentage total kernel recovered was found to be 68.20% at moisture content, cylinder speed, clearance, feed rate and cylinder bar inclination values of 13.74% (w.b.), 240.0 rpm, 8 mm, 21.28 kg/hr and 40^o respectively. The percentage total kernel recovered decreased with the clearance, moisture content, feed rate and cylinder bar inclination. However, percentage total kernel recovered tends to increase with increase in the cylinder speed.

$$PTK = 198.05 + 64.77(C) - 8.58(MC) - 1.10(CS) - 8.69(FR) + 0.091(CBI) - 2.53(C)(MC) + 0.046(C)(CS) - 0.898(C)(FR) - 0.503(C)(CBI) + 0.024(MC)(CS) + 0.419(MC)(FR) + 0.121(MC)(CBI) + 0.0192(CS)(FR) - 7.64 \times 10^{-4}(CS)(CBI) + 0.071(FR)(CBI)$$

CONCLUSION

In conclusion, the findings on the effects of seed condition, operation and design parameters on moringa kernel out-turn revealed the following:

i. The optimum value for percentage whole kernel recovered was found to be 39.08%. The percentage whole kernel recovered was significantly affected by cylinder speed and cylinder bar inclination ($p \leq 5\%$).
ii. The optimum value for percentage broken kernel recovered was found to be 24.69%. The percentage broken kernel recovered was significantly affected by moisture content and feed rate ($p \leq 5\%$).
iii. The optimum value for percentage total kernel recovered was found to be 68.20%. The percentage total kernel recovered was significantly affected by moisture content, cylinder speed, clearance, feed rate and cylinder bar inclination ($p \leq 5\%$).

iv. The percentage total kernel recovered decreased with the clearance, moisture content, feed rate and cylinder bar inclination. However, percentage total kernel recovered tends to increase with increase in the cylinder speed.

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EFFECT OF SOME PROCESS CONDITIONS ON OIL RECOVERY EFFICIENCY FROM PALM KERNEL UNDER UNIAXIAL COMPRESSION

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ABSTRACT

The effect of some process conditions on Oil Recovery Efficiency from palm karnel under uniaxial compression was studied. Palm Kernel (Dura Variety) were obtained from the Nigerian Institute for Oil Palm Research (NIFOR), Benin, Nigeria and were dried to 4.5% moisture content. The palm kernels were reduced to particle sizes of fine and coarse respectively while a prototype laboratory mechanical oil expeller with a temperature controller and a force measuring device was used to express oil from the palm kernel under uniaxial compression using a 15 tones hydraulic press. The effects of heating temperature and applied pressure on the Oil Recovery Efficiency was studied for each of the particle size at heating temperatures of 70, 90, 110 and 130 °C and applied pressures of 6.0, 9.0, 12.0, and 15.0 MPa respectively. The results obtained were subjected to statistical analysis using Analysis of Variance (ANOVA). From the results, oil recovery efficiency increased with increasing heating temperature from 70 °C to 110 °C and later decreased when the heating temperature was further increased from 110 to 130 °C for each of the particle size investigated. The results also revealed that oil recovery efficiency increased proportionally as the applied pressure increased from 6 MPa to 15 MPa for both particle sizes. The results further revealed that the mean oil recovery efficiency from fine particle size is significantly higher than that of coarse particle sizes at 5 % level of significance. It is then concluded that in order to maximize oil recovery efficiency during mechanical expression of Palm Kernel oil under uniaxial compression, the process conditions (heating temperature and applied pressure) must be properly controlled.

KEY WORDS: *Palm Kernel Oil, Oil Recovery Efficiency, uniaxial compression*

INTRODUCTION

The increase in world's population has no doubt increased the demand for fat and oil obtained from oil bearing crops. Oil bearing crops are classified into three namely: Oil seeds and beans; Nuts; and mesocaps or fruits. The Oil Palm (*Elaeis guineensis)*, gives both Palm Oil (PO) and Palm Kernel Oil (PKO) (Hartley, 1988). The Palm Oil (PO), which is reddish in colour, is obtained from the Orange colour mesocarp, while the PKO is obtained from the hard-liquefied cell within the nut, called the kernel.

Modern processing of oil bearing crops (seeds or nuts) into edible or industrial oil is practiced using different methods, which may be categorized into three, (Praven, 1997; Breadson, 1983). One is the solvent extraction method in which a solvent, when brought in contact with the preconditioned oil seed or nut, dissolves the oil present in the oil bearing material and the separated mixture is later heated to evaporate the solvent and obtain the oil. Mechanical oil expression is the second method. In this process, the preconditioned oil seed or nut is passed through a screw press, a hydraulic press or a ram press, where a combination of high temperature and pressure is used to crush the oil bearing material to release the oil. The third method is the wet processing in which the oil bearing material is boiled in water leading to a partial separation of oil (clarification).

Mwthiga and Moriasi, (2007); Olayanju *et al*., (2006) and Ajibola *et al*., (2000), reported that the parameters used before and during mechanical expression of oil from oil seeds affects oil pressing processes. These parameters according to the researchers include particle size, heating temperature, heating time, moisture content and applied pressure. Olaniyan (2010) investigated the effects of some process conditions like nature of bean, heating temperature and pressing time on the yield and quality of oil mechanically expressed from castor bean using a piston-cylinder rig in association with California Bearing Ratio Universal Testing Machine (CBR – UTM). The Results showed that process conditions and their interactions were significant on oil yield at 0.05 % level of significance. However, only the pressing time was significant on the extraction pressure while Oil yield increased with increased heating temperature and pressing time for the crushed bean, shelled bean and unshelled bean.

Bamigboye and Adejumo (2011) reported the effects of the processing parameters of Roselle Seed on its oil yield. The seeds were ground and classified into two particle sizes (fine and coarse). According to the researchers, the investigations showed that oil yield increases with an increase in the processing parameters of pressure up to 30 MPa, temperature of 100 °C and decreased beyond these points, while ground samples were found to have a higher yield than coarsely ground samples at the different processing parameters. They concluded by affirming that processing parameters affect the oil yield from Roselle Seeds.

Olaniyan, (2006) on the experiment he carried out on Shear butter using the mechanical oil expression rig, reported that higher process loss was observed to have occurred at higher heating temperatures. According to him, this was so because at higher temperature, there was higher moisture evaporation and oil sublimation.

Not much can be found in the literatures on studies undertaken on processing factors as related to oil recovery efficiency from palm kernel. This study is therefore aimed at investigating the effect of some process conditions such as pre-treatment temperature, applied pressure and particle size on oil recovery efficiency during mechanical oil expression under uniaxial loading.

MATERIALS AND METHOD

All experimental investigations were carried out in the Engineering Materials Testing laboratory of the Engineering and Scientific Services (ESS) department of the National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria. The room temperature of the laboratory throughout the duration of the experimental works was averagely 30 °C.

Material Preparation

Pam Kernel (Dura Variety) used in this experiment were obtained from the Nigerian Institute for Oil Palm Research (NIFOR), Benin, Nigeria. Moisture content of the palm kernel at the point of procurement was determined and found to be 11.5 %. The kernels were further dried to 4.5% moisture content using sun drying method. The kernels were cleaned to remove stones and other foreign materials; after which they were packed into air tight containers and stored in the laboratory

Size Reduction

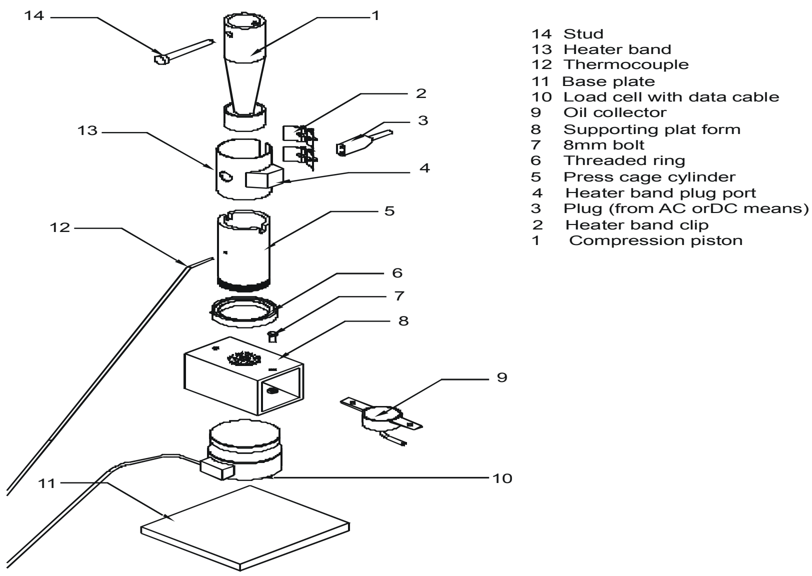
Preliminary investigation carried out prior to this experiment revealed that it is difficult to mechanically extract oil from whole Palm kernel using the hydraulic press and the Mechanical oil Expression Rig. As a result of this, size reduction of the kernels was carried out. In order to reduce the size of the palm kernel to particle sizes of fine and coarse respectively; the palm kernels were firstly crushed using a hammer mill, and later the crushed meal was further reduced using an attrition mill as reported by Olaniyan, (2006). After size reduction, particle size analysis was carried out using a set of laboratory Endocotts Test Sieves and Shaker (model SW19 3BR England) available in the Laboratory of the Soil and Water Management Engineering Department of NCAM.

Particle size analysis was done in accordance with ASAE (1989) Standard S319. In line with Adeeko and Ajibola (1990), samples that passed through the 5.6mm sieve but retained on the 2.36mm sieve were classified as coarse, while samples that passed through 2.36mm sieve but retained on the 0.6mm sieve were classified as fine.

Experimentation and instrumentation

In this study, a technique for heating oil seed sample before and during expression was adopted. A laboratory mechanical oil expressing piston-cylinder rig which is similar to the one used by Olaniyan (2006), and Mrema (1979) was used.

The model laboratory mechanical oil expeller is made up of three major components: the compression piston, the press cage cylinder and the supporting platform (Olaniyan, 2006). The press cage cylinder was made from a mild steel pipe with an inside diameter of 66 mm, 7 mm thick and 140 mm long. A 600 W electric band heater was installed round the press cage cylinder to serve as a heating device for the expression process. A 5 mm hole was drilled on one side of the press cage cylinder at a height of 70 mm from the base; this hole is for the fixing of thermocouple probe for temperature monitoring. The rig was adequately instrumented with a temperature controller to control the expression temperature, while the pressure for oil expression was obtained from the hydraulic press via the instrumentation system (force measuring device).



Experimental Design

In order to study the effects of operative processing conditions like heating temperature, applied pressure and particle size respectively on oil recovery efficiency during mechanical expression of oil from palm kernel under uniaxial loading, a suitable experimental design that incorporated four levels of heating temperature (i.e. 70 ° C, 90 °C, 110 °C and 130 °C), four levels of applied pressure (i.e. 6.0 MPa, 9.0 MPa, 12.0 MPa and 15.0 MPa) and two particle sizes (i.e. Fine and Coarse) was designed. A 4^2 x 2 factorial experimental design in a Complete Randomized Block Design (CRBD) was used. Each test was performed in three replicates at each level of the factors. The ranges of values of factors such as moisture content, heating time and pressing time were also obtained through preliminary investigations and were kept constant throughout the experiments in order to reduce the data to a reasonable size.

Experimental Investigation Procedures

Moisture content determination

Moisture content of the sample was determined by oven drying of 100g ground sample at 130°C for 6 hours; as recommended for oil seeds by Young *et al* (1982) and used by Tunde-Akintunde *et al* (2001). The average moisture content of 4.5 % was adopted for all the samples used throughout the experiments in order to reduce the data to a reasonable size.

Heating of samples

Heating of the sample (ground palm kernel) was achieved by weighing 200g of the sample in line with Olaniyan (2006), and transfer of the weighed sample into the press cage already encircled with the temperature controlled heater band. The samples in the press cage where heated to temperatures of 70 °C, 90 °C, 110 °C and 130 °C respectively for 30 minutes before expression begins. The lower limit of 70 °C and upper limit of 130 °C were selected based on preliminary laboratory investigation, which revealed that heating milled palm kernel sample below 70 °C did not give good oil yield during expression; while heating above 130 °C resulted in excessive burning and darkening of the oil. Also, the heating time of 30 minutes used in this study was based on preliminary investigations and also on the fact that the period allows for temperature uniformity and equilibration of the oil seed cake as reported by Hamzat and Clarke (1993).

Applied Pressure

Pressure was applied to the sample in the press cage cylinder via the compression piston attached to the spindle of the hydraulic press. Samples were subjected to applied pressures of 6.0 MPa, 9.0 MPa, 12.0 MPa, and 15.0 MPa for 10 minutes respectively. The lower limit of 6.0 MPa applied pressure was selected based on preliminary investigation which revealed that reasonable quantity of oil cannot be expressed from coarse palm kernel samples at applied pressure below 6.0 MPa, while the upper limit of 15.0 MPa applied pressure was selected based on the capacity of the existing Universal Testing Machine, which was used at the preliminary stage of this work.

Sequence of Mechanical oil Expression

Before coupling the mechanical oil expression rig, a stainless steel wire mesh was placed at the bottom of the cylinder guide in order to cover the drainage area and at the same time serve as a filter during the oil expression process.
After the coupling, a sample of 200g weight of ground palm kernel was poured into the press cage cylinder. The sample was then heated for 30 minutes at heating temperatures of 70°C. Using the actuating lever of the hydraulic press, the compression piston was moved down to touch the sample and pre-compact it to a height of 70mm (Olaniyan, 2006) inside the press cage cylinder. After the pre-compaction, the sample was further compressed by the hydraulic press via the compression piston to a pressure of 6.0 MPa for 10 minutes. The oil expressed drains into the oil collector and was collected through the outlet pipe.
The same procedure was followed to carry out the experiment for three other heating temperature levels of 90 °C, 110 °C, and 130 °C at three other applied pressure levels of 9.0 MPa, 12.0 MPa, and 15.0 MPa for the coarse and fine particles size respectively.

Determination of oil recovery efficiency

Oil recovery efficiency was calculated as the ration of the weight of oil expressed to the total weight of oil in the milled palm kernel sample before expression. It was mathematically expressed by Adeeko and Ajibola (1989) as

$$RE = \frac{WEO}{XW_S} \times \frac{100}{1} \quad (3.8)$$

Where:
RE = OilRecovery efficiency (%)
WEO = Weight of oil expressed (g)
Ws = Original Weight of sample before expression (g); and
X = Oil content of palm kernel (48 %)

RESULTS AND DISCUSSION

Table 1 is the summary of the test result obtained for oil recovery efficiency at various operative conditions while table 2 is the summary of ANOVA showing the effects of process conditions on oil recovery efficiency during mechanical expression of oil from palm kernel.
From the ANOVA table, it can be observed that the process conditions and their interactions had significant effect on oil recovery efficiency at 1% level of significance for the fine and coarse particle sizes respectively. Hence, the hypothesis of equality of mean treatment effect is rejected, and it can be implied that at least one of the mean treatment effect is significantly different from the others.

Table 1: Summary of the Result of Effect of Process Conditions on Measured Parameters

Parameter			Pressure (MPa)			
	Temperature (°C)	Particle size	6	9	12	15
Oil Recovery Efficiency (%)	70	Fine	14.69	16.75	18.61	17.10
		Coarse	2.95	3.71	8.18	4.67
	90	Fine	16.75	18.61	17.10	26.45
		Coarse	3.71	8.18	4.67	4.90
	110	Fine	18.61	17.10	26.45	36.57
		Coarse	8.18	4.67	4.90	8.09
	130	Fine	17.10	26.45	36.57	38.93
		Coarse	4.67	4.90	8.09	20.32

Table 2: Summary of Analysis of Variance (ANOVA) of the Effects of Temperature, Pressure and Particle size on Oil Recovery Efficiency

Parameter	Particle Size	Source of Variation	df	Ss	Ms	F_{cal}	Prob.
Oil Recovery Efficiency	Fine	Temperature(A)	3	1522.290	507.430	56.207	0.001
		Pressure(B)	3	9246.183	3082.061	341.395	0.001
		AxB	9	625.671	69.519	7.701	0.001
		Error	32	288.891	9.028		
		Total	47	11683.035			
	Coarse	Temperature(A)	3	972.323	324.108	371.225	0.001

Pressure(B)	3	2707.013	902.338	1.034E3	0.001
AxB	9	263.510	29.279	33.535	0.001
Error	32	27.938	0.873		
Total	47	3970.784			

Effects of heating temperature on Oil recovery efficiency

In order to determine the differences in the mean treatment effect of heating temperature on oil recovery efficiency for both particle sizes, New Duncan's Multiple Range Test (NDMRT) was carried out. The result of the comparison among the four levels of heating temperature for each of the particle size is presented in table 3.

Table 3: Temperature comparison on Oil Recovery Efficiency using New Duncan Multiple Range Test (NDMRT)

Particle Size	Temperature	Oil Recovery Eff. (%)
Fine	70	28.48[a]
	90	37.01[b]
	110	43.89[c]
	130	39.60[d]
Coarse	70	10.01[a]
	90	12.39[b]
	110	21.84[c]
	130	16.64[d]

Means with the same letters are not significantly different at p≤0.05 using the DNMRT

In comparing the means of oil recovery efficiency at the four levels of heating temperature, it can be observed from the table that the highest average oil recovery efficiency was obtained at 110 °C, while the lowest was at 70 °C for both fine and coarse particle size. The table also confirmed that an increase in temperature from 70 °C to 90 °C produced more increase in oil recovery efficiency when compared with increase in heating temperature from 90 °C to 110 °C for fine particle size. The table further confirms a decrease in oil recovery efficiency due to an increase in heating temperature from 110 °C to 130 °C. Also, it was evident from the table that the average oil recovery efficiency at each of the four levels of heating temperature was significantly different from each other at 95 percent confidence level. This confirmed that increasing the heating temperature from one level to the next higher level contributed reasonably to changes in oil recovery efficiency at the level of significance considered in this study.

The effect of heating temperature on oil recovery efficiency at different pressures during mechanical expression of oil from palm kernel was also graphically investigated as seen in figures 1A to 1D. From these figures, it can be seen that oil recovery efficiency increased with increasing heating temperature from 70 °C to 110 °C and later decreased when the heating temperature was further increased from 110 °C to 130 °C for each of the particle size investigated.

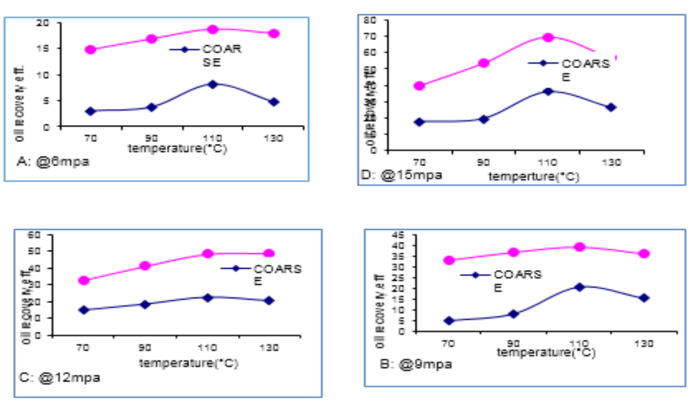


Fig. 1A – 1D: Effect of temperature on oil recovery efficiency at various pressures

This implies that in mechanical oil expression process, there is an optimum temperature beyond which there will be a reduction in the efficiency of the expression process. From figures 1A and 1B, it can be observed that at lower applied pressures (6.0 MPa to 9 MPa) an increase in heating temperature from 70 °C to 90 °C resulted to steady minimal increase in oil recovery efficiency lower than when the heating temperature was increased from 90 °C to 110 °C. This is indicated in the almost parallel nature of the curve from 70 °C to 90 °C followed by a steep slope from 90 °C to 110 °C after which a reduction in oil recovery efficiency as shown by a negative gentle slope from 110 °C to 130 °C. This trend is the same for the fine and coarse particle size of palm kernel. Meanwhile, at higher applied pressures (12 MPa to 15 MPa), the increase in oil recovery efficiency was consistent and progressive with an increase in the heating temperature from 70 °C to 110 °C for fine particle sizes (figures 1C-1D), but took a different trend for the coarse particle sizes at 15 MPa (figure 1D).

It appears that the increase in the heating temperature from 70 °C to 110 °C triggered some vital processes within the oil bearing material that induced higher oil recovery efficiency. This no doubt resulted in the sharp increase in oil recovery efficiency within this temperature range. In the same manner, an increase in the heating temperature from 110 °C to 130 °C induced some processes in the oil bearing material that do not enhance oil recovery efficiency. Such induced processes are 'surface' or 'case' hardening, oil seed cake consolidation, de-polymerization of the oil seed material (Praven, 1997 and Lehninger, 1987), burning of the cake and sublimation of the oil in the oil capillaries (Olaniyan, 2006). All these either collectively or individually was responsible for the reduction in the oil recovery efficiency at temperatures beyond 110 °C as observed in this study.

Furthermore, high oil recovery efficiency was obtained from samples heated at 110 °C. This result is an improvement when compared to Akinoso (2006) that obtained the maximum oil recovery at 130 °C using a screw press.

Effect of Applied Pressure on Measured Parameters

In order to determine the differences in the treatment effect of applied pressure that contributed more to the changes in the oil yield, New Duncan Multiple Range Test (NDMRT) was employed and the result of the comparison is as presented in Table 4.

Table 4: Pressure comparison on Measured Parameters using New Duncan Multiple Range Test

Particle Size	Pressure	Oil Recovery Eff. (%)
Fine	6	16.78[a]
	9	34.44[b]
	12	42.85[c]
	15	54.92[d]
Coarse	6	4.87[a]
	9	12.11[b]
	12	18.94[c]
	15	24.97[d]

Means with the same letters are not significantly different at p≤0.05 using the DNMRT

The table clearly shows that at all levels of applied pressure, the means of oil recovery efficiency obtained for each of the particle size was significantly different from each other at 95 % confident level. This implies that increasing the pressure from one level to the next higher level resulted to reasonable increase in oil recovery efficiency during mechanical expression of oil from palm kernel under uniaxial loading. The table also shows that the lowest mean value of oil recovery efficiency was achieved at 6.0 MPa, while the highest mean value was at 15 MPa. Generally, the trend of increasing oil recovery efficiency as a result of corresponding increase in applied pressure from 6.0 MPa to 15 MPa was also confirmed by the NDMTR table for each of the particle sizes investigated.

Figures 2A – 2D shows the effect of applied pressure on oil recovery efficiency at different heating temperature during mechanical expression of oil from fine and coarse particle sizes of palm kernel under uniaxial loading. From the figures, it can be seen that oil recovery efficiency increased proportionally as the applied pressure increased from 6 MPa to 15 MPa for both fine and coarse particle size. However, the figures also showed that increasing the applied pressure from 6 MPa to 12 MPa produced higher increment in oil recovery efficiency when compared to increasing applied pressure from 12 MPa to 15 MPa.

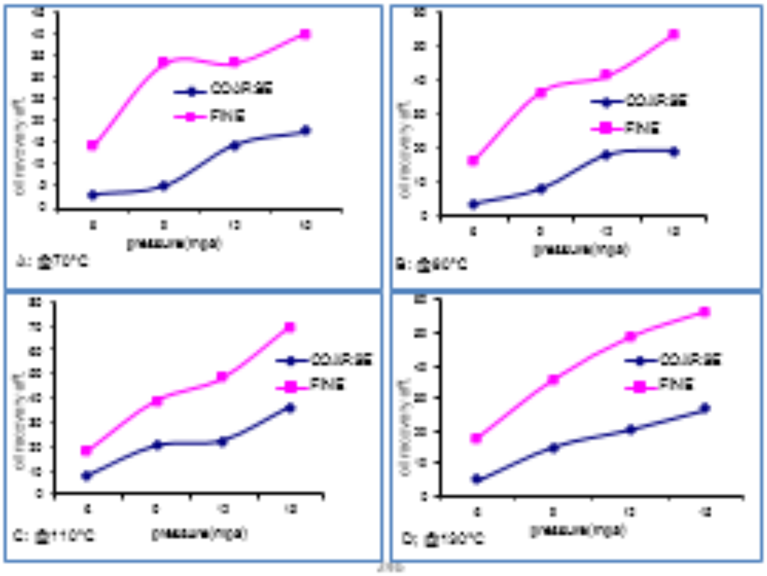


Fig. 2A – 2D: Effect of pressure on oil recovery efficiency at various temperatures.

It therefore can be deduced from this study that with a progressive increase in applied pressure during mechanical oil expression, adequate rupturing of oil capillaries results in the flow of oil out of the cells. This can be attributed to the sharp initial increase in oil recovery efficiency recorded when the applied pressure increased from 6 MPa to 12 MPa. Meanwhile, as the applied pressure was increased from 12 MPa to 15 MPa, there was a reasonable sealing of oil capillaries as a result of which the sample behave like a consolidated oil seed cake (as reported by Faborode and Favie, 1997) and Mrema and MacNulty, 1985 respectively). These consolidation effects have been reported to reduce the flow of oil during mechanical oil expression process. Thus, the increase in oil recovery efficiency at applied pressure beyond 12MPa was reduced. This trend was also observed by Ajibola *et al*, (1998) while studying mechanical expression of oil from Castor seeds, Adeeko and Ajibola (1989) in the mechanical expression of groundnut oil, and Tunde-Akintunde et al (2001) while studying mechanical expression of Soybean oil.

The Effect of Particle Size on Oil Recovery Efficiency

The independent t-test was used to compare the means of fine and coarse particle sizes for each of the parameters measured. The result is shown in table 5.

Table 5: Effect of Particle Size on Measured Parameters

Parameter	Size	T	Df	Sig.	MD.	SE (MD)
Oil Yield	Fine	8.771	94	0.001	11.66	1.33
	Coarse	8.771	72.37	0.001	11.66	1.33
Oil Recovery	Fine	8.363	94	0.001	22.030	2.634
Efficiency	Coarse	8.363	75.64	0.001	22.030	2.634
Process Loss	Fine	1.731	94	0.087	0.503	0.291
	Coarse	1.731	91.2	0.087	0.503	0.291

MD is mean difference, SE is standard error

From table 5, the mean of oil recovery efficiency from fine particle size is significantly higher than that of coarse particle sizes at 5 % level of significance. The t-test statistics confirms that the differences observed in the mean values of oil recovery efficiency between the fine and coarse particle sizes was not due to random occurrence alone (i.e. by chance). This significant difference in the oil recovery efficiency is also evident in figures 2A to 2D seen earlier. From the figures, it was clear that irrespective of the pressure and temperature range, the oil recovery efficiency from fine particle size is consistently higher than that from the coarse particle size. This can be attributed to higher surface area of the fine particle sizes subjected to applied pressure, and temperature, and weakening of more oil cells that readily expels oil on any slight increase in applied pressure and heating temperature.

CONCLUSION

The study revealed that increase in heating temperature from 70 °C to 110 °C irrespective of the applied pressure, results to a corresponding increase in oil recovery efficiency from the fine and coarse particle size, but further increase in heating temperature from 110 °C to 130 °C results in decrease in oil recovery efficiency from both particle sizes. The study also reveals that, oil recovery efficiency increases as the applied pressure increases from 6 MPa to 15 MPa at any heating temperature for the fine and coarse particle size respectively. The highest oil recovery efficiency was recorded at applied pressure of 15 MPa while the minimum was at 6 MPa. It was also established that oil recovery efficiency from fine particle size are higher and significantly different from that obtained from the coarse particle size. It then implies that, In order to maximize oil recovery efficiency during mechanical expression of Palm Kernel oil under uniaxial loading, the process conditions (i.e. heating temperature and applied pressure) must be properly controlled.

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EFFECTS OF PARTICLE SIZE ON OIL YIELD EXPELLED FROM PALM KERNEL UNDER UNIAXIAL LOADING

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ABSTRACT

The effect of particle size on oil yield expelled from palm kernel under uniaxial loading was investigated. Palm Kernel (Dura Variety) was obtained and were dried to 4.5% (wb) moisture content. The palm kernels were crushed using a hammer mill and the crushed samples were further reduced using an attrition mill. The crushed samples were classified into fine and coarse particle sizes using a set of laboratory Endocotts Test Sieves and Shaker. A prototype laboratory mechanical oil expeller with a temperature controller and a force measuring device was used to express oil from the palm kernel under uniaxial compression using a 15 tones hydraulic press. The effects of each particle size on oil yield was studied at heating temperatures of 70, 90, 110 and 130°C and applied pressures of 6.0, 9.0, 12.0, and 15.0 MPa respectively. The results obtained were subjected to statistical analysis using Analysis of Variance (ANOVA) and T-test was used to compare variations among the means. The results showed that particle size had significant effect on oil yield ($p \leq 1\%$). The study also revealed that oil yield from fine particle size are higher and significantly different from that obtained from the coarse particle size at all operative parameters (temperature and pressure) investigated. It is then concluded that, in order to maximize oil yield during mechanical expression of oil from palm kernel, the palm kernel size should be reduced to fine particles.

Keywords: *Oil yield, Uniaxial compression, Particle size, Palm kernel*

INTRODUCTION

The increase in world's population has no doubt increased the demand for fat and oil obtained from oil bearing crops. Oil bearing crops are classified into three namely: oil seeds and beans; Nuts; and mesocaps or fruits. The oil palm (*Elaeisguineensis)*, gives both palm oil (PO) and palm kernel Oil (PKO) (Hartley, 1988). The Palm Oil (PO), which is reddish in colour, is obtained from the orange colour mesocarp, while the PKO is obtained from the hard-liquefied cell within the nut, called the kernel.

Modern processing of oil bearing crops (seeds or nuts) into edible or industrial oil is practiced using different methods, which may be categorized into three (Praven, 1997; Breadson, 1983). One is the solvent extraction method in which a solvent, when brought in contact with the preconditioned oil seed or nut, dissolves the oil present in the oil bearing material and the separated mixture is later heated to evaporate the solvent and obtain the oil. Mechanical oil expression is the second method. In this process, the preconditioned oil seed or nut is passed through a screw press, a hydraulic press or a ram press, where a combination of high temperature and pressure is used to crush the oil bearing material to release the oil. The third method is the wet processing in which the oil bearing material is boiled in water leading to a partial separation of oil (clarification).

Mwthiga and Moriasi, (2007); Olayanju *et al*., (2006) and Ajibola *et al*., (2000), reported that The parameters used before and during mechanical expression of oil from oil seeds affects oil pressing processes. These parameters according to the researchers include particle size, heating temperature, heating time, moisture content and applied pressure. Ajibola *et al.,* (1990) reported the work carried out on mechanical expression of oil from melon seeds. The processing factors investigated were particle size, moisture content, heating temperature and heating time. They reported that coarsely ground samples gave consistently lower yields than finely ground samples. Also, the oil yield was affected by the seed moisture content, heating temperature and heating time.

Bamigboye and Adejumo (2011) reported on the effects of the process parameters of roselle seed on its oil yield. The seeds were ground and classified into two particle sizes (fine and coarse). According to the researchers, the investigations showed that the ground samples have higher oil yield than coarsely ground samples at the different processing parameters. They concluded by affirming that particle size affect the oil yield from roselle seeds.

The effect of particle size, heating temperature, heating time, applied pressure and duration of pressing on the yield and quality of mechanically expressed groundnut oil were investigated by Adeeko and Ajibola (1989). Result showed that oil yields from coarsely ground groundnut samples were higher than those from finely ground samples but the free fatty acid values were lower.

Not much work has been done on oil extraction from size reduced palm kernel seed. This study was to investigate the effect of particle size on oil yield expelled from palm kernel under uniaxial loading.

MATERIALS AND METHOD

All experimental investigations were carried out in the Engineering Materials Testing laboratory of the Engineering and Scientific Services (ESS) department of the National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria. The room temperature of the laboratory throughout the duration of the experimental works was averagely 30 °C.

Material Preparation

Pam Kernel (Dura Variety) used in this experiment were obtained from the Nigerian Institute for Oil Palm Research (NIFOR), Benin, Nigeria. Moisture content of the palm kernel at the point of procurement was determined and found to be 11.5%. The kernels were further dried to 4.5% (wb) moisture content using sun drying method. The kernels were cleaned to remove stones and other foreign materials; after which they were packed into dry air tight containers and stored in the laboratory.

Size Reduction

Preliminary investigation carried out prior to this experiment revealed that it is difficult to mechanically extract oil from whole Palm kernel using the hydraulic press and the Mechanical oil Expression Rig. As a result of this, size reduction of the kernels was carried out. In order to reduce the size of the palm kernel to particle sizes of fine and coarse respectively; the palm kernels were firstly crushed using a hammer mill, and later the crushed meal was further reduced using an attrition mill as reported by Olaniyan, (2006). After size reduction, particle size analysis was carried out using a set of laboratory Endocotts Test Sieves and Shaker (model SW19 3BR England) available in the Laboratory of the Soil and Water Management Engineering Department of NCAM.

Particle size analysis was done in accordance with ASAE (1989) Standard S319. In line with Adeeko and Ajibola (1989), samples that passed through the 5.6mm sieve but retained on the 2.36mm sieve were classified as coarse, while samples that passed through 2.36mm sieve but retained on the 0.6mm sieve were classified as fine.

Experimental Machines and instrumentation

In this study, a technique for heating oil seed sample before and during expression was adopted. A laboratory mechanical oil expressing piston-cylinder rig which is similar to the one used by Olaniyan (2006), and Mrema (1979) was used.

The laboratory mechanical oil expeller is made up of three major components: the compression piston, the press cage cylinder and the supporting platform (Olaniyan, 2006). The press cage cylinder was made from a mild steel pipe with an inside diameter of 66 mm, 7 mm thick and 140 mm long. A 600 W electric band heater was installed round the press cage cylinder to serve as a heating device for the expression process. A 5 mm hole was drilled on one side of the press cage cylinder at a height of 70 mm from the base; this hole is for the fixing of thermocouple probe for temperature monitoring. The rig was adequately instrumented with a temperature controller to control the expression temperature, while the pressure for oil expression was obtained from the hydraulic press via the instrumentation system (force measuring device).

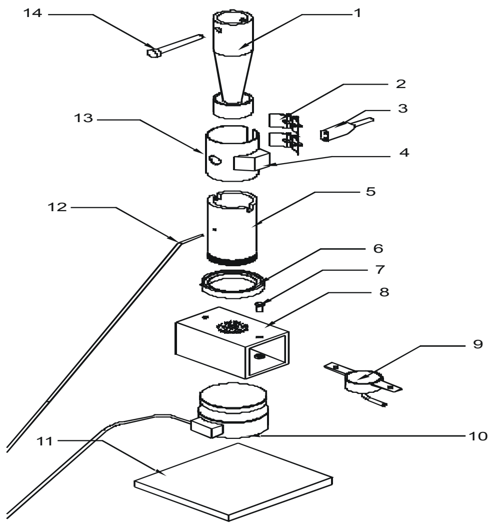

Figure 1: Exploded view of the Model laboratory Mechanical Oil Expression Rig

Experimental Design

In order to study the effect of particle size on oil yield during mechanical expression of oil from palm kernel under uniaxial loading, a suitable experimental design that incorporated two particle sizes (i.e. Fine and Coarse), four levels of heating temperature (i.e. 70 ° C, 90 °C, 110 °C and 130 °C) and four levels of applied pressure (i.e. 6.0 MPa, 9.0 MPa, 12.0 MPa and 15.0 MPa) was designed. A 4^2 x 2 factorial experimental design in a Randomized Complete Block Design (RCBD) was used. Each test was performed in three replicates at each level of the factors. The ranges of values of factors such as moisture content, heating time and pressing time were also obtained through preliminary investigations and were kept constant throughout the experiments in order to reduce the data to a reasonable size.

Experimental Investigation Procedures

Moisture content determination

Moisture content of the sample was determined by oven drying 100g ground sample at 130°C for 6 hours; as recommended for oil seeds by Young *et al* (1982) and used by Tunde-Akintunde *et al.,* (2001). The average moisture content of 4.5% was adopted for all the samples used throughout the experiments in order to reduce the data to a reasonable size.

Heat treatment

Heating of the sample (ground palm kernel) was achieved by weighing 200g of the sample in line with Olaniyan (2006), and transfer of the weighed sample into the press cage already encircled with the temperature controlled heater band. The samples in the press cage where heated to temperatures of 70 °C, 90 °C, 110 °C and 130 °C respectively for 30 minutes before expression begins. The lower limit of 70 °C and upper limit of 130 °C were selected based on preliminary laboratory investigation, which revealed that heating milled palm kernel sample below 70 °C did not give good oil yield during expression; while heating above 130 °C resulted in excessive burning and darkening of the oil. Also, the heating time of 30 minutes used in this study was based on preliminary investigations and also on the fact that the period allows for temperature uniformity and equilibration of the oil seed cake as reported by Hamzat and Clarke (1993).

Applied Pressure

Pressure was applied to the sample in the press cage cylinder via the compression piston attached to the spindle of the hydraulic press. Samples were subjected to applied pressures of 6.0 MPa, 9.0 MPa, 12.0 MPa, and 15.0 MPa for 10 minutes respectively. The lower limit of 6.0 MPa applied pressure was selected based on preliminary investigation which revealed that reasonable quantity of oil cannot be expressed from coarse palm kernel samples at applied pressure below 6.0 MPa, while the upper limit of 15.0 MPa applied pressure was selected based on the capacity of the existing Universal Testing Machine, which was used at the preliminary stage of this work.

Sequence of Mechanical oil Expression

The complete assembly of the hydraulic press, the mechanical oil expression rig with the temperature regulator, and the compressive force measuring device used in this experiment is as shown in Figure 2. Before coupling the mechanical oil expression rig, a stainless steel wire mesh was placed at the bottom of the cylinder guide in order to cover the drainage area and at the same time serve as a filter during the oil expression process.

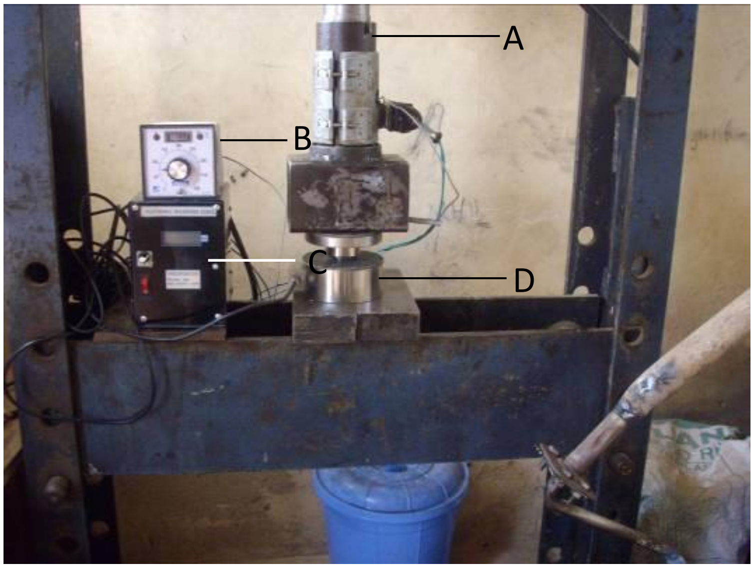

Figure 2: Complete Assembly of the Force Measuring Device, the Mechanical Oil Expression Rig with the Temperature Controller on Hydraulic Press.

Legend

A	Mechanical Oil Expression Rig
B	Temperature Controller
C	Amplifier with display Unit (Force Measuring Device)
D	Load Cell

After the coupling, a sample of 200g weight of ground palm kernel was poured into the press cage cylinder. The sample was then heated for 30 minutes at heating temperatures of 70°C. Using the actuating lever of the hydraulic press, the compression piston was moved down to touch the sample and pre-compact it to a height of 70mm inside the press cage cylinder (Olaniyan, 2006). After the pre-compaction, the sample was further compressed by the hydraulic press via the compression piston to a pressure of 6.0 MPa for 10 minutes. The oil expressed drains into the oil collector and was collected through the outlet pipe.

The same procedure was followed to carry out the experiment for three other heating temperature levels of 90 °C, 110 °C, and 130 °C at three other applied pressure levels of 9.0 MPa, 12.0 MPa, and 15.0 MPa for the coarse and fine particles size respectively.

Oil Yield

Oil yield was calculated as the ratio of the weight of oil expressed to the weight of the sample before expression. Adeeko and Ajibola (1989) Expressed it mathematically as:

$$Oy = \frac{\text{Weight of oil expressed (WEO)}}{\text{Originalweightofsamplebeforeexpression } (WS)} \times \frac{100}{1}$$

$$Oy = \frac{\text{WEO}}{WS} \times \frac{100}{1}$$

RESULTS AND DISCUSSION

Table 1 shows the summary of the test result obtained for oil yield at various operative conditions while Table 2 is the summary of ANOVA showing the effects of particle size on oil yield during mechanical expression of oil from palm kernel.

Table 1: Summary of the test result for oil yield at various operative conditions

Parameter	Temperature (°C)	Particle size	Pressure (MPa)			
			6	9	12	15
Oil Yield (%)	70	Fine	7.27	13.25	17.7	22.90
		Coarse	1.41	2.20	7.02	7.79
	90	Fine	8.37	9.18	8.6	13.30
		Coarse	1.78	3.93	2.1	2.19
	110	Fine	9.18	8.60	13.3	17.10
		Coarse	3.93	2.10	2.19	3.72
	130	Fine	8.60	13.3	17.1	18.70
		Coarse	2.10	2.19	3.72	9.43

Table 2: Summary of ANOVA showing the effect of particle size on oil yield

Parameter	Particle Size	Source of Variation	df	Ss	Ms	F_{cal}	Prob.
Oil yield (%)	Fine	Temperature(A)	3	278.864	92.955	118.388	0.001
		Pressure(B)	3	2692.530	897.510	1143	0.001
		AxB	9	90.643	10.071	12.827	0.001
		Error	32	25.125	0.785		
		Total	47	3087.162			
	Coarse	Temperature(A)	3	227.346	75.782	168.868	0.001
		Pressure(B)	3	598.956	199.652	444.892	0.001
		AxB	9	64.139	7.127	15.880	0.001
		Error	32	14.360	0.449		
		Total	47	904.801			

From Table 2, it can be observed that the particle size had significant effect on oil yield at 1% level of significance. Hence, the hypothesis of equality of mean treatment effect is rejected, and it can be implied that at least one of the mean treatment effect is significantly different from the others.
The independent t-test was used to compare the means of fine and coarse particle sizes for Oil Yield. The result is shown in Table 3

Table 3: Effect of Particle Size on oil yield

Parameter	Size	T	Df	Sig.	MD.	SE (MD)

Oil Yield	Fine	8.771	94	0.001	11.66	1.33
	Coarse	8.771	72.37	0.001	11.66	1.33

MD is mean difference, SE is standard error

From table 3, the mean of oil yield from fine particle sizes was observed to be significantly higher than that of coarse particle sizes at 1% level of significance. The increase in the oil yield from fine particle sizes can be attributed to the weakening of more oil cell walls during size reduction. The weak (or broken) oil cell-walls readily expel oil on the application of little pressure. Also, size reduction exposed a greater area of oil bearing cell walls to heat (during heat treatment) and pressure application.

The effect of particle size on oil yield at various heating temperatures and applied pressures is shown in Figure 3. This demonstrates a significant higher oil yield from fine particle sizes when compared with coarse particle sizes.

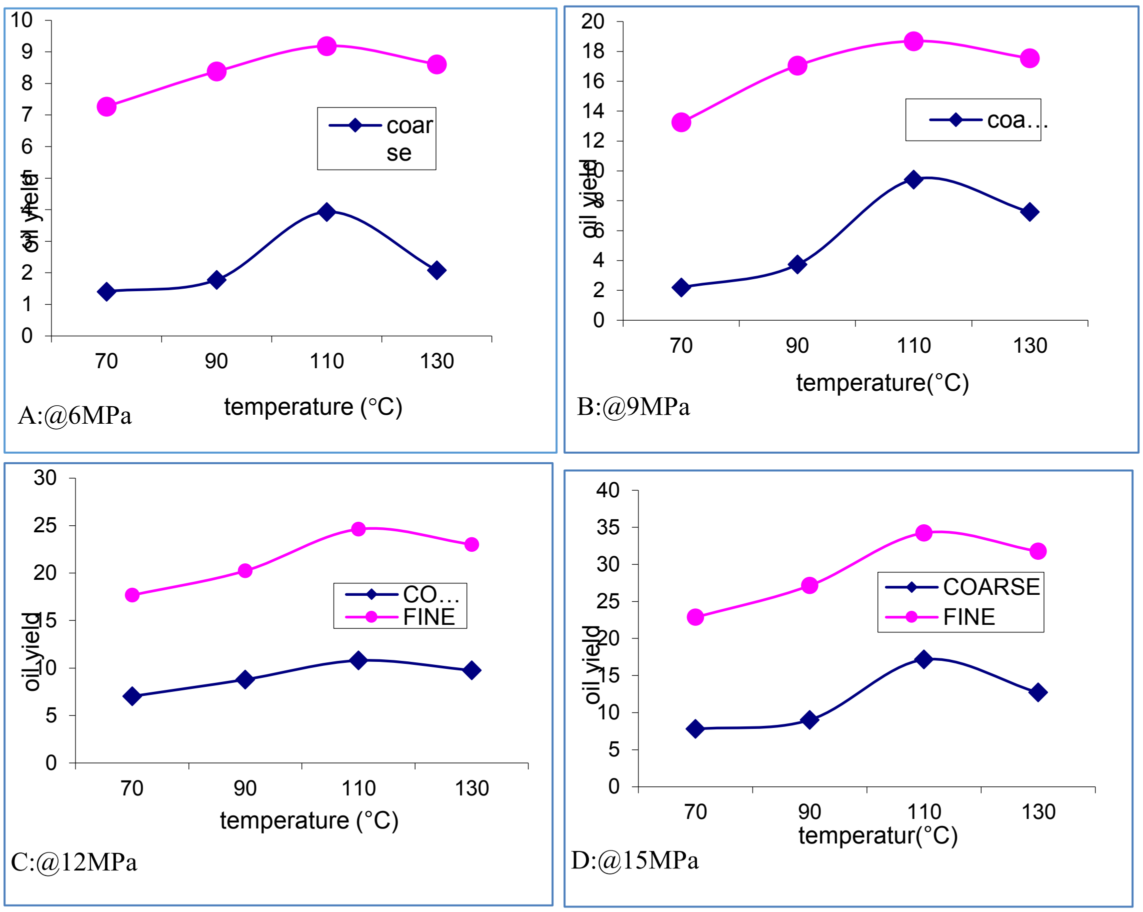

Figure 3: Effect of Particle size on oil yield at various heating temperatures and applied pressures.

Figures 3A and 3B further showed that there is a gradual increase in oil yield for coarse as well as fine particle sizes when heating temperature was increased from 70°C to 90°C at a pressure of 6MPa and 9MPa respectively. However, when temperature was increased from 90°C to 110°C, there was a rapid increase in oil yield from coarse particle size while the fine particles maintained a gradual increase at the same treatment conditions. As the temperature was further increased from 110°C to 130°C, a sharp decline in oil yield was observed for coarse particle size while a gradual decline in oil yield was observed for fine particle sizes. This rapid increase in oil yield for coarse particle size could be attributed to rapid thermal breakdown of oil cellsas well as reduction of oil viscosity at heating temperatures from90°C to 110°C; while on the other hand, mechanical breakdown of oil cell walls had occurred during the mechanical size reduction for fine particle size but required heat treatment for reduction of oil viscosity resulting in a gradual increase in oil yield.

The sharp decline in oil yield for coarse particle size when temperature was further increased from 110°C to 130°C, could be attributed to excessive burning of oil which gave rise to sublimation of oil and case hardening of the sample; however, for fine particle sizes, case hardening occurred moderately at the same treatment conditions, giving rise to a gradual decline in oil yield. This is similar to the result obtained at applied pressure of 15MPa as shown in figure 3D but showed slight difference from the result obtained at 12MPa of applied pressure as seen in figure 3C. It can be observed in fig 3C that there is no rapid increase or decline in oil yield from both particle sizes at 12MPa of applied pressure.

This result agrees with the findings of Ajibola *et al.,* (1990), who reported that coarsely ground samples gave consistently lower yields of oil than finely ground samples while working on the mechanical expression of oil from melon seeds.

CONCLUSION

The effect of particle size on oil yield during mechanical expression of oil from palm kernel under uniaxial loading was studied. The study revealed that oil yield from fine particle size are higher and significantly different ($p \leq 1\%$) from that obtained from the coarse particle size. It then implies that, in order to maximize oil yield during mechanical expression process, the palm kernel size should be reduced to fine particles.

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EFFECTS OF OPERATING SPEED AND SCREEN DIAMETERS ON THE EFFICIENCY OF A HAMMER MILL

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ABSTRACT

A hammer mill was developed for pulverizing dried yam, the evaluation of the machine was carried out using screens of different sizes (1.5mm and 5.0mm); and different operating speeds(650 rpm and 1200rpm) to ascertain their effects on the machine output efficiency, capacity and fineness of the end-products. Four replicate samples were prepared namely: A – [5.0mm ø screen, 650rpm speed], B – [1.5mm ø screen, 650rpm speed], C – [1.5mm ø screen, 1200rpm speed] and D – [5.0mm ø screen, 1200rpm speed] respectively. The end-products were subjected to sieve analysis; the following inferences were drawn: (i) D is most time efficient with operational time of 8.10sec for 10Kg of dried yam, followed by C (8.60sec), A (9.15sec) and B (9.40sec) respectively for same mass of test material; this shows that higher operational speed enhances the milling time.(ii) The output efficiency (%) are in the order: C (81.50%), B (79.40%), D (77.10%) and A (73.39%) respectively; best output efficiency was achieved at higher speed cum small screen hole diameter.(iii) Also that the operational speed and screen hole diameter affects the machine output capacity, as shown: D (74.07 Kg/hr), C (69.77 Kg/hr), A (65.57 Kg/hr), and B (63.83Kg/hr) in decreasing order respectively and fineness modulus: A (0.88), D (0.84), B (0.75) and C (0.62) in increasing order respectively. Hence, suitable operational speed of 1200 rpm and screen size of 1.5mm is recommended for optimal operation of the hammer mill.

***Key words**: Hammer mills, Screen, Pulverizing, Efficiency and Sieve analysis.*

INTRODUCTION

Nigeria is the world's largest yam producer, contributing approximately two thirds of the global production with about 2,837,000 hectares land area under yam cultivation (FAO, 2013). Yam is an important staple food crop in Nigeria, produced both for household consumption and as a cash crop. It is an important source of carbohydrate for many people of the sub-Sahara region, especially in the yam zone of West Africa (Akissoe et al., 2003). Yam contributes more than 200 dietary calories per capita daily for more than 150 million people in West Africa and serves as an important source of income to the people (Babaleye, 2003). It is not rich in vitamin A and C as sweet potatoes but tends to be higher in protein and minerals like phosphorous and potassium than any other root crops (Degras, 1993). According to AMCOST (2006), pre- and postharvest food crop loss among African countries is estimated at about 40%, which is higher than the global average. Onebunne (2006), reported that due to its perishable nature, lack of good processing equipment and methods and poor storage facilities, high percentage of yam (about 30%) produced is wasted annually in Nigeria. Various efforts has been made to add value to this pernicious crop in order to retain, sustain and maintain its quality and quantity. Part of this efforts is the storage of yam in pit, building structures, platform and barn (Igbeka, 1985). Yam can be stored in these various structures for 4 to 6 months in fresh weight (Hounhouingan, 2006).

Fresh yam can be dried as lump or sliced, this extends the shelf life to between 11-14 months under proper storage. This makes yam less susceptible to pest and rodent attacks; makes it readily available in the market during off- season and helps to reduce post- harvest losses. (Hounhouingan, 2006). Dried yam can further be processed into flour which stores longer under proper storage and is used in making special local delicacy called "Amala" (an elastic food paste) enjoyed in the Western part of Nigeria and some parts of West Africa. The process line for yam after harvest is highlighted below,

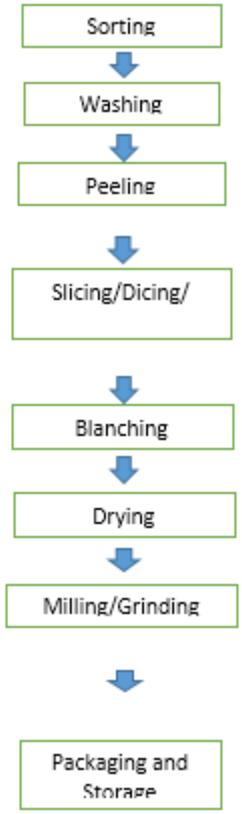

Figure 1: Block diagram for processing yam to flour.

Processing of dried yam into flour is a series of size reduction processes. The general term size reduction includes the mechanical processes of cutting, shearing, crushing, grinding, and milling feed grains. These processes expose more surface area for digestion without causing any noticeable change in the chemical properties of the material. At the same time, size reduction facilitates uniform mixing. And although uniformity in size and shape of the reduced particles is usually desired, it is seldom attained (Rudnitski et al, 2012).

Traditionally, this is done using mortal and pestle, the end product gotten is sifted with sieve and the process repeated over again till the chaff residue is minimal. After the introduction of the burr mill, the manually pulverized dried yam is milled into fine powder with the help of the burr mill.

Presently, the manual pulverization with the mortal and pestle has been removed with the invention of hammer mill, which is used in pulverizing dried yam mechanically before the process is completed with the use to burr mill. In other words, a typical dried yam milling shop is equipped with a hammer mill and a burr mill with a diesel engine in between them for power supply to each of the machine one after the other (*personal findings*). These mechanical means of pulverizing dried yam saves times and energy and better end product is gotten than the old traditional means.

Various hammer mill had been developed for different purposes and most of the machines had been evaluated without recourse to the effects of operating speed and screen size. Nasir (2005) developed a multi-purpose hammer miller for cereals and dried cassava tubers, he evaluated the performance based on the time of operation using cereals and dried cassava. Ngabea et al (2015) fabricated a magnetic sieve crusher to remove metal objects from the test materials. Xuan et al (2012) developed a hammer mill with separate sieving device and evaluated the machine based on the sieve performance.

Efforts to improve milling process would be further boosted through this research by establishing a suitable operational speed and screen size for optimum output result of end-product. The hammer mill used for this research was designed and fabricated for pulverizing dried yam with a modification in the mechanism by incorporating sets of rollers with the hammers with an interchangeable screen. The performance evaluation of the machine was carried out to investigate the effect of speed and screen size on the machine efficiency by using an adjustable motor (prime mover) to vary the operating speed and interchangeable screen of different diameter on the machine.

MATERIAL AND METHODS

Materials

Dried yam lumps were sourced from Ijeru market, in Ogbomoso South Local Government Area of Oyo state for the performance evaluation. A weighing scale of accuracy ±0.01kg was used for weighing each portion of the test material, a tachometer to determine the operating speed of the machine when loaded, collecting bowls for collecting the crushed sample, a stopwatch to record the time of operation at each instance and polythene bags for storing the end product for save keep.

Methodology

Two screens of diameters 1.5 mm and 5.0mm were made. An adjustable motor (prime mover) of 1440rpm was used to vary the operating speed. From literatures, the average speed used for operating hammer mill was 775rpm (Nasir, 2005 and Ngabea et al, 2015). Therefore, a speed slightly below (650rpm) and a higher speed (1200 rpm) was chosen respectively. 10 Kg of the dried yam lump was weighed out in four portions on the weighing balance at a moisture content of 23% dry base and tagged A, B, C and D respectively.

The screen was interchanged one after the other at the two speeds with the operating time recorded. The four replicates of the end-product were tagged accordingly as follow: A – (5.0mm screen diameter cum 650rpm speed), B – (1.5mm screen diameter with 650 rpm speed), C – (1.5mm screen diameter with 1200rpm speed) and D – (5.0 mm screen diameter with 1200 rpm speed).

The end-products gotten were taken for particle size analysis to determine the degree of fineness and uniformity index of the four replicates. The procedure as explained by California Test 202 (2011) was followed: 200g of the grinded replicates were weighed out and shake through 5 set of Tyler sieves for 5 minutes by means of tapping sieve shaker. The mesh number of the 5 sieves are 40, 60, 80, 100 and 150 microns from top to base respectively. The sieves are designated 1 – 5 starting from the smallest to the biggest (i.e. from 150 to 40) while the pan is designated as 0. The following were thereafter determined,

(i) The percentage of material retained on each sieve by:

$$\%\, retained\ in\ sieve = \frac{W_{sieve}}{W_{total}} \times 100 \quad (1)$$

Where, W_{sieve} is the weight of aggregate in the sieve, W_{total} is the total weight of the aggregate.

(ii) $$\%\, cumulative\ retained = R_{S1} + R_{S2} + \cdots + R_{S5} \quad (2)$$

Where, R_s- % retained on each sieve from largest to smallest.

(iii) The percentage of material passing each sieve:

$$\%\, cumulative\ passing = 100 - \%\, cumulative\ retained \quad (3)$$

(iv) The machine output efficiency was determined by:

$$machine\ efficiency = \frac{mass\ output}{mass\ input} \times 100 \quad (4)$$

(v) $$material\ loss = \frac{(M_b - M_a)}{M_b} \quad (5)$$

Where, M_a- Mass after grinding, M_b- Mass before grinding.

(vi) $machine\ capacity = \frac{mass\ of\ input\ material}{milling\ time} \times 60 minutes$ (6)

(vii) $\Sigma FM = \frac{\Sigma\ \%\ retained}{100}$ (7)

Where, ΣFM- Fineness modulus.

RESULTS AND DISCUSSION

The effect of operating speed and screen size on particle size.

Higher operating speed cum small screen size gave the finest result (Figure 2). The percentage of material retained is lowest for sample C followed by B, D and A respectively. The optimal grinder configuration for maximal process throughput and efficiency of hammer mill is strongly dependent on tip speed of the rotor, screen diameter, feedstock type and properties, such as moisture content. (Anderson, 2003 and Yancey, et al, 2014). Hence, in selecting the proper grinder process parameters, speed and screen size is an important factor.

The effect of operating speed and screen size on operation time.

The time for milling same quantity of dried yam increased in the order: D, C ,A and B respectively (table 1); showing that at bigger screen size and higher speed the operation is more time efficient. This shows that high speed and large screen enhance the time efficiency of the hammer milling operation. El Shal et al (2010) reported that aside moisture content factors like screen size, speed rating, etc. also affects the residence time of feed in hammer mill operation.

The effect of operating speed and screen size on machine throughput.

The machine throughput (table 1) is highest for D, followed by C, A, and B respectively in decreasing order. This connotes that the higher the operating speed and screen size, the higher the output capacity because of lower residency time in the machine (Yancey, et al, 2014).

The effect of operating speed and screen size on machine efficiency.

Based on fineness of the end-products, C, was best followed by B, D and A in the decreasing order (table 1). This conforms to Yancey, et al, (2014) which reported that smaller the size of the screen the finer the grains generated from the grinding machine.

Table1: Parameters from machine testing.

Sample	Mass of material input (Kg)	Milling Time (Min.)	Machine Capacity(Kg/hr)	Material Output(Kg)	Material Loss(Kg)	Machine Efficiency (%)
A	10.00	9.15	65.57	7.34	2.66	73.40
B	10.00	9.40	63.83	7.94	2.06	79.40
C	10.00	8.60	69.77	8.15	1.85	81.50
D	10.00	8.10	74.07	7.71	2.29	77.10
Average	**10.00**	**8.81**	**68.31**	**7.79**	**2.21**	**77.85**

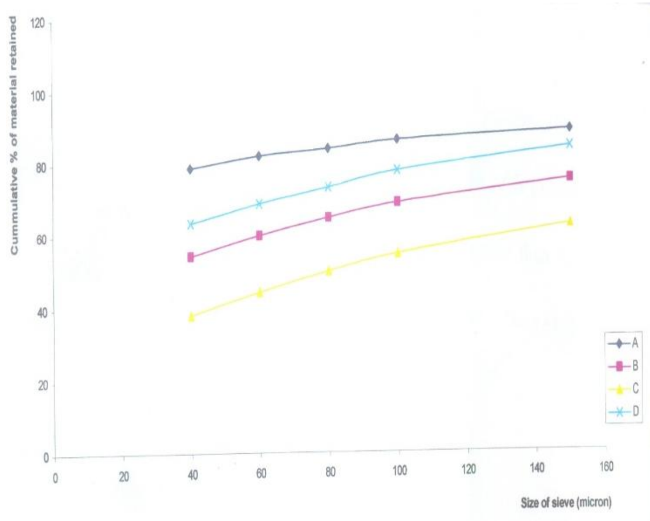

Figure 2: Graph of the sieve analysis of the samples of crushed dried yam showing the fineness in increasing order from top to down.

CONCLUSIONS

Hammer mills as a processing equipment are more efficient if operated at the appropriate optimal conditions. The machine throughput, efficiency, fineness of end-product and timeliness of operation is essential to the overall performance of the machine. This research has been able to establish that higher operational speed (1200 rpm) and smaller screen size (1.5mm) is best among other operational instances used giving a throughput of 69.77 Kg/hr, working efficiency of 81.50% in terms of fineness of end-product and operational time of 8 minutes 60 seconds for 10 Kg of dried yam lump at 23% moisture content.

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Design, Construction and Performance Evaluation of an Orange Juice Extractor

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ABSTRACT

A manually operated orange juice extractor was designed, constructed and tested using locally available materials. The machine consists of the hopper, screw, screen and concave, a let-out chute, a pipe collector for juice, and handle. The machine uses a masticating method (slow crushing and squeezing) to extract the juice from the orange. Test result of the machine performance gave extraction capacity of 13.38 l/h and extraction efficiency of 48.03%. The construction cost of the machine was ₦15,600:00 based on the current cost of materials in the market. Recommendations were given for the improvement of the machine.

***Key words**: Orange, juice, extractor, and perfomance evaluation*

INTRODUCTION

The orange fruit is a specialized type of berry known to the botanists as hesperidia (Aye and Ashwe, 2012). Orange belongs to the family of dicotyledonous berries known as *Citrus sinensis.* According to Elyatem (1996), orange, also known as citrus is considered as one of the major fruits crops produced in the West Asia and North African regions (WANA). The term citrus includes four different types of fruits, namely, oranges, mandarin (tangerine), lemon and grape fruit. Citrus fruits vary in their relative susceptibility to chilling injury; grapefruits, lemons, are much more susceptible to chilling injury than are oranges and mandarins (Kader et al.; 1985). It has a soft, pithy central axis surrounded by 10-15 segment containing pulp and juice (Aye and Ashwe, 2012). The fruit contains sweet-testing juice when ripped, and is normally consumed mostly fresh. In Nigeria, about 930,000 tons of orange fruits are produced anually from an estimated land area of about 3 million hectares (FAO, 2008). Major orange producing states in Nigeria include: Benue, Nassarawa, Kogi, Osun, Oyo, Delta, Taraba, among others (Taiwo, 2005). Orange juice is normally obtained by squeezing or pressing the fresh orange, by drying and later rehydrating the liquid, or by concentration of the juice and later adding water to the concentrate.

Literally, the term extraction means the idea of pressing something out of something else. A device for pressing liquids out any fruit is known as a "juice extractor". Orange juice extractor extracts juice from orange, removing the solid matter and pulp, and then clarifying the juice to be able to control the colour, taste and overall quality of the end product. There are two principal methods of juice extraction from orange (Olaniyan 2010). The first method involves continuous crushing and pressing of orange fruit in a single operation; while the second method involves the slicing of the orange fruit into smaller pieces and then pressing them using a suitable pressing machine to extract the liquid. Different types of extraction machines defer in the mode they are operated. Some common types of juice extractors include centrifugal press, manual press, single auger, dual cage auger and twin press. Centrifugal press models are one of the oldest types and have a simple design with a shredder and strainer. They use the centrifugal principles to separate the juice from the pulp. Badmus and Adeyemi (2004) designed and fabricated a small scale whole pineapple fruit juice extractor. The machine consists of beater blades and a shaft in conjunction with a powered screw pressing mechanism. The machine successfully processed 12 kg of ripe pineapple fruit into 8 l of pineapple juice. Ishiwu and Oluka (2004) developed and carried out performance evaluation of a juice extractor based on its extraction efficiency. The extractor consisted of screw jack, frame, connecting rod, pressing mechanism, interlock, feeding pot, receiving pot and discharge mechanism. Performance tests revealed a juice yield, extraction efficiency and extraction loss of 76, 83 and 3%, respectively.

Many species of fruits are produced annually, biennially and perennially of which man consumes. Due to the lack of proper handling and processing, much of the fruits are lost to spoilage. Most fruits are produced in excess of the consumer demand, hence farmers are compelled to offer the produce for sale at harvest at very low price to minimise further loss. Fruit like orange change taste and give offensive odor due to bacteria when not properly handled. With this knowledge of perishable nature of orange fruits, the extraction and preservation of their juice is neccessary. It is therefore, important to encourage extraction of juice from the orange fruits by the use of locally developed extractor.

This will assist in processing the fruits juice for use during off season of the fruit, minimise economic loss due to spoilage, create job opportunities to the youth, and is environmentally friendly.

To store the orange fruit at harvest, in its fresh form, have failed due to lack of storage facilities. Therefore, the better way of storage and preservation is to process the fruit into juice. The objective of this work is, therefore, to design, construct and evaluate the performance of a manually operated orange juice extractor using locally available materials.

MATERIALS AND METHOD

The machine was contructed and tested in the Department of Agricultural and Environmental Resources Engineering Teaching workshop, University of Maiduguri.

Design Considerations

In order to choose materials for the construction of the orange juice extractor, the following factors were considered hardness and rigidity (the ability of the machine components to resist deformation when subjected to applied forces). The ability of the machine to extract juice from orange fruits efficiently was also considered. The density of orange which was determined experimentally by weihging a certain quantity of orange in to a 1 m^3 box and was founed to be 53.8 kg/m^3. The force required to cause failure (crush) of the orange fruit is 0.3kN (Oguntuyi, 1989). Finally, the cost and availability of the materials was also put in to consideration.

Design of Components

The materials used in the construction of this orange juice extractor are listed below:

a. Plane steel sheet, gauge 18 (1.5mm thick)
b. Angle iron for frame
c. Solid pipe for the shaft of the screw
d. Ball bearing
e. Bolts and nuts of various sizes for coupling.

On the other hand, the hand tools and equipment used were: Hack saw, hammer, center punch, devider, bench vice, hand shear cutter, file, calipers, T-square, anvil, metal rule and 100 cm steel rule. Also, machines used in this construction work include: grinding machine, lathe machine, rolling machine, drilling machine, electri arc welding machine.

The machine developed comprised of the following components: the frame, hopper, screw, screen and cylinder, chaff outlet, handle and bearings. Some of these components are explained below.

The Frame: The frame was constructed from an angle-iron of 2.54 × 2.54 cm of mild steel material. A total lenght of 642 cm was cut from the given material. Using rule and scribber, two 53 cm, four 34 cm, two 60 cm and four 70 cm were marked out. The pieces were cut with the use of hack saw. The four 70 cm were placed parallel to each other at distance of 72 cm apart. Using the arc welding machine, the pieces were then joined together. The frame is used to support the whole machine. It is braced at the centre so as to make strong and stable.

The Hopper: This is a box used for holding the oranges to be processed. Steel sheet of gauge No. 18 (1.5 mm thickness) was used in constructing the hopper. During the construction process the dimensions of the hopper were marked out on the steel plate using a scribber. The marked portions were cut out using a hand shear. Later, the cut out plates were all welded using an electric arc welding machine. The shape of the hopper is trapezoidal as shown in Figure 1. This is to allow the oranges to fall freely under gravity in to the pressing chamber.

The lower size of the hopper was taken to be 15 cm. This is to allow for atleast three oranges to be supplied into the squeezing chamber at a time. The top of the hopper was considered as 35 cm. The length of the hopper was also considered as 45 cm. From the experimentally determined bulk density of orange (53.8 kg/m^3) and the machine being manually operated, the machine was designed to operate using 2.5 kg of orange at the start of operation. Therefore, the hopper size was calculated as follows:

$$2.5kg = 100\ \%$$

$$53.8kg = 1m^3 = 1\times10^6\ cm^3$$

$$2.5kg = (1\times10^6/53.8)\times2.5 = 4.64\times10^4\ cm^3$$

Using, volume = Area × length

Area of a triapezium, $A = \frac{1}{2}h(M + N)$, cm^2

Where: h= height, cm

M and N = Size of the opposite parallels, cm

Therefore, $4.64×10^4 = 1/2h\ (15+35) × 45$

$h = 4.64×10^4/25×45 = 41cm$

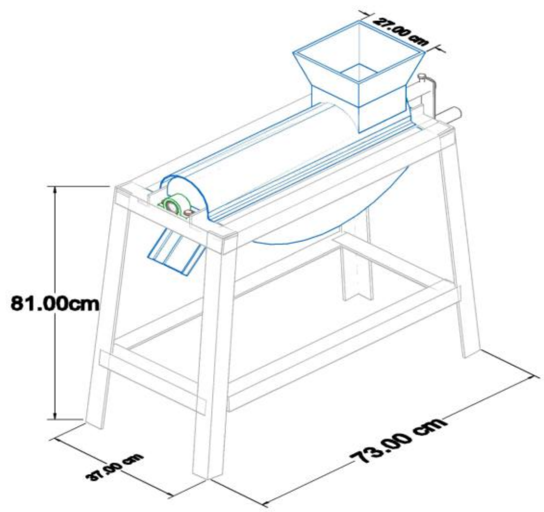

Figure 1: Isometric view of the orainge juice extractor

Screw: This is the component that compresses the orange fruit against the screen to extract the juice. The screw was constructed using a solid shaft and circular discs. The solid shaft is of 35 mm diameter and 53 cm long. It was cut from a solid round shaft bar using hacksaw. The shaft was worked on the lathe machine to reduce the diameter to 30 mm. The discs of 100 mm diameter were constructed from steel metal sheet. From the 100 mm circular sheets, a hole of 30 mm diameter was bored. The discs were then cut in between to make a spiral shape by welding it on the solid shaft at 50 mm intervals. Thus, the screw pitch was 50 mm (Plate 1).

The rotational power of the screw was calculated as follows:

$$P= T\,\omega\,W \quad (1)$$

Where; P= power required, W; T= torque, Nm; and ω = angular velocity, rad/s

It is known that, $\omega = 2\pi N$ (2)

and $T = Fr$ (3)

Where: N= speed of rotation, rpm; F= force required, kN; and r = radius of the screw, m.

Substituting equations 2 and 3 in equation 1,

$$P= 2\pi NFr/ 60,\ W \quad (4)$$

The force, F, required to crush a fruit orange is 0.3 kN (Oguntuyi 1989). The screw was assumed to be normally rotated at 25 rpm by an average human being considering his ergonomics behaviour. A shaft of diameter 30 mm was used and the screw diameter of 100 mm was selected as in the design above.

From these assumptions, the power required was calculated as:

$P = 2\pi NFr / 60 = 3.93$ W

It is known that, 746 W is equal to 1hp.

Therefore, 102 W = 1/746 × 3.93 = 0.0053 hp

This value is within the range of the normal human output of 0.25 hp as reported by Kawuyo (1992). The isometric view of the machine is shown in Figure 1 and the orthograhic projection is shown in the Appendix.

Screen and Cylinder: The screen was constructed from steel metal sheet of 50 by 30 cm which was marked with a divider and cut with a hand shear cutter. Center punch was used to mark the centres for the holes. Holes of 3 mm were drilled using punches at 5 cm intervals. It was later rolled using the rolling machine. The screen also serves as the component on which the orange is pressed by the screw. The juice extracted fall by gravity to the cylinder which is of steel sheet material. A delivery opening is located at the bottom of the cylinder. Wire mesh is fitted at the enterance of the delivery opening. This is to ensure complete sieving of suspension from the juice (Plate 2).

Bearings: is a machine component used to support shafts, axles, and other rotating parts and to take up radial and axial loads. A bearing consists of rolling elements (balls or rollers) between an outer and inner rings. Cages are used to space the rolling elements from each other. The choice of a bearing is a function of factors such as magnitude and direction of the expected load and the manner of load variation, shaft diameter, cost and space available for the bearing.

Assembly of the Machine

The orange juice extractor was assembled after the construction of the various component parts. The procedure undertaken during the assembly of the components are explained below:

i. The two ball bearings of 20 mm diameter were mounted, one on each end of the screw shaft.
ii. The screw (auger) was screwed through the folded screen and bolted on the main frame.
iii. The hopper was mounted on the cylinder cover by welding using electric welding machine.
iv. The concave was bolted at the bottom of the screen.
v. The outlet chute was welded at one side of the auger on the concave so that the chaff of the orange will be removed out through the chute.
vi. Then the handle of the machine was fixed at one side of the shaft so as to turn the shaft manually to compressed the orange and covey the chaff of the oranges.

Mode of Operation of the Machine

The operation of the machine involves the rotation of a spiral screw in a halved cylinder by manually rotating the screw shaft. The cylinder is to cause flow of the extracted juice to the collecting funnel whose entrance is fitted with mesh wire to sieve the suspension in the juice. Peeled and washed oranges were poured into the hopper, the rotary motion of the flight screw presses the orange and conveys the oranges to the end area of the cylinder. The juice drops through the perforated cylinder in to a collector. The waste products (chaff) passed out through the chaff outlet.

Performance Test and Evaluation

Testing of the orange juice extractor followed the construction. Average of 1,100 g of peeled and washed oranges were fed in to the hopper. The handle was was rotated manually to operate the auger. This process compressed the orange and extracted the juice. A stop watch was set to determine the time taken for the machine to extract the juice from the orange. The juice extracted was collected through the outlet point at bottom of the concave and was weighed. The machine was put to test three times and the average juice extracted, average juice loses, average time taken, efficiency of the machine, and capacity of the machine were determined.

The efficiency and capacity of the machine are determined as follow:

Mean Juice Extracted (output), $J = \frac{\text{Total output}}{\text{Number of trials}}$, L

Mean Juice Loses, $J_l = \frac{\text{Total juice loses}}{\text{Number of trials}}$, L

Mean Mass of Orange (input), $M_i = \frac{\text{Total input}}{\text{Number of trials}}$, Kg

Mean Time Taken, $\mathrm{T_t} = \frac{\text{Total time taken}}{\text{Number of trials}}$, sec

Efficiency of the Machine, $\mathrm{M_e} = \frac{\text{Aveage output}}{\text{Total input}} \times 100, \%$

Extraction Capacity, $\mathrm{C_p} = \frac{\text{Average output}}{\text{Average time taken}}, \mathrm{l/hr}$

RESULTS AND DISCUSSIONS

The result is presented in Table 1 below. It was observed that the machine performed satisfactorily on the test fruit. It was further observed that the juice contained some macerated pulps of the fruit. The mean of oranges fed in to the machine was 1,100 g. It was also observed that less than halve of the fruit weight was obtained as juice. This could be attributed to the low efficiency of the machine and the period of harvest (dry season). This can be removed by filtering the juice after extraction. It was also based on the care that the fruit could not be over pressed so as to avoid breaking of the seeds. The extraction capacity of the extractor was 13.38 kg/h, this low value can be attributed to the low standard deviation. The extraction efficiency was 48.03 %, this is by far lower than 83.86% value as repoeted by Abulude et al.; 2007. This could be based on the weaker material used in constructing the screw (metal sheet).

Table 1: Performance evaluation of the orange juice extractor

Parameter	Mean	±SD
Mass of orange used (peeled), g	1,100	81.65
Mass of juice extracted, g	528.33	40.28
Mass of chaff obtained, g	571.67	62.63
Test time, min	2.37	0.45
Extraction capacity, kg/h	13.38	1.26
Extraction efficiency, %	48.03	2.35

CONCLUSION

The work has achieved the aim of developing a local orange juice extractor. Performance test of the machine resulted to the extraction capacity of 13.38 l/h and extraction efficiency of 48.03 %. These values may be low due to the materials used in constructing the screw. The screw was contructed from metal sheet. It is recommended that, the diameter of the perforated screen to be reduced for complete sieving of juice from the chaff. Also the screw should be made by winding rod round the shaft instead of the steel sheet or by using a plate. This is expected to increase the efficiency of the machine. Finally, it is recommended the hopper and screen be make using galvanised sheet to enable the eating ability of the juice extracted by the machine.

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Plate 1: Screw of the orange juice extractor

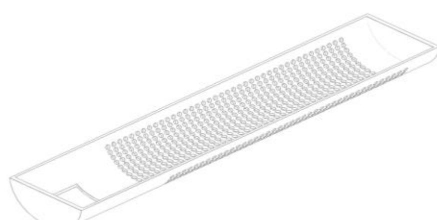
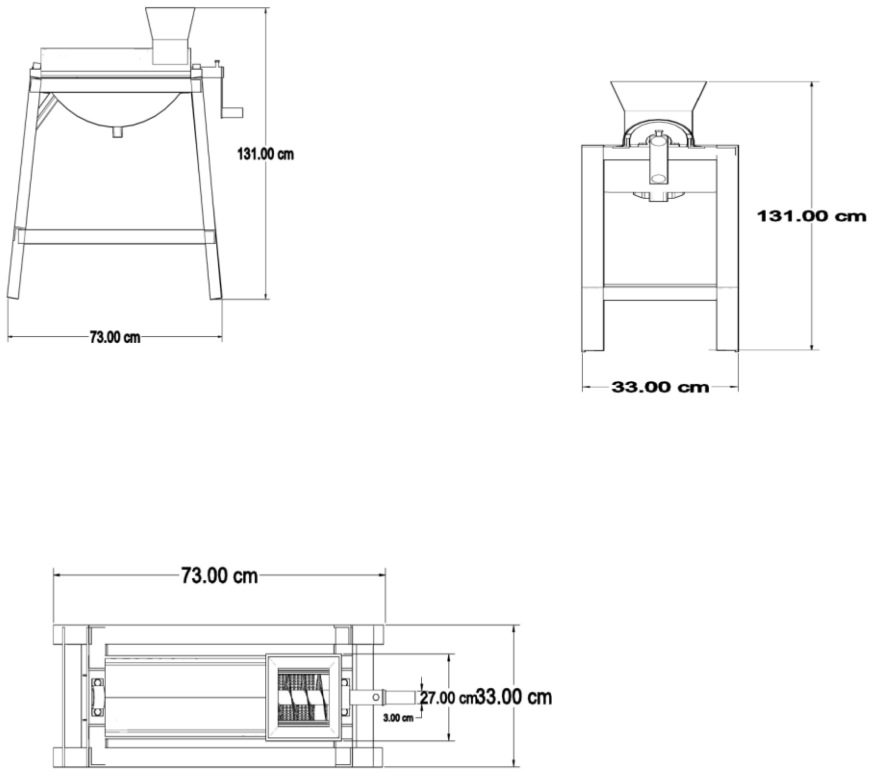


Plate 2: Screen of orange juice extractor



Appendix: Orthographic Projection of the Machine

SOME MECHANICAL PROPERTIES OF SUGARCANE AT DIFFERENT SIZES AND LOADINGS RELEVANT TO DESIGN AND CONSTRUCTION OF SUGARCANE JUICE EXTRACTOR.

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ABSTRACT
Sugarcane is an economically important grass that is rich in calcium, chromium, cobalt and other health supportive substances. The stress undergone by the teeth while chewing sugarcane to obtain the juice content in addition to the inherent postharvest losses has necessitated the study of its mechanical properties to enhance effective mechanization of its processing and handling. This study evaluated the mechanical properties of two varieties of sugarcane; Saccharum officinarum and Saccharum barberi. Some mechanical properties (rupture force, rupture energy, bio-yield force, bio-yield energy and deformation at horizontal and vertical loading direction) were investigated using a Universal testing machine. At sugarcane sizes (diameter) from 33-40, rupture force, rupture energy, bio-yield force, bio-yield energy and deformation are 2677 N, 11.15 N.m, 2828 N, 8.92 N.m and 7.32 mm respectively at vertical loading direction, and at horizontal loading direction rupture force, rupture energy, bio-yield force, bio-yield energy and deformation are 3157 N, 17.83 N.m, 3115 N, 11.43 N.m and 8.41 mm respectively for Saccharum officinarum. At sugarcane sizes (diameter) from 30-37, rupture force, rupture energy, bio-yield force, bio-yield energy and deformation are 2890 N, 29.68 N.m, 2991 N, 5.98 N.m and 10.35 mm respectively at vertical loading direction, and at horizontal loading direction rupture force, rupture energy, bio-yield force, bio-yield energy and deformation are 3510 N, 35.95 N.m, 4574 N, 15.49 N.m and 12.78 mm respectively for Saccharum barberi. The results will be useful in designing sugarcane harvester and sugarcane juice extractor.

Keywords**:** mechanical properties, sugarcane stalk diameter, sugarcane, juice extractor

INTRODUCTION
Sugarcane (*Saccharium spp*) is a tall grass with a stout jointed and fibrous stalk that looks similar to bamboo (McCaffrey, 2011). It belongs to perennial herbs of a genus of the grass family *Saccharium* and tribe *Andropogoneae* (Priya and Lakshmi, 2012). It is extensively cultivated in tropical and subtropical regions of the world for the sugar contained within its stems. Sugarcane is known as *Ireke* in Yoruba, *Okpete* in Igbo and *Reke* in Hausa languages, in Nigeria. It is rich in calcium, chromium, cobalt, copper, magnesium, manganese, phosphorous, potassium and zinc (Priya and Lakshmi, 2012). It also contains iron and vitamins A, C, B_1, B_2, B_3, B_5, and B_6, plus a high concentration of phytonutrients (including chlorophyll), antioxidants, proteins, soluble fiber and numerous other health supportive compounds (Priya and Lakshmi, 2012). Matured sugarcane stalk is found to be composed of 11-16% fiber, 12-16% soluble sugars, 2-3% non-sugars, and 63-73% water (McCaffrey, 2011).
The current estimated sugarcane production of the nation as at 2008 was put at over 1.4m tones (Aina *et al*., 2015). The varieties of sugarcane available in Nigeria and the world in general as of today as not been estimated, but Agidi (2002) and Nmadu *et al.* (2014) categorized the types of sugarcane in Nigeria into Industrial (*Saccharum officinarum*) and Local Chewing Sugarcane (*Saccharum barberi*).
In sub- Sahara African Countries, the suckle in sugarcane has been enjoyed by using teeth to bite off the rind and chewing off the internal tissues, then the juice is sucked in the mouth and the bagasse is spat out. This consumption method is considered to be grossly; unhealthy and uncivil aside the stress the teeth have to undergo (Makinde-Ojo, 2010). Hence mechanization of sugarcane processing is not only necessary to meet the need for fresh sugarcane juice but also for reducing the post-harvest loss in sugarcane. Hence, an engine powered sugarcane juice extractor is essential for small and medium scale farmers. Keeping the above factors in mind, some properties of sugarcane pertaining to the crushing of sugarcane and extraction of juice is conducted for the design of an engine powered sugarcane extractor. The design of the major units such as the crushing unit, engine motor selection, the separation unit is dependents on the properties.
A lot of researches have been reported on sugarcane such as physical properties of sugarcane (Bastian and Shridar, 2014a), characteristics of sugarcane fibres Asagekar and Joshi (2013). Quasi-static tests using a universal testing machine to determine shear, compressive resistance and bending resistance of forage crops Chattopadhyay and Pandey (1999). Investigation of the mechanical properties of sugarcane stalks viz; bending resistance, cutting resistance, penetration resistance and crushing resistance for the development of a whole cane combine harvester Bastian and Shridar (2014b). Based on the review of previous work on sugarcane, the variation in sizes of sugarcane from one internodes to another has not been considered to see their effect on the mechanical properties of sugarcane, its becomes

of interest to investigate if the variation in sizes will have effect on its mechanical properties. The specific objective of this study is to determine some mechanical properties of sugarcane namely rupture force, rupture energy, bio-yield force, bio-yield energy and deformation at rupture point over a range of some selected sugarcane size (diameter).

MATERIALS AND METHODS

Sample Preparation

Two sugarcane varieties used for this study were sourced from Oja Gboro in Ilorin, Kwara State, Nigeria. The two varieties are; *Saccharum officinarum* (Industrial) and *Saccharum barberi* (Local Chewing) sugarcane, which were peeled and unpeeled, and replicated three times, under vertical and horizontal loading direction. (Plate 1 and 2), this combined gives and experimental design of 2 × 2 × 2 × 3. They were cut into the same sizes of 10 cm (average size of a sugarcane node) with twelve (12) samples for each variety making a total of twenty four (24) samples for the analysis.

Plate 1: *Saccharum officinarum* (Industrial Sugarcane)

Plate 2: *Saccharum barberi (*Local Chewing Sugarcane)

Diameter of Sugarcane

The diameter of sugarcane varies from bottom to top and this variation depends upon the variety and the climatic condition which prevailed in the growth phase of the sugarcane (Bastian and Shridar, 2014a). Sugarcane diameter plays a significant role in the design of rollers used in sugarcane extractor and in the selection of the maximum and minimum clearance between the rollers**.** The diameters of the two varieties of sugarcane used in the compression test were carefully selected with the help of a vernier caliper with code number 532-120, 0-200 mm range and accuracy of ±0.03 mm and taken as minimum, mean and maximum in the range as shown in Table 1 for horizontal and vertical loading as reported by (Bastian and Shridar , 2014a ; Olawuyi, 2014).

Table 1: Some selected sugarcane diameter

Variety	min. dia. (mm)	mean dia. (mm)	max. dia. (mm)
Saccharum officinarum	33	36	40
Saccharum barberi	30	34	37

Mechanical properties

The compression tests were carried out using a Universal testing machine that is equipped with a 50 kg compression load cell and integrator with machine number 0500-10080. The measurement accuracy was 0.001 N and 0.001 mm in deformation (Ahmadi *et al.* 2012). The rupture force, rupture energy, bio-yield force, bio-yield energy and deformation at rupture point were determined from the vertical and horizontal loading position; at a loading speed of 5 mm/min (ASABE, 2004). An individual sample of the sugarcane was placed on the lower plate (Plate.3a and b) and the top section attached to the chuck moved downward with a constant speed until fracture occurred as it is denoted in the force – deformation curve (Plate 4). The loading is stopped once the fracture was detected. Three replicates were made for each loading.

Plate 3a: Compressive test for peeled sugarcane sample

Plate 3b: Compressive test for unpeeled sugarcane sample

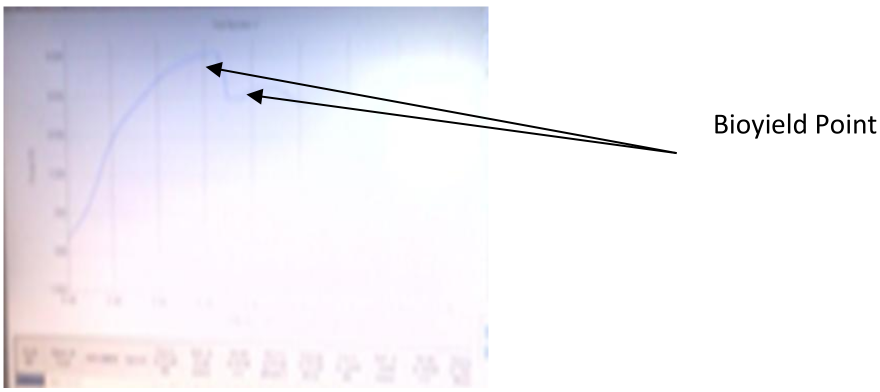

Plate 4: Force- deformation curve

Analysis of results

The data obtained were analysed using Analysis of Variance (ANOVA) and regression in Minitab 16.2.1 software (2010 Minitab Inc.) to determine the effects of different sizes (diameter) on the mechanical properties of industrial and local chewing sugarcane varieties.

RESULTS AND DISCUSSION

Results of the compressive tests conducted on the two sugarcane varieties are presented in Table 2 and 3.

Rupture Force:

The rupture force of the Industrial and local chewing sugarcane varieties at the two loading directions are presented in Fig. 1. The rupture force of *Saccharum officinarum* increases linearly from 2677 to 3157 N for vertical and non-linearly from 1073 to 1586 N for horizontal as the sugarcane size or diameter increases from 33 to 40 mm and so also the rupture force of the *Saccharum barberi* increases linearly from 2890 to 3510 N for vertical and quadratically from 573 to 1316 N for horizontal as the sugarcane size or diameter increases from 30 to 37 mm.

Table 2. Mechanical properties of sugarcane at vertical and horizontal loading directions

	vertical loading direction				horizontal loading direction		
Properties	unit	minimum	mean	maximum	minimum	mean	maximum
a. *Saccharum officinarum*							
Rupture Force	N	2677.00	2891.33	3157.00	1073.00	1360.33	1586.00
Rupture Energy	Nm	11.15	14.16	17.83	3.09	4.47	6.90
Bio-yield Force	N	2828.00	2992.00	3115.00	1609.00	1617.33	1630.00
Bio-yield Energy	Nm	8.92	10.49	11.43	1.73	2.26	2.56
Deformation	mm	7.32	7.71	8.41	3.28	4.71	6.45
b. : *Saccharum barberi*							
Rupture Force	N	2890.00	3235.00	3510.00	573.00	855.33	1316.00

Rupture Energy	Nm	29.68	33.64	35.95	1.41	2.74	4.83
Bio-yield Force	N	2991.00	3974.33	4574.00	898.00	1014.67	1203.00
Bio-yield Energy	Nm	5.98	11.94	15.49	0.89	1.16	1.29
Deformation	mm	10.35	11.43	12.78	3.19	3.91	4.96

Table 3. Mechanical properties of sugarcane at vertical and horizontal loading directions analysed by Duncan multiple range test (p≤0.05)

Properties	Min.	Mean	Max.
	Saccharium officinarum		
Vertical loading direction			
Rupture force (N)	2646.67 ± 16.12 ^{b}	2867.21 ± 23.45 ^{b}	3059.00 ± 49.33^{b}
Rupture energy (N.m)	11.13 ± 0.04 ^{a}	14.17 ± 0.10 ^{a}	16.88 ± 0.56 ^{a}
Bio-yield force (N)	2820.67 ± 3.71 ^{c}	2945.33 ± 26.29 ^{c}	3073.67 ± 34.57 ^{b}
Bio-yield energy (N.m)	8.71 ± 0.20 ^{a}	10.35 ± 0.07 ^{a}	11.27 ± 0.14 ^{a}
Deformation (mm)	7.21 ± 0.10 ^{a}	7.40 ± 0.21 ^{a}	8.34 ± 0.06 ^{a}
Horizontal loading direction			
Rupture force (N)	1045.00 ± 22.27 ^{b}	1211.11 ± 104.00 ^{b}	1478.66 ± 55.57 ^{b}
Rupture energy (N.m)	3.10 ± 0.06 ^{a}	4.18 ± 0.14 ^{a}	6.37 ± 0.27 ^{a}
Bio-yield force (N)	1597.33 ± 7.62 ^{c}	1548.11 ± 68.05 ^{c}	1527.00 ± 60.65 ^{b}
Bio-yield energy (N.m)	1.71 ± 0.01 ^{a}	2.12 ± 0.07 ^{a}	2.27 ± 0.15 ^{a}
Deformation (mm)	3.12 ± 0.08 ^{a}	4.40 ± 0.37 ^{a}	6.15 ± 0.15 ^{a}
	Saccharum barberi		
Vertical loading direction			
Rupture force (N)	2779.33 ± 57.33 ^{b}	3159.66 ± 64.17 ^{b}	3481 ± 23.25 ^{b}
Rupture energy (N.m)	27.50 ± 1.18 ^{a}	31.81 ± 0.93 ^{a}	35.29 ± 0.68 ^{a}
Bio-yield force (N)	2905.67 ± 45.83 ^{b}	3350.23 ± 30.04 ^{ab}	4498.00 ± 38.92 ^{c}
Bio-yield energy (N.m)	5.39 ± 0.29 ^{a}	11.33 ± 0.32 ^{a}	14.67 ± 0.46 ^{a}
Deformation (mm)	10.12 ± 0.13 ^{a}	11.17 ± 0.16 ^{a}	12.26 ± 0.26 ^{a}
Horizontal loading direction			
Rupture force (N)	563.00 ± 9.01 ^{b}	823.77 ± 16.15 ^{b}	1262 ± 32.07 ^{c}
Rupture energy (N.m)	1.23 ± 0.09 ^{a}	2.64 ± 0.05 ^{a}	4.71 ± 0.06 ^{a}
Bio-yield force (N)	887.34 ± 5.81 ^{c}	1005.52 ± 4.61 ^{c}	1141.67 ± 31.01 ^{b}
Bio-yield energy (N.m)	0.78 ± 0.05 ^{a}	1.1 ± 0.04 ^{a}	1.13 ± 0.08 ^{a}
Deformation (mm)	3.07 ± 0.06 ^{a}	3.81 ± 0.05 ^{a}	4.82 ± 0.09 ^{a}

a, b, c: Means superscript with different letters in the same row differ significantly

The force required to fracture the industrial sugarcane at vertical direction was significantly higher than for horizontal position (p≤0.05) at all experimental diameters for both sugarcane varieties. Similar results were reported by Dauda *et al.*(2014) on mechanical properties of kenaf stems at varying moisture content, Xue *et al.* (2015) on mechanical properties of cassava stalks and Eissa *et al.* (2008) on physical and mechanical characteristics for some agricultural residue such as cotton stalk, maize stalks and sugarcane bagasse which are reported for different directions. The relationship between the sample rupture forces with different diameters at vertical and horizontal loading directions for *Saccharum officinarum* and *Saccharum barberi* was significantly correlated (p≤0.05) and can be expressed using equations 1 to 4.

Saccharum officinarum

$R_f = 421 + 68.5D_i R^2 = 0.999$ (Vertical direction) (1)

$R_f = -1290 + 72.4D_i R^2 = 0.977$ (Horizontal direction) (2)

: *Saccharum barberi*

$R_f = 234 + 88.4D_i R^2 = 0.999$ (Vertical direction) (3)

$R_f = -2594 + 104D_i R^2 = 0.952$ (Horizontal direction) (4)

Where;

R_f is the rupture force (N) and
D_i is the diameter of sugarcane (mm).
Crushing and juice extraction is a subject of rupture force and the diameter of the sugarcane. Therefore for the design of a sugarcane juice extractor, the values of the rupture force will be needed for the selection of the pulley or sprocket so as to determine the required speed that will supply the force needed to extract the juice from the sugarcane.

Rupture Energy

The rupture energy of the Industrial and local chewing cane is shown in Fig. 2. Rupture energy was greater for *Saccharum barberi* than *Saccharum officinarum* at vertical loading but lower for *Saccharum barberi* than *Saccharum officinarum* at horizontal loading. The rupture energy increases for *Saccharum officinarum* from 11.15 to 17.83 N.m and *Saccharum barberi* from 29.68 to 35.95 N.m at vertical loading, so also increases at horizontal loading for *Saccharum officinarum* from 3.09 to 6.90 N.m and *Saccharum barberi* from 1.41 to 4.80 N.m. There is a clear difference in the rupture energy for both varieties as it is known that *Saccharum barberi* is harder and have smaller diameter than *Saccharum officinarum*. The results are similar to those reported by Sonde *et al.* (2015) on mechanical characteristics for cotton and pigeon pie as agricultural residue and Dauda *et al.*(2014) on mechanical properties of kenaf stems at varying moisture content but are not reported for different direction which is important to machine design. In vertical and horizontal direction of loading, rupture energy shows strong significant (P≤0.05) correlation to a size of sugarcane (diameter),
The relationship between rupture energy and size of sugarcane (diameter) at vertical and horizontal loading directions for *Saccharum officinarum* and *Saccharum barberi* are shown using the regression equations 5 to 8.

Saccharum officinarum
$R_e = -20.2 + 0.95 D_i R^2 = 0.999$ (Vertical direction) (5)
$R_e = -15.1 + 0.548 D_i R^2 = 0.994$ (Horizontal direction) (6)
Saccharum barberi
$R_e = 2.76 + 0.901 D_i R^2 = 0.995$ (Vertical direction) (7)
$R_e = -13.0 + 0.47 D_i R^2 = 0.958$ (Horizontal direction) (8)
Where;
R_e is the rupture energy (N.m) and
D_i is the diameter of sugarcane (mm).

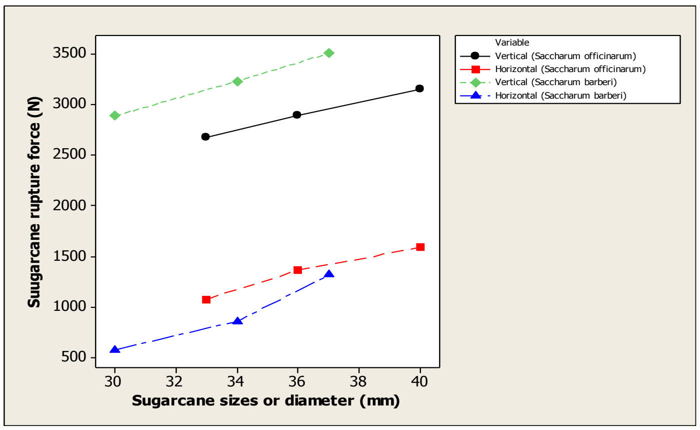

Figure 1: Effect of different sugarcane diameter on rupture force of *Saccharum officinarum* and *Saccharum barberi*

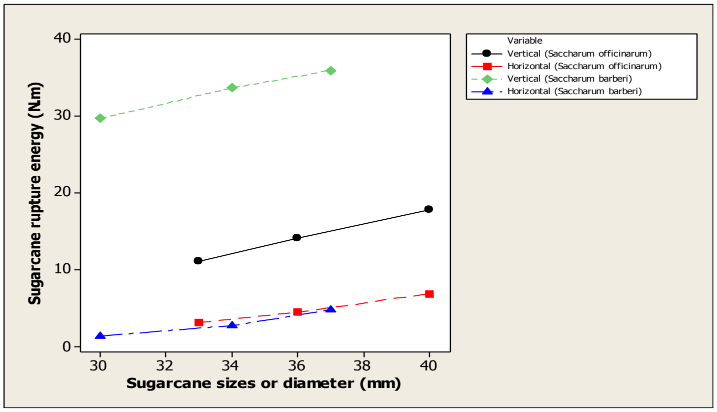

Figure 2: Effect of different sugarcane diameter on rupture energy of *Saccharum officinarum* and *Saccharum barberi*

Bio-yield force and energy

The bio-yield force and energy of the *Saccharum officinarum* and *Saccharum barberi* are shown in Figs. 3 and 4, respectively. The bio-yield force for *Saccharum officinarum* at vertical and horizontal loading increases from 2828 to 3115 N and 1609 to 1630 N, respectively at the sugarcane size of 33 to 40 mm while the *Saccharum officinarum* bio-yield force at both vertical and horizontal direction increases from 2991 to 4574 N and 898 to 1203 N, respectively at the sugarcane size of 30 to 37 mm. Similar findings were reported by Adigun and Alonge (2000) for bio-yield force of pods of *proposis Aficana* and Ekinci *et al.* (2010) on mechanical properties of Carob pod (*Ceratonia Siliqua L.*). Bio-yield force is greater than rupture force in all loading directions, and it is observed from the result that the bio-yield force for *Saccharum officinarum* is higher at horizontal direction than the *Saccharum barberi*, this may be due to the fact that *Saccharum barberi* generally are smaller in diameter and harder than *Saccharum officinarum*. At vertical and horizontal loading direction, the bio-yield energy for industrial and local chewing sugarcane increases linearly from 8.92 to 11.43 N.m, 1.72 to 2.56 N.m, 5.98 to 15.49 N.m and non-linearly from 0.89 to 1.29 N.m respectively. The relation between bio-yield force, bio-yield energy and the size of sugarcane (diameter) for *Saccharum officinarum* and *Saccharum barberi* under vertical and horizontal loading was significantly correlated ($p \leq 0.05$) and can be expressed using equations 9 to 16.

Saccharum officinarum

$B_f = 1509 + 40.4 D_i R^2 = 0.973$ (Vertical direction) (9)

$B_e = -2.51 + 0.352 D_i R^2 = 0.950$ (Vertical direction) (10)

$B_f = 1509 + 3.01 D_i R^2 = 0.999$ (Horizontal direction) (11)

$B_e = -2.09 + 0.118 D_i R^2 = 0.941$ (Horizontal direction) (12)

Saccharum barberi

$B_f = -3803 + 227 D_i R^2 = 0.997$ (Vertical direction) (13)

$B_f = -402 + 42.8 D_i R^2 = 0.954$ (Vertical direction) (14)

$B_e = -34.8 + 1.37 D_i R^2 = 0.996$ (Horizontal direction) (15)

$B_e = -0.829 + 0.0577 D_i R^2 = 0.986$ (Horizontal direction) (16)

Where;

B_f is the bio-yield force (N),

B_e is the bio-yield energy (N.m),

D_i is the diameter of sugarcane (mm).

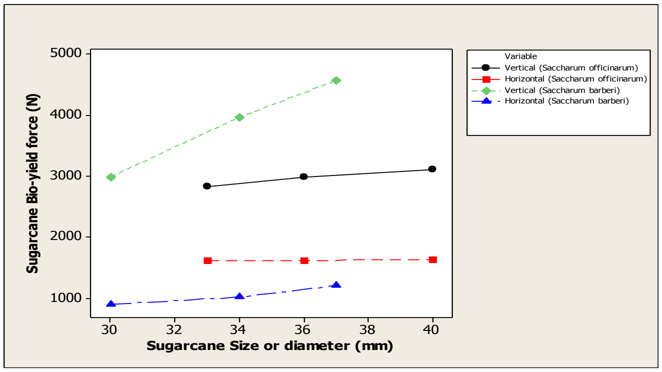

Figure 3: Effect of different sugarcane diameter on bio-yield force of *Saccharum officinaru* and *Saccharum barberi*

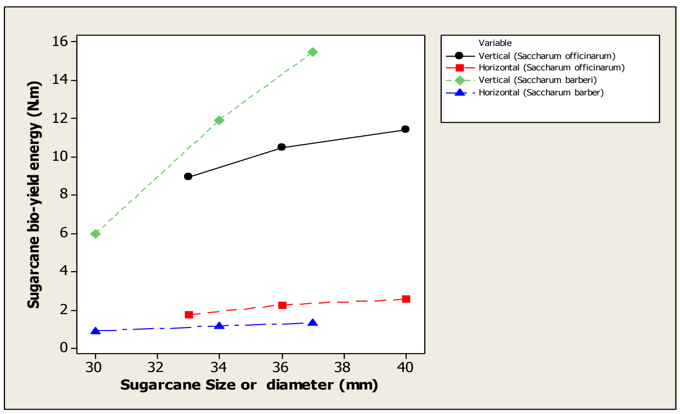

Figure 4: Effect of different sugarcane size or diameter on bio-yield energy of *Saccharum officinarum* and *Saccharum barberi*

Deformation at rupture point:

The deformation at rupture point is presented in Fig 5 for both Industrial and Local chewing sugarcane at vertical and horizontal loading direction. The deformation for *Saccharum officinarum* increases from 7.32 to 8.41 mm in vertical loading direction and 3.28 to 6.45 mm in horizontal loading direction, while for *Saccharum barberi* increases from 10.35 to 12.78 mm in vertical loading direction and 3.19 to 4.96 mm in horizontal loading direction. It was observed that the deformation is higher for *Saccharum barberi* in vertical loading direction than for industrial sugarcane and vice versa in horizontal loading direction. Similar findings were reported by Adedipe *et al.* (2013) on some mechanical properties of agbaraba-a native Nigeria bamboo but were not reported for different direction.

The relationship between deformation and different sizes of sugarcane (diameter) at vertical and horizontal loading for *Saccharum officinarum* and *Saccharum barberi* was significantly correlated (p≤0.05) and can be expressed respectively using the equation 17 to 20.

Saccharum officinarum

$D_{rp} = 2.12 + 0.157D_i R^2 = 0.994$ (Vertical direction) (17)

$D_{rp} = -11.6 + 0.452D_i R^2 = 0.999$ (Horizontal direction) (18)

Saccharum barberi

$D_{rp} = -0.03 + 0.343D_i R^2 = 0.979$ (Vertical direction) (19)

$D_{rp} = -4.36 + 0.249D_i R^2 = 0.965$ (Horizontal direction) (20)

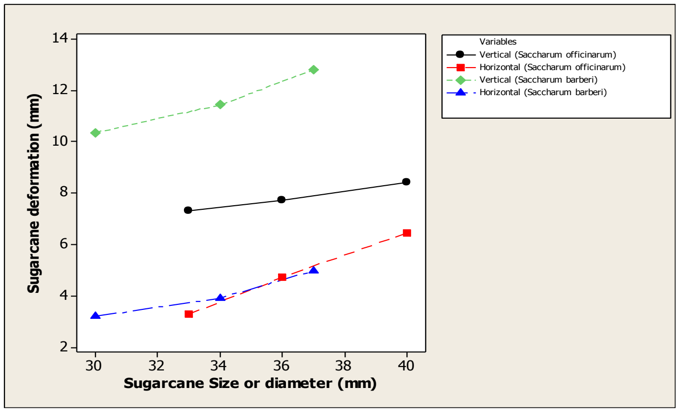

Figure 5: Effect of different sugarcane size or diameter on deformation of *Saccharum officinarum* and *Saccharum barberi*

CONCLUSION

Some of the mechanical properties required for the design and fabrication of sugarcane juice extractor have been determined (the rupture force and energy, bio-yield force and energy, and deformation). The mechanical properties are function of the sugarcane size, an adjustable mechanism will be necessary in the construction of a sugarcane extractor to accommodate different sizes of sugarcane. Data obtained will be useful in the design of sugarcane crusher, juice extractor and other sugarcane processing machine.

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PERFORMANCE EVALUATION OF AN IMPROVED FISH SMOKING KILN

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ABSTRACT

Development of appropriate fishing machinery and techniques that employed effective production, handling, harvesting, processing and storage, cannot be over emphasized in Nigeria. It is on this basis that this paper evaluated the performance of an improved smoking kiln for increased income and improved hygienic fish consumption. Catfish and tilapia fish were used for the study with charcoal as fuel source and working temperatures between 60^0C – 110^0C. It was revealed that there was a gradual drop in weight for both catfish and tilapia fish from 18.7 kg to 15.8 kg and 3.9 kg to 3.6 kg within 2 hours and 58 minutes of smoking respectively. The average thermal efficiency is 11.28%. The nutritional content and the hygiene level of the fish smoked with the improved smoking kiln as reported by the selected tasters were better and attractive than that from the traditional kiln.

Keywords: Smoking kiln, temperature, fuel, thermal efficiency

INTRODUCTION

Fish is one of the most important foods in the world. Its flesh is a source of quality protein for many in less developed countries of the world, producing a significant proportion of animal protein in their diet, either as fresh fish or processed in a variety of ways. Fish can also be a renewable natural resources provided seas, lakes, rivers, reservoirs, lagoons are not over-exploited and fish harvesting are regulated. Harvesting, handling, processing and distribution of fish provide millions of people a livelihood as well as foreign exchange earning to many countries (Al-Jufaili and Opara, 2006). Fish is a perishable agricultural commodity that deteriorates immediately when harvested, resulting in spoilage. Spoilage occurs as a result of the action of enzymes (autolysis) and bacteria and also chemical oxidation of the fat causing rancidity. Prevalence of high temperatures in tropical countries like Nigeria, bacterial and enzymes actions are enhanced. Fish invariably become putrid within a few hours of capture unless they are preserved or processed in some way to reduce this microbial and autolysis activity and hence, retard spoilage. Appropriate processing of fish enables maximal use of raw material and production of value added products, obviously the basis of processing profitability (Ito, 2005; Davies and Davies, 2009).

Fish processing like other crops are expected to assure best market quality, provide a proper form of semi-processed final product, assure health safety of products, apply the most appropriate processing method and reduce wastes to the barest minimum. Akinneye *et al.,* (2007) and Davies and Davies (2009) reported that the development of appropriate fishing machinery and techniques that employed effective production, handling, harvesting, processing and storage, cannot be over emphasized especially when aqua cultural development is fast gathering momentum in Nigeria. The use of appropriate fish processing technology could be an approach to stem up production and processing technique. The need to mechanize fish processing techniques should be an advocacy by National Agricultural Research Institutes to devote utmost interest and resources to Agricultural Engineering Research in operation, to minimize the drudgery, reduce labour operations, and unsanitary and inherent unhygienic handling mostly encountered in the traditional manual operations of fish processing. The objective of this study is to evaluate the performance of an improved smoking kiln for improved income and hygienic fish consumption.

Scarcity of fish is often encountered during flood and rainy seasons, it is imperative at this period to preserve and process harvested fish during glut period. This reduces post-harvest losses, increase shelf life and guarantee sustainable fish supply all year round with concomitant increase in the profit of fisher-folks (Davies and Davies, 2009).In order to reduce scarcity resulting from post-harvest losses and to improve the quality of fish and fishery products, traditional processing technology must be improved upon in Nigeria. This includes upgrading the traditional fish processing technology and adoption of artificial dryers. Most of the modern drying technologies available are expensive and not appropriate for a developing country like Nigeria, particularly in the areas where prerequisites for these technologies, such as electricity are simply not available adequately.

Adamu *et al.,* (2013) designed and constructed a fish smoking kiln. The kiln has a metal frame and angle iron. Handle that controls the ventilation speed using chain and sprocket. Charcoal housing made of perforated metal sheet that allow for proper ventilation. The kiln is operated manually by turning the handle which drives the fan to augment natural ventilation. The machine performance was evaluated using fish samples (African mud Fish) smoked to an average moisture content of 11.46% within an average time span of 5 h, and the average final weight of the dried fish was0.9827 Kg. It was found that the fish can be kept for at least two months before showing the sign ofspoilage. Also, Ashaolu (2014) designed and fabricated a smoking kiln with locally available materials. The smoking process adopts a natural convection of heated air with temperature ranging between 60^0C and 110^0C.The fish smoking kiln has a dimension of 1600 x 1220 x750mm and uses charcoal as the main source of energy. The average capacity of the smoking chamber is 120kg. He conducted a performance test to ascertain the kiln performance. Result showed that moisture content was reduced from 80% to 30% with an average smoking time of 60mins. He concluded in his study that fishes smoked by the kiln have a longer shelf life during storage when compared with traditional (drum) method, due to hot smoking temperature that reduces moisture faster. The overall average percentage weight loss obtained for three species tested were *Etholmosa Fimbriata* (36%, *Scombridae mackerel* (37%) and *Clarias gariepinus* (cat fish) 45%.

MATERIALS AND METHOD

A fish smoking kiln was developed and tested using local available materials accessible to fisher folks. The kiln developed was a very simple and easy to use device that does not require electricity or sophisticated mechanical appliances for heat generation and distribution. Rather, heat distribution is by natural convection through vents. It is squared shape with dimensions of 675 mm X 550 mm X 925 mm using mild steel metal. The major components of the kiln are chimney, smoking compartment, randomly perforated smoking tray, heating compartment, and charcoal pot as presented in plate 1. The volume of each tray was developed to be 9,680 cm and the volume of smoking and heating compartment are 146,191.5 cm^3 and 103, 163.5 cm^3 respectively. The volume of both the smoking and heating compartment were used to determine the capacity and efficiencies of the smoking kiln.

Design Expression

The volume

The volume of the smoking kiln was calculated using the formular

$$\text{Volume } (m^3) = L \times B \times H \;\ldots\ldots\ldots\ldots\ldots\ldots\; (1)$$

The Kiln Temperature

The inside kiln temperature was approximated using the expression

$$Q + W = \Delta E \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

But no work is added to the air inside the kiln

$$\Delta E = Q \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Air in the kiln smoking chamber = volume of kiln as calculated in equation (1)

$$m = Vx\rho_a \text{.........................}(4)$$

$$\Delta E = mC_p \Delta T \text{..................}(5)$$

$$\Delta T = \frac{\Delta E}{m.C_p} \text{....................}(6)$$

Where:

Q = Heat absorbed (J)

W = Work (J)

ΔE = Internal energy (kcal/min)

ΔT = Temperature change (^{0}C)

C_p = Heat capacity (kcal/^{0}C)

m = Air mass (kg)

Plate 1: Pictorial view of the developed smoking kiln

Performance Evaluation

This study focuses on evaluating the performance of the smoking kiln considering parameters and factors like fish species, initial and final weight of fish, duration of smoking, duration of heat applied, smoking and heating compartment temperatures, quantity of charcoal used. Two species of fish commonly found in the locality were used in evaluating the performance of the smoking kiln, they are catfish (*Clarias gariepinus*) and tilapia fish (*Oreochromisniloticus*). The two species were purchased from Unity fish market in Ilorin, Kwara State.

Preliminary preparation

The samples of fish purchased were killed and properly washed with salt. The catfish was carefully folded and left for about 15 minutes to allow it drip. As the fish drips, the kiln was ignited with a known weight of charcoal for the air within the kiln to be heated up and circulated through natural convection. The thermometer was positioned in the kiln to monitor the kiln temperature until it reaches about 60^{0}C, then the fish were weighed using a sensitive digital weighing scale and arranged on the tray in the kiln. The working temperature for the performance evaluation by intermittent observations ranges between 60^{0}C and 110^{0}C as studied from literatures.

Test Methodology

The catfish was weighed and arranged in the smoking kiln. Subsequently, the weight were measured and recorded often until a uniform weight was achieved on both trays. The catfish were turned each time the weight is taken and the temperature monitored by adding more charcoal to the coal pot used as the need arises. After about 2 ½ hours of this process, the catfish was satisfied to be okay based on the uniform weight achieved and the colour before it was discharged from the kiln. The same procedure was repeated for the tilapia fish for about an hour. The discharged fish was allowed to cool and the final weight taken and recorded. A subjective organoleptic test was conducted on the smoked fish by people living on protein (diabetic patients). Their oral reports about the fish from the improved smoking kiln were noted. Other results obtained were recorded and presented in tables 1 and 2.

RESULTS

Table 1: Results of smoked Catfish (*Clarias gariepinus*)

Replicates	**Initial Weight (kg)**	**Final Weight (kg)**	**Smoking time (hrs.)**	**Moisture Content (%)**	**Quantity of charcoal used (kg)**
1	18.7	16.3	2.35	12.8	1.3
2	17.9	15.8	2.15	11.7	1.1
3	18.3	15.9	2.10	13.1	0.9
Mean	**18.3**	**16.0**	**2.20**	**12.5**	**1.1**

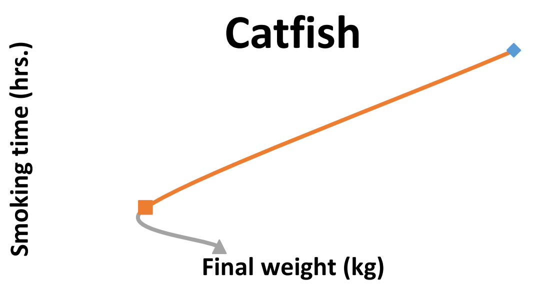

Figure 1: Graph showing the relationship between final weight and smoking time for catfish

Table 2: results of smoked Tilapia fish (*Oreochromisniloticus*)

Replicates	Initial Weight (kg)	Final Weight (kg)	Smoking time (hrs.)	Moisture Content (%)	Quantity of charcoal used (kg)
1	4.2	3.8	0.58	9.5	0.9
2	3.9	3.5	0.49	10.3	0.8
3	3.7	3.4	0.45	8.1	0.8
Mean	3.9	3.6	0.51	9.3	0.83

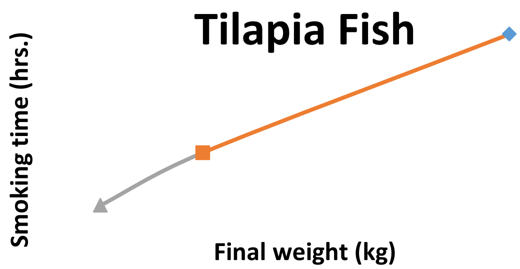

Figure 2: Graph showing the relationship between final weight and smoking time for tilapia fish

The results obtained from the performance evaluation were used to compute the thermal efficiency, and kiln capacity. Literatures revealed that thermal efficiency is highly relevant in smoking. Thermal efficiency relates the heat utilized to the sensible heat, either supplied by fuel or by nature. The mathematical expression used in determining this parameters was that stated by Ojha and Micheal (2005) as presented in the equation 7.

$$Thermal\ Effeciency = \frac{Heat\ utilized\ (water\ removed)}{Heat\ \sup pplied\ (fuel\ used)} ....(7)$$

$$TE_{tilapia} = \frac{9.3}{0.83} = 11.2\%$$

$$TE_{catfish} = \frac{12.1}{1.1} = 11.36\%$$

DISCUSSION

Results as presented in Table 1 showed that catfish had a steady decline in weight from 18.7 kg to 15.9 kg within the duration of 2 hours 20 minutes used to smoke it at steady heat supply with an average fuel consumption of 1.1 kg through natural convection. This is clearly presented in figure 1 with the gentle steep of the graph from 16.4 kg to 15.8 kg of the final weight. This is in conformity with the studies of Adamu *et al.,* (2013) and Ashaolu (2014). Table 2 and Figure 2 presents the results evaluated for tilapia fish indicating an average drop in weight from 3.9 kg to 3.6 kg within the 51 minutes of smoking. The average moisture content and fuel used were 9.3 % and 0.83 kg respectively .It was also confirmed in this study as stated by Adamu *et al.,* (2013) that the smoking duration is a function of fish weight, fat content, heat intensity and uniform distribution of heat. The thermal efficiency of smoking both catfish and tilapia fish was calculated to be 11.2% and 11.36% respectively, an indication of prudent utilization of fuel. The prudent fuel utilization reflected in the smoked fishes from the clear golden colour and the taste as reported by the tasters. The tasters certified that the smoked fish using the developed smoking kiln retains high protein, firm texture and flavor resulting from uniform heat distribution into the fish and the fuel management during smoking.

CONCLUSION

The performance evaluation conducted on the developed fish smoking kiln revealed that for the both fish (catfish and tilapia) the tastes, colour and time incurred in smoking the fish are much more economical, less strenuous, time saving and hygienic product when compared to the traditional smoking method. The fuel utilized in terms of thermal efficiency is 11.28% at a charcoal cost of about ₦350 to smoke 18 kg of fish within 2 hours. More so, the cost of required capital in terms of fabrication, fish to be smoked and fuel are all affordable and materials required are as well available. The nutritional content and the hygiene level of the fish smoked with the improved smoking kiln were better and attractive than that from the traditional kiln. It is hereby recommended that, fish smoking using traditional kiln be faced out and use of modern smoking kiln be encouraged through extension dissemination of such available technologies.

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DEVELOPMENT AND TESTING OF AN OIL EXTRACTION UNIT POWERED BY UNIVERSAL TESTING MACHINE

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ABSTRACT
The compression of oil seeds by agricultural equipment has become a matter of increasing concern due to drudgery and unavailability of equipment required for expressing oil. This research considered the extraction of oil from loofah seeds in order to optimize the numerous economic importance of loofah seed oil. The extractor comprise of the pressure rod made from 100 mm diameter mild steel having a height of 200 mm to accommodate the applied force from the Universal Testing Machine (UTM), a pressure plate made from mild steel flange having a thickness of 8 mm and a circular diameter of 240 mm joined to the pressure rod in order to distribute the lateral force received from the UTM to a circular force that is exerted on the loofah paste. A 3 mm mild steel plate was drilled and folded into a cylinder where the loofah paste is positioned to receive the pressure from the pressure plate allowing the oil to be expelled into an outer drum (aluminium pot) having a dimension of 230 mm high and 400 mm diameter where the oil is deposited and collected after expression without contaminating the expressed oil. Results revealed that the maximum oil expressed was at a roasting temperature of 60 ^{0}C and a roasting time of 60 minutes at an applied force of 115 kN having a corresponding pressing time of 3 minutes 30 seconds expressing a quantity of oil amounting to 37.3 ml. Moreover, at the same roasting temperature of 60 ^{0}C; the oil expressed at roasting time of 15 minutes and 30 minutes were found to be 30.3 ml and 33.3 ml within 4 minutes having a corresponding applied force of 118.7 kN and 118.0 kN respectively.

Keywords: *Loofah seed, compression*

INTRODUCTION

The loofah (*Luffacylindricais*) species are tropical and sub-tropical annual vines comprising the genus Luffa. Loofah belongs to the family called *Cucurbitaceae. L. acutangula* (Angled luffa, Ridged Luffa), L. aegyptiaca (Smooth luffa, Egyptian luffa), L. operculata (Sponge cucumber), are some species. It is commonly called "nenwa".Loofah requires warm summer temperatures and long lost-free growing season when grown in temperate regions. It is an annual climbing crop which produces fruit containing fibrous vascular system. It has a long history of cultivation in the tropical countries of Asia and Africa (Oboh and Aluyor*,* 2009). Loofah monoecious and the inflorescence of the male flower is a raceme and one female flower exists. Its fruit, a gourd, is green and has a large cylinder-like shape. The outside of the fruit has vertical lines and a reticulate develops inside of the flesh. It grows about 12 cm long. The stem is green and pentagonal and grows climbing other physical solid. Loofah plant is cultivated in many countries, including Brazil, china, Korea, India, Japan and Central America where its cultivation has an increasing economic importance; the main commercial production countries are China, Korea, India, Japan and Central America (Mazaliand Alves, 2005; Oboh and Aluyor*,* 2009; Bal *et al.,* 2004).

Loofah plant has numerous economic importance, few among them are its medicinal use, commercial use of its by product in manufacturing household utensils, consumption of fleshy fruit as vegetable in daily food and its contribution to the welfare of people. The Plant is a bitter tonic, emetic, diuretic and purgative useful in asthma, skin diseases and splenic enlargement. It is used internally for rheumatism, backache, internal hemorrhage, chest pains as well as hemorrhoids. The dried fruit fibers are used as abrasive sponges in skin care, kernel of seeds is expectorant used in dysentery. The seeds can be roasted as a snack or pressed to produce oil used externally for shingles, boils, leprosy and other skin diseases.

In order to maximally utilize the above essential composition of the plant, the oil has to be extracted. Extraction of oil from various oil bearing seeds has been a tiring and time consuming task with lots of drudgery. Such constraints can be alleviated through mechanical extraction of oil especially in loofah seeds. Therefore, this research paper is aimed at developing an oil extraction unit powered by a universal testing machine in order to optimize the numerous economic importance of loofah seed oil.

Oil is extracted from a number of fruits, nuts and seeds for use in cooking and soap making or as an ingredient in other foods such as baked or fried goods. Oil is a valuable product with universal demand, and the possible income from oil extraction is therefore often enough to justify the relatively high cost of setting up and running a small scale oil milling business. The compression of oil seeds by agricultural equipment has become matter of increasing concern because for each crop there is an optimum level of pressure for maximum yield. Oil seeds are most of the time subjected to compressive loads in order to express oil from them. These forces tend to either increase or decrease the quantum of oil expressed (Williams and Haq, 2002). Uziak and Loukanov (2007) evaluated the performance of some commonly used ram press machines such as BP-35, BP-30 and FI-32, to establish their suitability for small rural oil expression technology from locally grown sunflower. The machines were tested using three varieties of sunflower seeds and their outputs obtained by conducting a high production and high expression tests. In terms of the speed of oil production the BP-35 performed better than other machines.

Ajao *et al*., (2010) designed and developed an expelling machine for extracting oil from groundnut seeds. The machine has a speed reduction gear, expellant unit having a screw expellant shaft with expellant barrel, drains collector, driving and driven pulleys, and the hopper. The groundnut seeds were pre-heated by roasting before extraction of the oil and gave a better performance at a speed of 60 revolutions per minute. Olaniyan (2010) investigated the effects of some process conditions (nature of bean, heating temperature and pressing time) on the yield and quality of oil mechanically expressed from castor bean using a piston-cylinder rig in association with California bearing ratio universal testing Machine (CBR-UTM). Castor beans were shelled, cleaned, crushed and heated in an oven at temperatures 30, 60 and 90 °C for 30 minutes respectively before the oil was mechanically expressed for 8, 10 and 12 minutes with each trial replicated thrice. The oil expressed was collected and the oil yield was estimated as a percentage of the raw sample before expression. This showed that seed condition, heating temperature and pressing time and their combinations had influence on oil yield, extraction efficiency and extraction pressure during the oil expression process.

Moreover, Ozumba *et al.,* (2010) designed and constructed a compressive force measuring system for oil seeds in order to device strategies in determining the effects of such forces on the target materials. The device was designed in such a way that it has high reliability, accuracy, repeatability and reasonable sensitivity suitable for measuring both dead load and slow varying force ranging from 0-100 kN. The oil yield obtained by expressing oil from Palm Kernel seed under various compressive forces measured using the device and the UTM respectively; shows that there was no significant difference between the values obtained from each of the machines at 5% confidence level using T-test. Thus, it then implies that the designed device compares favourably with any compressive force-measuring machine\device. An evaluation of the combined groundnut roaster and oil extractor was performed by Ajav and Olatunde (2011) to establish the influence of moisture content, heating time and heating temperature on percentage oil yield and to achieve the optimal moisture content, heating time and heating temperature for oil yield. Three moisture content levels (6, 7 and 8 % wet basis) and heating duration (10, 20 and 25 minutes) were used for evaluating four temperature settings 70, 80, 90 and 100 ^{0}C. The highest percentage oil yield 41.6, 31.3 and 25.5 % at 6, 7 and 8 % moisture content wet basis respectively were all observed at 100 ^{0}C. The best moisture content, heating duration and heating temperature were 6 % wet basis, 25 minutes and 100 ºC respectively.

MATERIALS AND METHODS

Design Considerations

The materials considered for the development of this machine were durable and highly efficient, carefully selected by taking into account the properties and qualities of available materials in the market. The criteria considered in materials selection were; strength, durability, ease of transportation, shape, vibration, rigidity and rheological properties of the oil bearing seed.

Design Analysis and Expression

The diagram of the extractor is shown in figure 1. The downward pointing arrows indicate the direction of the applied force from the Universal Testing Machine (UTM). The cylinder (pressure rod) receives the point force before distributing it to the pressure plate beneath the cylinder.

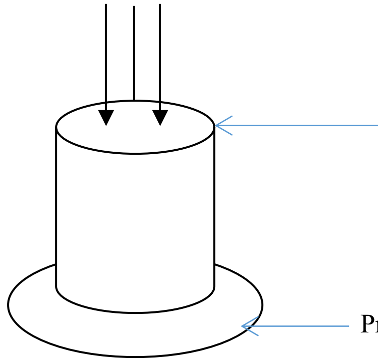

Fig. 1: Elemental part of the extracting unit

Khurmi and Gupta (2005), described a resilience unit as the energy absorbed in a body when strained within elastic limit, the resilience per unit volume of a material is termed modulus of resilience, expressed mathematically as:

$$U = \frac{\sigma^2 x V}{2E} \text{...(1)}$$

$$Modulus\ of\ Resilence = \frac{\sigma^2}{2E} \text{.............................(2)}$$

Where:

σ = Tensile or compressive stress

V = Volume of the body and

E = Young's modulus of the material

The cylinder that receives the pressure in terms of force from the above unit is designed considering the volume using the expression:

$$V = \pi r^2 h \text{...(3)}$$

Where:

r = Radius of surface area (m),

h = Height of the cylinder (m) and

V = Volume of the cylinder (m^3)

Description of the Machine

The extractor fabricated comprise of the pressure rod made from 100 mm diameter mild steel having a height of 200 mm that will accommodate the applied force from the Universal Testing Machine (UTM)**,** a pressure plate made from mild steel flange having a thickness of 8 mm and a circular diameter of 240 mm that is joined to the pressure rod in order to distribute the lateral force received from the UTM to a circular force that is exerted on the loofah paste. A 3 mm mild steel plate was drilled and folded into a cylinder where the loofah paste is positioned to receive the pressure from the pressure plate allowing the oil to be expelled into an outer drum (aluminium pot) having a dimension of 230 mm high and 400 mm diameters shown in plate 1. The oil expressed is deposited in the outer drum without contamination.

Plate 1**:** Pictorial view of the experimental set up before the oil expression process

Operating Principle of the Machine

The milled loofah paste that has been poured in a fine sack is gently placed in the inner drum. The inner drum with the sacked paste are then placed in the outer drum which is then positioned
on the Universal Testing Machine (UTM). The circular pressure plate and pressure rod are then centrally positioned on the sack having the loofah paste in it. Pressure was then applied from the UTM through both the pressure rod and pressure plate to the loofah paste and the oil is then extracted into the outer drum which is then collected and weighed.

Test procedure

The loofah plant was collected from uncompleted buildings around Ilorin metropolis. The seeds were removed from their pod, sorted and cleaned and then dried to a moisture content of 16 % using oven dry method. The dried seeds were weighed with a digital weighing scale as presented in plate 2 to measure out the uniform quantity required for extraction. The seeds were then roasted at temperatures of 30 ^{0}C, 60 ^{0}C and 90 ^{0}Cin an oven. The roasting time considered for this experiment was 15, 30 and 90 minutes for each temperature treatment. The roasting temperatures and roasting time were both obtained from literatures for effective oil extraction and high oil yield. Thereafter, the roasted loofah seed was milled and poured in a fine sack and placed in the set up presented in plate 1. Pressures between 105 – 150 kN was applied to the roasted seeds in the sack from the UTM. Results obtained are presented.

Plate 2**:** Weighing the cleaned loofah seeds

RESULTS AND DISCUSSION

The results obtained from the experimental tests are presented in table 1.

Table 1: Summary of result of seed roasted at different temperatures and time

Temperature (^{0}C)	Roasting Time (mins.)	Applied Force (kN)	Expression Time (mins.)	Oil Yield (ml.)
30	15	149.7	4.7	18
	30	139.7	4.2	27
	60	140.7	4.12	26

60	15	118.7	3.55	30.3
	30	118.0	3.57	33.3
	60	115.0	3.30	37.2
90	15	108.7	3.19	41.3
	30	108.7	3.30	36.3
	60	109.3	3.20	35.3

Results from table 1 showed that seeds roasted at 30 ^{0}C for 30 minutes at applied force of 139 kN produces an oil yield of 27 ml, while the oil yield at roasting time 15 minutes and 60 minutes were 18 and 26 ml at an applied force of 149.7 and 140.7 kN respectively. Moreover, seeds roasted at 60 ^{0}C, has a maximum oil yield of 37.3 ml at an applied force of 115 kN within 3 minutes 30 seconds. This was as a result of roasting temperature that creates sufficient crack on the loofah seeds, allowing the oil to be rapidly expelled from the seeds. This was corroborated with the findings of Gikuru and Lamech (2007). At the same roasting temperature; the roasting time of 15 and 30 minutes a corresponding force applied of 118.7 kN and 118 kN produces an oil yield of 30.3 and 33.3 ml within 3 and 6 minutes respectively. The average result of seed roasted at 90 ^{0}C are presented in table 1, reveals that though the roasting temperature was appropriate for extraction at all the roasting time; the best performance at this temperature was at 15 minutes roasting time at an applied force of 108.7 kN having an oil yield of 41.3 ml. Study of Arisanu (2013) confirms this claims.

CONCLUSION

Oil expression from loofah seed was found to be tedious despite the varying roasting temperatures and time, Results revealed that maximum oil expressed was at a roasting temperature and time of 60 ^{0}C and 60 minutes respectively at an applied force of 115 kN. At pressing time of 3 minutes 30 seconds, quantity of oil expressed was 37.3 ml. At the same roasting temperature of 60 ^{0}C; the oil expressed at roasting time of 15 minutes and 30 minutes was found to be 30.3 and 33.3 ml respectively within 4 minutes at a corresponding applied force of 118.7 kN and 118.0 kN respectively. Though the oil expressed at roasting temperature 90 ^{0}C was higher than that at 60 ^{0}C but the oil was dark due to the fact that the seed has been over roasted and almost got burnt, the oil expressed was dark.

Oil expression from loofah seed using mechanical method was found to be ineffective. The quantity of oil expressed using this method was very small; hence, this study recommends the use of solvent method of extraction and seed treatments at varying moisture contents. This may improve the quantity of oil expressed from loofah seed.

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MODELLING AND OPTIMIZATION OF THE WEEDING EFFICIENCY OF DEVELOPED POWER WEEDER

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ABSTRACT

Manual weeding is very slow and energy demanding, and are usually inadequate at peak periods of demand. Chemical weeding is very effective but very environmentally unfriendly. Mechanical weed control is proving to be more effective and equally environmental friendly. Many researchers have made attempts to design, construct and test some of the constructed weeding machines majorly on flat lands, some existing machines lack facility for varying machine dependent variables. Modelling, maximization and or minimization of some of the performance parameters of weeding machines with respect to some of the machine dependent variables are limited. A 7Hp power Weeder measuring 160 cm x 70 cm x 85 cm was designed, constructed and evaluated on a sandy loam soil in Samaru, Zaria, Nigeria. The weeding operations were replicated three times on plots measuring 4m x 5m each at three weeding speeds S1=100rpm, S2=200rpm and S3= 300rpm three weeding depths, depths D1 = 1cm, D2= 2cm, D3 = 3 cm and with two sets of blades numbers B1=10 bladse, B2=20 blades. The weedings were done two weeks after sowing (2WAS), four weeks after sowing (4WAS) and six weeks after sowing (6WAS). Results indicated that weedings done 2WAS had higher efficiencies than those done 4WAS and 6WAS. The observed field values from the effect of the machine variables were then statically analyzed. Furthermore three variables Lagrange polynomials with inequality constraints were used to model the observed field weeding efficiencies, the developed second order Lagrange polynomials were then used to determine optimal weeding efficiencies using Maple version 14 (a modeling and optimization software).

INTRODUCTION

Weeding is one of the most important labour consuming operation on the farm (Jagvir and Intikhab, 2008); Oni (1990) reported that weeding accounts for about 80% of the total labour required for food production in Nigeria, Rangasamy et al. (1993), reported that weeding requires 560 man hr/ha of a total of 1536 man hr/ha required for the cultivation of a crop. Weed control is usually expensive but a necessary part of agricultural production. If not properly done, weeds can reduce crop production and increase the cost of agricultural production. Weeds compete with the growing crops for space, water, light, nutrients. In addition they harbour insects, pests, diseases, fungus and very importantly, they also affect the micro-climate around the growing plants (Behara et al., 1996., Isiaka, 2005., Okafor and De Detta, 1976., Islam and Haq, 1991., Manuwa et al., 2009). Weeding can be done in many ways, depending on the size of the farm, the soil condition, type of weed, crops planted, time of weeding and the availability of labour. Weediing can be done manually, chemically, biologically or organically and Mechanically. Manual weeding is labour intensive, slow, low effective work capacity, low output and usually suffers acute labour shortages in the peak season which further delays the weeding of farm lands (Biswas et al., 2000 and Jagvir and Intikhab 2008). chemical weeding using herbicides have indicated worrisome results during environmental impact assessments (Ewaoda, 2010) and by Olawale and Oguntude (2006)., Manuwa et al., (2009), they are not environmentally friendly, are toxic, promote desert encroachment and causes contamination of crops and food sources (Karg,1986), the safety in the use of chemical weeding is a major concern, giving serious health concerns to farmers and a big threat to the environment. Mechanical weed control which is essentially the use of mechanical devices, simple or complex to physically remove, uproot, cut, shred and shatter inter-row and intra row weeds, or even bury the weeds completely. In addition, Ragvir and Sahastrarashmi (2007) reported that mechanical weed control not only uproots the weeds between crops but also keeps the soil surface loose ensuring better soil aeration and water intake capacity of the weeded area. Studies on existing mechanical methods of weed control (Khan and Diesto, 1987, Islam and Haq, 1991, Das, 1996, Behara et. al., 1996, Olukunle, 2005, Olakunle and Oguntunde, 2006, Manuwa et. al., 2009) have not addressed the effects of some machine related parameters like weeding speed, weeding depths and number of weeding blades on weeder performance, in addition, the performance characteristics of most weeders have not been optimized for efficient and effective weeding operation for the purpose of large scale production and distribution. The objective of this paper is to model and optimize the weeding efficiency of a developed power weeder when the weeder is operated at different levels of weeding speed , weeding depth with different numbers of weeding blades.

MATERIALS AND METHODS.

This study was conducted on the sandy loam upland soils of Samaru in Zaria, Kaduna Nigeria (11^0.11'N, $07^0$38'E and 685m above sea level). The average rainfall of the area was about 1100mm spreaded between May and October. The soil is classified as alfisol (Moberg and Esau, 1989; Yusuf, 2001). With surface always hard and compact on account of the high proportion of fine sand and therefore the soils were particularly prone to sheet erosion because of their compactness (Yusuf, 2001).The field was crossed harrowed thrice and ridged 35-45cm high and to a 75cm spacing between ridges, then it was cropped with maize (2-3 seeds per stand) which were planted two weeks before the trials with the constructed weeder. Field evaluations were then carried out two, four and six weeks after sowing (2WAS, 4WAS and 6WAS)

To carry out the evaluation, a power weeder was designed and constructed (Ewaoda et al., 2014) measuring 160cm x 70cm x 83cm was driven by a 7Hp, 2007 model of Honda/Simba CG175 internal combustion petrol engine with a clutchable 5 speed transmission system as the prime mover and evaluated using on plots measuring 4m wide x 5m long All the plots were labeled with the various combinations of the weeding speed (S) weeding depth (D), and numbers of weeding blades (B), the plots were later pegged, and randomized appropriately. To evaluate the performance of the power weeder with particular reference to the weeding efficiency, three weeding speeds (S1=100rpm, S2=200rpm and S3= 300rpm), three weeding depths (D1=1cm, D2=2cm, D3=3cm) and two numbers of weeding blades were(B1=10, B2=20) were chosen and used and each of the field trials using the various combinations of the machine variables were replicated three times each. The weeding efficiencies obtained from each plot using various combinations of of the machine variables were determined using Manuwa et al.,(2009) expressed as

$$W_i = \frac{(W_1 - W_2)}{W_1} x100 \quad \text{..........1}$$

Where,

W_f = Weeding efficiency (%)

W_1 and W_2 are Weed count before and after weeding (unitless)

Weed counts were done by physically counting the No. of weeds per square area in every plot before the Weeding was done. Weed counting after weedings were done 2-3 days after weeding so that unweeded grass would have been re-established for easy counting.

Development of Weeding Efficiency Model Equations

Development of models from empirical data to predict the behavior of processes and machines can be done in several ways. Some can be done statistically and others can be done analytically or mathematically, statistical approaches using regression analysis are probabilistic and are estimates using lines of best fits. The analytical approaches are deterministic and as such their outcome from the predicted equations are far more accurate. Modelling of the weeding efficiencies obtained from the field trials of the power weeder was done using the three variables Lagrange interpolating polynomials (which is a mathematical approach) used to develop the models.

The general lagrange interpolating polynomial for n+1 data points for a one variable experiment at Xo, X_1,…Xn can be expressed as using the expression given by Stroud and Booth (2003)

$$P(x) = \frac{(x-x_1)(x-x_2)(\ldots)(x-x_n)}{(x_o-x_1)(x_o-x_2)(\ldots)(x_o-x_n)} f(x_o)\ldots + \frac{(x-x_o)(x-x_2)(\ldots)(x-x_n)}{(x_o-x_1)(x_1-x_2)(\ldots)(x_1-x_n)} f(x_1) + \ldots \frac{(x-x_o)(x-x_1)(\ldots)(x-x_{n-1})}{(x_n-x_o)(x_n-x_1)(\ldots)(x_n-x_{n-1})} f(x_n) \quad \text{….2}$$

Where P(x) is a polynomial of one variable (x) and f(x) are data points of the experiment.

For the field trials of the designed and constructed power weeder there were three independent variables X,Y and Z representing weeding speed weeding depth and No. of weeding blades respectively, therefore the general form of the lagrange polynomial that was derived and used to generate the model equations to predict the dependent variable was of the form

$$p(x,y,z)=\frac{(z-z_1)}{z_0-z_1}\cdot\left(\frac{(y-y_1).(y-y_2)}{(y_0-y_1).(y_0-y_2)}\right)+\left(\frac{(x-x_0).(x-x_2)}{(x_1-x_0).(x_1-x_2)}\right)+\frac{(y-y_0).(y-y_2)}{(y_1-y_0).(y_1-y_2)}+\frac{(x-x_0).(x-x_2)}{(x_1-x_0).(x_1-x_2)}f_1\ldots+$$

$$\frac{(z-z_0)}{(z_1-z_0)}\cdot\left(\frac{(y-y_0).(y-y_2)}{(y_1-y_0).(y_1-y_2)}\right)+\left(\frac{(x-x_0).(x-x_2)}{(x_1-x_0).(x_1-x_2)}\right)+\left(\frac{(y-y_1).(y-y_2)}{(y_0-y_1).(y_0-y_2)}\right)+\left(\frac{(x-x_0).(x-x_1)}{(x_1-x_0).(x_1-x_2)}f_n\right)$$

Where, x_0, x_1, x_2 refer to the rotary speed of the weeder, 100rpm, 200rpm, 300rpm respectively

y_o, y_1 *and* y_2 refers to the weeding depths, 1cm, 2cm, and 3cm of the weeder respectively and z_o, z_1 refer to the no of weeding blades

Objective function for the maximization of weeding efficiency.

This was done by the constrained maximizing the weeding efficiency as a non linear problem (NLPP) by solving the function;

$$W_f = f(D,S,B,WAS) \text{ ....4}$$

Where,

W_f = Weeding Efficiency(%), D = Weeding Depth (cm), S = Rotary Speed (rpm)

B = No. of blades(unitless),WAS = Weeks after Sowing (weeks)

Subject to the following constraints

$g_1(D)\geq 1cm \leq 3cm$, $g_2(S)\geq 100rpm \leq 300rpm$, $g_3(B)\geq 10\leq 20$

$g_4(WAS)\geq 2WAS \leq 6WAS$

The optimum value was computed analytically as a Non Linear Programming Problem (NLPP) using Multi Variable Optimization between dependent and independent variables with Inequality Constraints and finally using a computer programme by use of MAPLE, Version 14. A software for modeling and optimization developed by Maple soft inc. (2010)

RESULTS AND DISCUSSIONS

Effect of the Machine Weeding Depth, Weeding Speed and Number of Weeding Blades on Weeding efficiency

That with respect to the levels of machine variables tested, we can observe that generally, the Weeding efficiencies (Weff.) increased with increase in the levels of the machine variables i.e weeding depth (D), weeding speed (S), and number of weeding blades (B). This increase was observed for any given set of combination of (D,S,B).

The weeding efficiencies (Weff.) were generally higher in the weedings conducted 2WAS than the weeding efficiencies obtained 4WAS and 6WAS respectively Fig.1, i.e the Weff. decreases with the age of the weeds in the order 2WAS >4WAS > 6WAS. The range of the weeding efficiencies when the weeding were done 2WAS, 4WAS and 6WAS in the trials were (1.2-63.9)%, (0.85-57.9)% and(0.43-67.5)% respectively, The higher efficiencies observed in the weeding done 2WAS were because the weeds were still in their tender stage and the weed density was low at this time compared to the weed's properties at the weeding of 4WAS and 6WAS which were tougher and had a higher weed density at the time of the weeding. In addition Weff. were higher in the weeding done 2WAS because all the physical characteristics of the fields i.e ridge height and furrow depths, were still mostly unchanged which allowed the weeding blades of the weeder to have maximum contact with soil and the weeds around the ridges.

It was also observed that the increment in Weff. was also directly proportional to the increase in the weeding depth (Weff. α D), and this increment followed the order D_3>D_2>D_1, Figs. 1. The lowest weeeding efficiencies were observed at D1, and the values of the Weff. for the weedings done ranged (1.2-23.5)%, (0.85-6.47)% and (0.50-1.07)% when the weeding was done 2WAS 4WAS and 6WAS respectively,

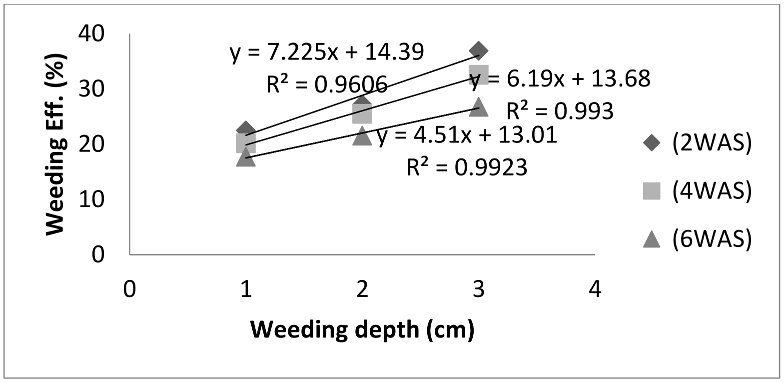

Fig. 1: Effect of weeding depths on weeding efficiencies (%) for the weeding done at 2WAS, 4WAS and 6WAS.

It was observed that the increment in Weff was directly proportional to the increase in the speed of the weeding unit (Weff. α S) and it followed the order $S_3>S_2>S_1$, as shown in Figs.2 The highest weeding efficiencies were observed as the weeder was operated at S3, their values ranged between (2.20-63.9)%, (2.29-57.9)% and (0.43-67.5)% in the weedings done 2WAS, 4WAS and 6WAS respectively, When the weeder was operated at S2, the ranges of the Weff. were (2.1-54.3)%, (1.44-46.23)% and (0.57-53.50)% for weedings done 2WAS, 4WAS and 6WAS respectively. The lowest Weff. in all the trial were observed when the weeder was ran at S1 and the ranges of the Weff. were (1.2-44.6)%, (0.85-46.5)% and (0.60-45.0)% for the weedings done 2WAS, 4WAS and 6WAS, respectively.

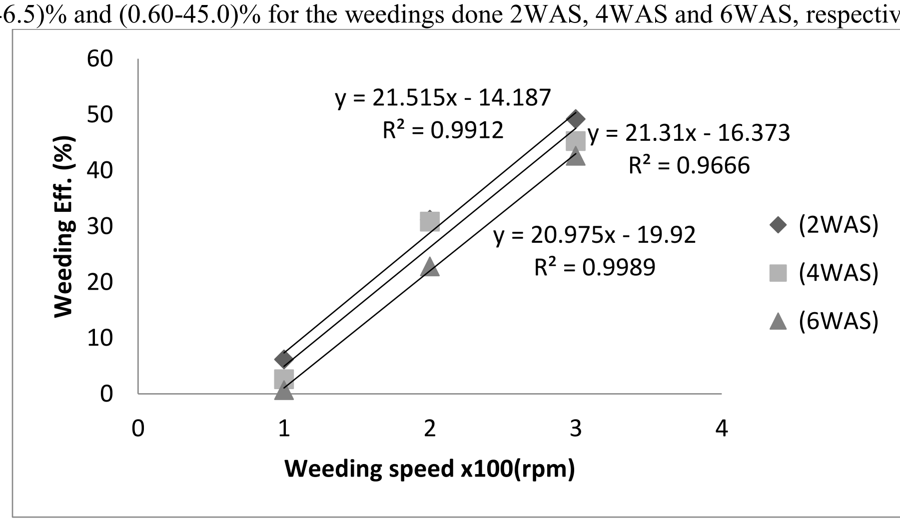

Fig. 2: Effect of weeding speed on weeding efficiencies (%) for the weeding done at 2WAS, 4WAS and 6WAS

This finding have proved that, increasing the speed of the weeding unit may have increased the total kinetic energy, surface area of the weeding blades contacting the weeds and the angular momentum of the blades consequently making them more effective in cutting the stem of the weed, cutting the soil, inverting and shattering the soil around the root zone hence detaching more weed from the soil.

The highest values of Weff in all the weedings were obtained when the weeding was done with B1 (20 No. blades) Fig. 3., and the Weff obtained when the weeding was done ranged between (1.2-63.9)%,(1.40-57.9)% and (0.50-67.5)% for weedings done 2WAS, 4WAS and 6WAS respectively. The higher efficiencies observed at higher No blades can be attributed to the increase in the total surface area of the weeding blades, consequently there was more blade contact with the weeds and the soil and as a result increasing the weeding efficiencies.

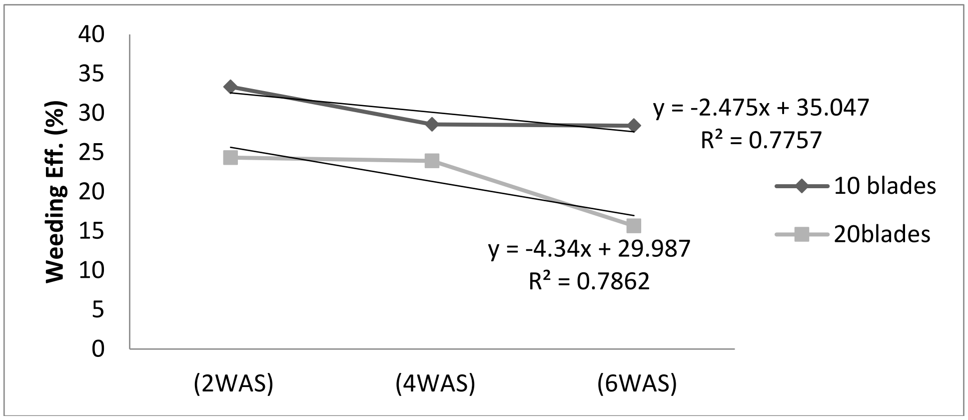

Fig. 3: Effect of the number of weeding blades on weeding efficiencies (%) for the weeding done at 2WAS, 4WAS and 6WAS

When the means of the effect of the machine variables on Weff. for the weedings done 2WAS, 4WAS and 6WAS were compared statistically as shown in Tables .1 -3. The tables indicated that all the levels of the machine variables had a highly significant effect on weeding efficiencies of the weeder, ($P \leq 0.01$) when the weedings were done 2WAS ,4WAS and 6WAS respectively. The effect of the interaction D*S and S*B on the Weff. were highly significant ($P \leq 0.01$) in the weedings done 4WAS and 6WAS but were not significant in the weedings done 2WAS. The interaction of D*B was only highly significant ($P \leq 0.01$) in the weedings done 6WAS, but was not significant ($P \leq 0.05$) in the weedings done 2WAS and 4WAS, respectively. The tables further indicated that the combined interaction D*S*B had a significant effect on weeding efficiencies of the weeder, ($P \leq 0.05$) only when the weeding was done 6WAS but was not significant ($P \geq 0.05$) when the weedings were done 2WAS and 4WAS, respectively.

Table 1: ANOVA table for the effect of machine weeding depth, speed and number of blades on weeding efficiency at 2WAS field evaluation

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	381.76148	190.88074	1.90	0.1655NS
D	2	1956.40481	978.20241	9.72	0.0005**
S	2	16814.27704	8407.13852	83.58	<.0001**
B	1	1093.50000	1093.50000	10.87	0.0023**
D*S	4	226.03519	56.50880	0.56	0.6920NS
D*B	2	71.89000	35.94500	0.36	0.7021NS
S*B	2	9.76000	4.88000	0.05	0.9527NS
D*S*B	4	648.97667	162.24417	1.61	0.1935NS
Error	34	3420.18519	100.59368		
Total	53	24622.79037			

*Note * = $P \leq 0.05$ (Significant at 5%),** $P \leq 0.01$ (Sign at 1%), N.S= Not significant ($P > 0.05$)*

Table 2: ANOVA table for the effect of machine weeding depth, speed and number of blades on weeding efficiency at 4WAS field evaluation

Source	DF	Anova SS	Mean Square	F Value	Pr>
REP	2	33.87729	16.93865	1.76	0.1879NS
D	2	1279.34538	639.67269	66.36	<.0001**
S	2	16900.56873	8450.28436	876.58	<.0001**
B	1	291.02092	291.02092	30.19	<.0001**
D*S	4	738.04754	184.51189	19.14	<.0001**
D*B	2	48.82160	24.41080	2.53	0.0944NS
S*B	2	150.62339	75.31170	7.81	0.0016**

D*S*B	4	22.46599	5.61650	0.58	0.6773NS
Error	34	327.76384	9.64011		
Total	53	19792.53468			

*Note * = P < 0.05 (Significant at 5%),** P < 0.01 (Significant at 1%), N.S= Not significant (P > 0.05)*

Table 3: ANOVA table for the effect of machine weeding depth, speed and number of blades on weeding efficiency at 6WAS field evaluation

Source	DF	Anova SS	Mean Square	F Value	Pr > F
REP	2	0.36293	0.18146	0.02	0.9784NS
D	2	738.02280	369.01140	44.49	<.0001**
S	2	15856.79551	7928.39776	955.89	<.0001**
B	1	2188.29977	2188.29977	263.83	<.0001**
D*S	4	439.62624	109.90656	13.25	<.0001**
D*B	2	249.73270	124.86635	15.05	<.0001**
S*B	2	1413.09986	706.54993	85.19	<.0001**
D*S*B	4	128.31074	32.07768	3.87	0.0108*
Error	34	282.00553	8.29428		
Total	53	21296.25608			

*Note * = P < 0.05 (Significant at 5%),** P < 0.01 (Significant at 1%), N.S= Not significant (P > 0.05)*

Development of model Equations for prediction Weeding Efficiencies

The equations for the predicting the weeding Efficiencies for the weedings done 2WAS, 4WAS and 6WAS were done using the three variables lagrange polynomial derived in equation 3, and using MAPLE 14 (modeling and optimization software) these were done by first constructing the basis polynomial Ln,k(x) from the set of data $(x_0, y_0), (x_1, y_1), \ldots, (x_n, y_n)$ with the properties

$$L_{n,k}(x) = \{1 \text{ when } j = k \text{ and } 0 \text{ when } j \neq 0,$$

The frame of the general model equation for forming the weeding efficiency models after substitutions into equation 3 is of the form

$$Weff.(x,y,z) = a_o + a_1z + a_2y + a_3x + a_4y^2 + a_5x^2 + a_6y^2x^2 + a_7y^2x + a_8yx^2 + a_9yx + a_{10}zy + a_{11}zx + a_{12}zy^2 + a_{13}zx^2 + a_{14}zy^2x^2 + a_{15}zy^2x + a_{16}zyx^2 + a_{17}zyx \ldots\ldots 5$$

Where a_o - a_{17} are coefficients and depends on the model or are model specific.

When x_0, x_1, x_2 (the rotary speed of the weeder), 100rpm, 200rpm, 300rpm respectively, y_o, y_1 *and* y_2 (the weeding depths) 1cm, 2cm, and 3cm of the weeder respectively and z_o, z_1 (the no of weeding blades) were substituted into the equation 3, above the model equation that was generated for the weeding efficiencies in the 2WAS, 4WAS and 6WAS were

Weff.(2WAS) = $36.62- 4.58z - 46.05y -0.77x +7.97y^2 +0.0021x^2 +0.00054y^2x^2 -0.17y^2x -0.0027yx^2 + 0.86yx + 5.82zy + 0.06zx - 1.03zy^2 - 0.00019zx^2 - 5.47x10^{-5}zy^2x^2 + 0.017zy^2x + 2.5x10^{-4}zyx^2 - 0.08zyx \ldots\ldots 6$

Weff.(4WAS) = $25.63 – 6.89z – 22.73y - 0.19x + 9.89y^2 +3.65x10^{-5}x^2 +6.1x10^{-5}y^2x^2 - 0.016y^2x -4.54x10\text{-}4yx^2 + 0.38yx + 7.52zy + 0.045zx - 1.83zy^2 -0.000089zx^2 -1.\ 52x10^{-5}zy^2x^2 + 0.0093zy^2x + 6.13x10^{-5}zyx^2 - 0.038zyx \ldots\ldots 7$

Weff.(6WAS)= $-69.14 + 1.48z + 0.72x + 89.90y +0.013zy^2x + 0.00004zy^2x^2 – 0.0002zyx^2 + 0.065zyx – 15.04y^2 – 0.0021x^2 – 0.0006y^2x^2 + 0.20y^2x + 0.0029yx^2 – 0.98yx – 0.046zx – 2.24zy +0.28zy^2 +0.0001zx^2 \ldots\ldots 8$

All the model equations developed above equations (5-8) were verified and validated using a graphic user interface developed with Visual BASIC .NET 2010, on the WINDOWS platform and built using Windows 8 operating system.

Optimization of the weeding Efficiency

In order to maximize or minimize the function f (x,y,z) which is subject to the constraint g_1, g_2 g_3 and g_4 we followed the procedure below using the MAPLE version14 (a software application for modeling and optimization) a product of Maple soft Inc. 2010 The inbuilt and coded optimization assistant enables the computation of the optimal values of the dependent variables (weeding efficiency) as a function of the inputed independent variables (weeding speed, weeding depth and no of weeding blades) once the constraints are specified and inputed.

Three dimensional graphs showing optimal operating ranges of the weeding efficiencies as a function of the independent variables are shown below

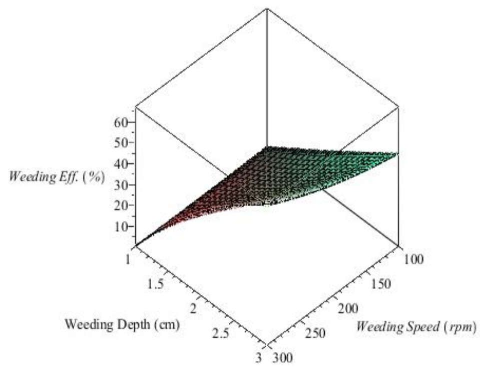

Fig.4; Effect of Weeding Speed and Weeding depth on the mazimization of the optimum Weeding Eff. in the weeding done 2WAS

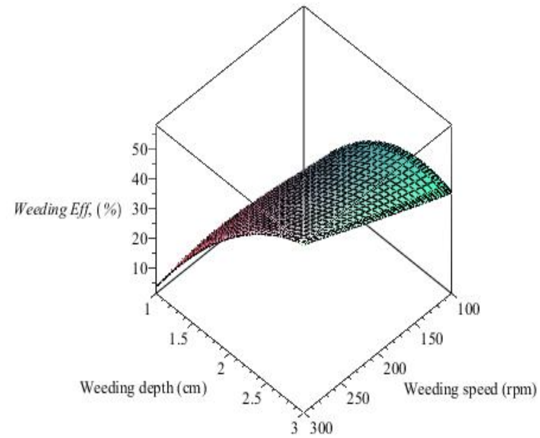

Fig.5 Effect of weeding speed and weeding depth on the maximization of the optimum weeding effciency for the weeding done 4WAS

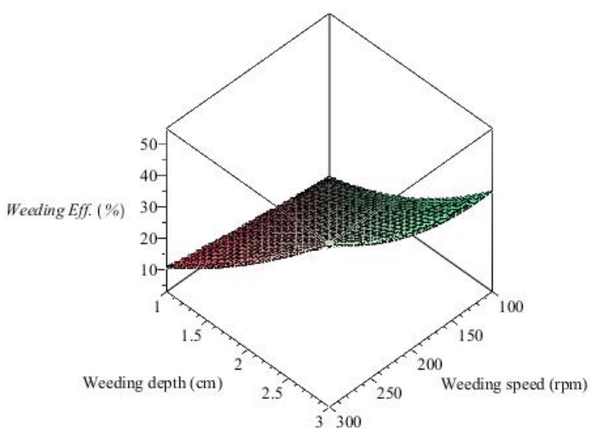

Fig. 6.Effect of weeding speed and weeding depth on the maximization of the optimum weeding Efficiency (%) for the weeding done 6WAS

It can be observed from the 3D graphs of the of the optimum weeding efficiencies obtained in the weedings done 2WAS, 4WAS and 6WAS, that the optimum weeding efficiencies as shown in the green portions of the graphs were usually maximizing as the weeding speeds and the weeding depths increased. The optimized weeding efficiency was highest when weedings are done 2WAS and lowest when weedings are done 6WAS. Optimum weeding efficiency obtained for the weeding done 2WAS was 67.30%, for 4WAS it was 57.90% and for 6WAS it was 54.72%. Table 4. below shows the optimal weeding conditions for the maximization of the weeding efficiencies of the designed and tested power weeder.

Table 4. Optimum weeding Efficiencies (%) obtained from the field trials of the power weeder

Time of weeding (WAS)	Optimized weeding Eff.(%)	Optimal weeding conditions		
		Weeding speed (rpm)	Weeding depth (cm)	No.of weeding blades
2WAS	67.30	300	3	20
4WAS	57.90	300	3	20
6WAS	54.72	300	3	20

CONCLUSIONS AND RECOMMENDATIONS

From the results obtained in the field trials of the power weeder we can be concluded that, weeding efficiencies of the designed power weeder were affected by the time (WAS) that the weedings were done. Weeding efficiencies are usually higher when weedings are done 2WAS and lowest when weedings are done 6WAS because at 2WAS weeds densities are lower than at 6WAS, hence more weeds can be uprooted at 2WAS than at 6WAS depending on the weed characteristics of the field. In addition weeds are more tender and shallow rooted at 2WAS than at 6WAS hence more weeds can be destroyed when weeding is done 2WAS than at 6WAS. However, from the observations made during the field trials it is recommended That during land preparations, the ridges should be made as straight and as parallel as possible with proper plough adjustments so that there will be uniformity of ridge and furrow configurations. Furthermore, the models were developed and optimized using 3 variable Lagrange polynomials and partial differentiation of the various model using Lagrange multipliers, efforts can be made to use statistical methods to develop the models and compare the predictions with those obtained using the Lagrange polynomial.

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EVELOPMENT AND TESTING OF A CENTRIFUGAL FERTILIZER APPLICATOR

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ABSTRACT

A centrifugal fertilizer applicator which makes use of centrifugal force to broadcast fertilizer on the farm with an effective capacity of 90 hectares/day was developed and tested in Desfabeng Company Nigeria Limited Bida, Nigeria. This work was done in order to alleviate the drudgeries encountered with the manual method of fertilizer broadcasting using hand and also eliminate the problems of sudden breakdown and high cost of imported fertilizer broadcasters. The major components of the machine include the hopper, agitator, spreader disc, feed control mechanism, 3-point hitch to the tractor, power transmission unit and the frame. Successful completion of the machine would help increase crop production in Nigeria. The device was fabricated with locally sourced materials that are not difficult to get. This makes maintenance and repairs on the device easy by local artisans since damaged parts can be easily repaired and if possible replaced with new parts. The fabricated spreader was tested over a hectare of land at four different ground speeds of 5, 10, 15 and 20 km/hr with a view of ascertaining the time taken, effective capacity and distribution pattern/uniformity over one hectare of land. Test results indicate that at 5, 10, 15 and 20 km/hr ground speeds, the time taken to cover one hectare was 16, 8, 5.3 and 4 minutes respectively while the corresponding effective capacities in ha/hr are 3.75, 7.50, 11.25 and 15.00 respectively. Using the tray collection and test tube method, at 15 km/hr optimum ground speed and an effective swath width of 10 m, the fertilizer distribution was even and uniform showing an oval spread pattern. Also visual inspection of the planted seeds after germination showed a uniform plant growth confirming that the fertilizer was evenly spread on the field.

Keywords: *Fertilizer, centrifugal, spreader, crop, soil*

INTRODUCTION

Fertilizers are materials of natural or synthetic origin manufactured from various chemical treatments which when applied to the soil increases soil fertility thereby increasing the growth and development of crops (Benton, 2012). Crops obviously need nutrients to grow and develop and they draw these nutrients from the soil. If this withdrawal is not compensated for, the crop yield goes down progressively. This withdrawal is compensated through fertilizers and manures to maintain the productivity of the soil and to achieve higher yields (Yadav and Pawar, 2015). Mineral fertilizer application currently accounts for 43% of the nutrients that global crop production extracts each year, and the contribution may be as high as 84% in the years to come (FAO, 2014).

Farmers need machinery which can spread fertilizers effectively with least cost and power requirement. Fertilizer broadcasters began as ground driven units which could be pulled by a horse or team of horses. The first successful automated fertilizer broadcaster was a manure spreader designed by Joseph Kemp in 1875 (Yadav and Pawar, 2015).

Sapkale *et.al* (2010) carried out a performance evaluation of a tractor operated manure spreader. The manure spreader was attached to a 45 HP tractor through the hitch point and test was conducted. A 540 rpm PTO speed was used to operate the rotary blades of the manure spreader. The distribution pattern of farm yard manure was uniformly spread over the area and little variation was found. This was due to clods in the manure. It showed that there was saving of 94 per cent in time as compared to traditional method. The field capacity of the manure spreader was also worked out in terms of area coverage per hour.

Suthakar *et.al.* (2008) evaluated the field performance of a tractor PTO operated manure spreader attached to a two wheel trailer and compared it with the traditional method of spreading manure. The machine mainly consists of a manure tub to load the manure, an endless chain conveyor for conveying the manure towards the rear end of the trailer and a hydraulically operated spreader drum to shear off manure. The machine was tested at Research Farms of the Tamil Nadu Agricultural University and at the farmer's fields. It possesses the linear relationship for the forward speed and chain conveyor speed with the application rate. But, the speed of the spreader drum did not influence the application rate of the manure.

The majority of farmers now use a broadcast spinner spreader, also known as centrifugal spreader, because of their large working width, low cost, robustness and spreading efficiency. The working principle is simple: the fertilizer particles fall onto a disk equipped with vanes. The disk rotates at 400 to 1000 rpm and consequently throws the particles into the field. Several factors affect the fertilizer distribution in the field such as the spreader settings and the fertilizers physical properties. This distribution or spreading pattern should correspond to the crop's needs as closely as possible. In fact, applying an imprecise amount of fertilizer might actually decrease the production efficiency (Olieslagers *et al.,* 1996; Scharf, 2009). For example, lodging of cereals due to an excess of nitrogen input decreases profit substantially (Grinsven *et al.,* 2012). To be able to spread the correct amount of fertilizer on the right place in the field, correct spreader settings are determined by performing a calibration test taking into account both machine and fertilizer properties. In most cases the fertilizer particles are collected in standardized trays and then weighed (Reumers *et al.,* 2003).

In Nigeria, most fertilizer broadcasting in the field are still done manually. Manual broadcasting is time consuming and the distribution is non-uniform. Also most of the fertilizer applicators used in the country are imported and very expensive to purchase and maintain. Most of them do not last especially the gearbox and they are not durable. The materials used often times are also made of light inferior materials which are not able to withstand our harsh climatic and soil condition.

To overcome these aforementioned problems, a centrifugal fertilizer applicator was designed and fabricated using locally available materials. The fabricated machine would be relatively cheap compared to the imported ones. It would help in applying fertilizer on the farm effectively. As such this paper explains the development and testing of a centrifugal fertilizer applicator which would comprise of a hopper that would house the agitator which continuously stirs the fertilizer in the hopper, two aperture openings for metering the fertilizer, a spreading disc connected to a gear box and then to the P.T.O. of the tractor for broadcasting the fertilizer on the field. This would help alleviate the drudgeries encountered during an entirely manual broadcasting operation and it would also help correct the abnormalities and problems encountered from other fertilizer applicators. Thus, increasing agricultural productivity in the country by an increase in the growth of crops. The fertilizer applicator was found to be relatively cheap, durable and easy to repair and maintain.

DESIGN CONSIDERATIONS

In carrying out this design work, much effort was directed towards obtaining a system that would give the desired compactness. The dimensions of the various components was calculated so as to minimize size and weight of the machine and at the same time not compromise the standard, strength and efficient functioning of the various parts.

The angle of repose and particle size of granular fertilizer was also considered as this would play a vital role during the metering and distribution of fertilizer on the farm.

Other criteria that were considered in designing the components of the centrifugal fertilizer applicator are as follows:

i. Capacity of the hopper.
ii. The rate of fertilizer discharge.
iii. The thickness and strength of the hopper that can withstand the load.
iv. Maximum swath width of the fertilizer distributed as a function of PTO speed.
v. Ease of passage/metering of the fertilizer to the spreader disc.
vi. Magnitude of centrifugal force developed by the spreader disc
vii. Thickness of the agitator for its intended purpose
viii. Thickness and length of shaft
ix. Stability and strength of the frames to carry other components and necessarily withstand further impacted load.

DESIGN CALCULATION

The aim of the design analysis, calculations and other necessary considerations is to evaluate the required and necessary design parameters. This would enhance the selection of appropriate materials and strength of the materials to be used for the construction of the various component parts of the centrifugal fertilizer applicator

Determination of the Centrifugal Force Developed

A centrifugal force is set up on the spreader disc assembly due to the rotation of the shaft when working and in line with the principle of centrifugal force; the direction of action of the force is from the centre towards the edges of the spreader disc. The centrifugal force generated is determined by applying equation 1.

$$F_C = \frac{M_T \omega^2 D}{2} \quad (1)$$

Where,

$F_C = Centrifugal\ Force$

$M_T = Total\ mass\ of\ spreader\ disc\ and\ shaft\ (kg)$

$\omega = angular\ velocity\ of\ the\ spreader\ disc\ assembly\ (rad/s)$

$D = Diameter\ of\ spreader\ disc\ (m)$

Linear Speed of the Spreader Disc Assembly

The linear speed of the spreader disc is related to the revolution per minute and diameter of the spreader disc as given by equation 2.

$$V = \pi N D \quad (2)$$

Where,

V = Linear speed of the spreader disc assembly (m/s)

N = Expected number of revolution per minute of the spreader disc assembly (rpm)

D = $Diameter\ of\ spreader\ disc\ (m)$

Allowable Thickness of the Material for the Construction of the Agitator

In order to withstand the expected stress on the edges and surface of the agitator, an appropriate thickness of the agitator has to be determined to prevent avoidable system failure. Kreg (1975) stated that the thickness of an agitator to withstand the stress is a function of the agitator and the maximum permissible stress of the material expressed by equation 3

$$t_k = \frac{\delta_b D}{2\delta_b} \quad (3)$$

Where,

$t_k = Thickness\ of\ the\ agitator\ blades\ (m)$

$\delta_b = Permissible\ stress\ of\ the\ material\ of\ the\ agitator$

$D = Diameter\ of\ hopper\ bottom\ (m)$

Determination of Weight of the Spreader Disc

The weight of the spreader disc was determined in order to know the amount of load being exerted on the shaft by the spreader disc. Therefore the weight of the spreader disc is given in equation 4

$$W = mg \quad (4)$$

Where,

W= weight of spreader disc (N)

m = mass of spreader disc (kg)

g = acceleration due to gravity ($9.8 m/s^2$)

Power Required to Move the Fertilizer to the Desired Swath Width

The power required to spread the fertilizer is expressed by equation 5

$$P = T\omega \quad (5)$$

Where,

P = power required (Watt)

T = torque of the spreader disc (Nm)

ω = angular Speed of the spreader disc (rad/s)

But $\omega = \frac{2\pi N}{60}$

Where,

N = speed of the spreader disc in rpm

Determination of the Area of the Spreader Disc

The area of the spreader disc was calculated in order to help ascertain the dimension of the hopper bottom. Since the area of the spreader disc must be larger than that of the hopper bottom. Therefore, the area of the spreader disc was calculated using equation 6

$$A = \pi r^2 \quad (6)$$

Where,

A = Area of the spreader disc (m^2)

r = radius of spreader disc (m)

Determination of the Rate of Fertilizer Discharge

The rate of fertilizer discharge will determine the rate of spread/swath width of fertilizer dispersed. The rate of fertilizer discharge and spread is determined by the equation 7

$$Q = VA \quad (7)$$

Where,

Q = Discharge rate (m^3/s)

A = Area of fertilizer Delivery Hole (m^2)

V = Speed at which fertilizer is delivered and spread (m/s)

Determination of the bearing shaft Diameter

The bearing shaft diameter is needed in order to determine the load carrying capacity of the shaft. For a solid shaft with little or no axial load, the diameter of the shaft is determined using equation 8

$d^3 = \frac{16}{\pi S_s} \times \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$ (Khurmi and Gupta, 2005) (8)

Where,

d= is the diameter of the shaft

S_s= is the allowable stress

K_b= Combine shock and fatigue factor applied to bending moment= 1.5 (Hall *et al*., 1980)

M_b= is the bending moment

K_t= Combine shock and fatigue factor applied to torsional moment = 3.0 (Hall *et al*., 1980)

Determination of the Maximum Shear Stress of the Shaft

The shaft is under a combined load of bending moment and torque and is given by equation 9

$\tau_{max} = \frac{16}{\pi d^3}\sqrt{(M^2 + T^2)}$ (Khurmi and Gupta, 2005) (9)

Where,

τ_{max} = Maximum shear stress (N/m)

T= Torque (Nm)

M= Bending moment of shaft (Nm)

d= shaft diameter (m)

Determination of Angle of Twist

The angle of twist helps to know whether the diameter of the shaft is safe to carry the applied load. According to Hall *et al*. (1980) the amount of twist permissible depends on particular application and varies about 0.3 degree per meter for a machine tool shaft and about 3 degree per meter for line shafting.

Therefore, angle of twist (θ); for solid shaft is given by equation 10

$\theta = \frac{584 M_t L}{G d^4}$ (10)

Where

L = length of shaft (m)

M_t = torsional moment (Nm)

G = torsional modulus (Nm^2)

Determination of the Speed Reduction ratio of the Gearbox

The speed reduction ratio of the gear unit is a function of the tractor PTO speed and the recommended speed of the rotary spreader connected to the gearbox. Thus, it is computed from equation 11

$$G_R = \frac{N_T N_P}{N_S N_T} \qquad (11)$$

Where,

G_R= The expected gear ratio of the gearbox

N_T= Speed of tractor PTO (540rpm)

N_P = Speed of propeller shaft (rpm)

N_R= Recommended speed of the rotary spreader (rpm)

N_S= Speed of spreader shaft (rpm)

Determination of the Capacity of the Hopper

The hopper design was based on the volume of frustum of a cone. The volume of the conical frustrum was obtained by taking the angle of repose for the granular fertilizer as 30^0 into consideration and by following the principle of determining volumetric and gravimetric capacity of hopper as given by Ilori *et al.*(1997) in equation 12

$$. \, Capacity\ of\ the\ (frustrum) hopper\ (V) = {}^{1}\!/_{3}\,\pi(R^2H - r^2h) \qquad (12)$$

Where,

V = $Capacity\ of\ the\ (frustrum) hopper$ (m^3)

R = Radius of the large diametric end of the hopper (m)

r = radius of the small diametric end (m)

H = Height of the entire projected cone (m)

h = Height of the small part of the projected cone (m)

Determination of the Capacity of the Fertilizer Spreader

The capacity of a machine is the number of units which it can process or cover in a specific time. Capacity is expressed as the hectares covered per hour or day.

The effective field capacity is the measure of a machines ability to do a job under actual field conditions. The effective field capacity can be obtained by calculating the theoretical field capacity and multiplying it by the field efficiency. To estimate the effective field capacity of the fertilizer spreader, the theoretical field capacity would be computed from equation 13

$$C_F = \frac{A_T\ (m^2/day)}{10{,}000\ (m^2/hectare)} \qquad (13)$$

Where

C_F = Theoretical Field Capacity of the fertilizer spreader in hectares/day

A_T = Total area covered per day in m^2/day

But $A_T = S \times W$ (14)

Where

S = Optimum forward speed of the tractor during the operation in km/hr.

W = Effective Swath width of the fertilizer broadcasted in metres

The fertilizer spreader cannot operate at its theoretical capacity at all times while it is in the field due to turning and idle travel, operating at less than full width, reloading of fertilizers, cleaning clogged equipment, machine adjustment, lubrication and re-fueling during the day. Consequently, the field efficiency is always less than 100percent.

From the operation data recorded during the testing of the machine,

S = 15km/hr. (Optimum speed from the four speeds used)

For a basis of eight (8) working hours per day (8hrs/day)

S = $15km/hr \times 8hrs/day = 120km/day$

∴ S= $(120 \times 1000)m/day = 120{,}000m/day$

W= $Swath\ Width\ of\ fertilizer\ spread\ on\ the\ Field$

$W = 10m$

From equation 14

A_T = 120,000m/day × 10m

$\therefore A_T = 1{,}200000\ m^2/day$ (15)

Substituting equation 15 into equation 13

$C_F = \frac{1{,}200000m^2/day}{10{,}000m^2/hectare}$

$C_F = 120hectares/day$

Therefore, the theoretical field capacity of the fertilizer spreader is 120hectares/day.

Using a field efficiency of 75% for fertilizer distributors as reported by ASAE (1993).

Effective field capacity = $Theoretical\ field\ capacity \times field\ efficiency$ (16)

Substituting $C_F = 120hectares/day$ into equation 16, we have

Effective field capacity = $120hectares/day \times 75\%$

∴Effective field capacity (EFC) $= 90hectares/day$

MACHINE DESCRIPTION

The centrifugal fertilizer applicator is made up of the following components.

Hopper: This is a conical container for temporarily holding the fertilizer before they are metered onto the spreading disc. It is made from guage 14 mild steel sheets and has a conical bottom with a slope of 30° so that the fertilizer contained in it easily moves towards the metering aperture. It has a diameter of 800 mm at the top and 250 mm at the bottom with a total height of 1200 mm as shown in figure 1. Attached to the top of the hopper is a lid with a peep hole of 80 mm for observing the quantity of fertilizer left in the hopper during operation. The lid helps to prevent fertilizer in the hopper from attaining its critical relative humidity when exposed to moist thereby making the fertilizer hygroscopic. The hopper bottom has two circular holes of 20 mm each for metering the fertilizer onto the spreading disc. The hopper is very strong in order to avoid buckling when filled with fertilizer.

Agitator: This is a stirring device made from spring steel which mechanically initiates the stirring of the fertilizer within the hopper so as to prevent agglomeration of the fertilizer granules. The agitator was kept at a vertical clearance of 3 mm above the aperture.

***Spreading Disc*:** This is a circular rotating disc of 450 mm diameter mounted at the bottom of the hopper just below the two aperture openings. The spreading disc has four equally spaced fins for even broadcasting of metered fertilizer granules. The spreading disc has a vertical clearance of 150 mm from the hopper bottom.

***Feed Control Mechanism*:** A suitable feed control mechanism with locking device was provided below the aperture to control the flow of fertilizer granules through the aperture. The mechanism was controlled by a hand lever from outside of the hopper.

***3-Point Hitch to the Tractor*:** The hitch is the place of connection of implement or equipment to the tractor. The three point hitch is standard on most tractors and consists of the upper link and two lower links. The 3-point hitch is very effective in lowering and lifting of the fertilizer broadcaster and to give it stability and support when used on the farm. The entire 3-point hitch structure of the fertilizer broadcaster was made of two shafts and an upper link welded at the top to increase strength and rigidity.

***Power Transmission Unit*:** This unit comprises of the P.T.O of the tractor, a gearbox and flanges. The flange helps to connect the gearbox to the propeller shaft and also to the spreading disc. The gear box was suitably arranged to give a peripheral speed of 540 rpm to the spreading disc.

***Frames and Covers*:** The supporting frame of the fertilizer applicator was fabricated with two inches angle iron and galvanised steel pipes while the machine covers were made from mild steel sheets.

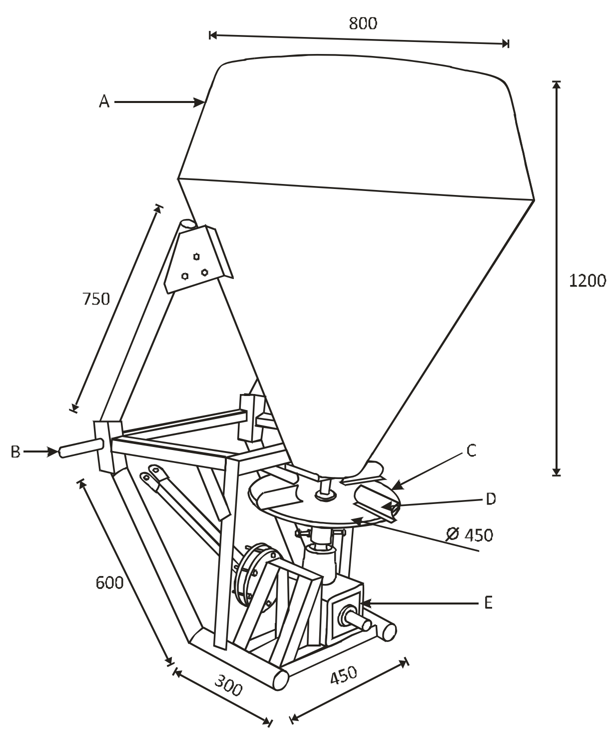

Fig. 1: Isometric View

All dimensions in mm

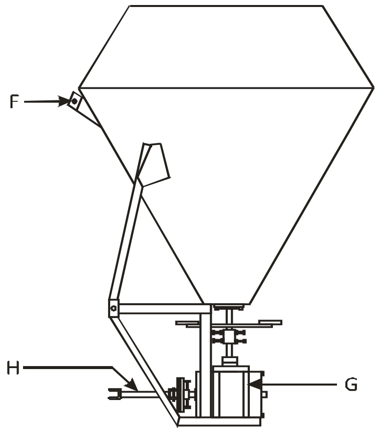

Fig.2: Side View

KEYS	DESCRIPTION
A	HOPPER
B	LOWER LINK ARM
C	SPREADER DISC
D	FIN
E	GEARBOX
F	UPPER LINK ARM
G	GEARBOX FRAME
H	PROPELLER SHAFT
I	SPLASH GUARD
J	FLANGE
K	AGITATOR
L	DELIVERY HOLE

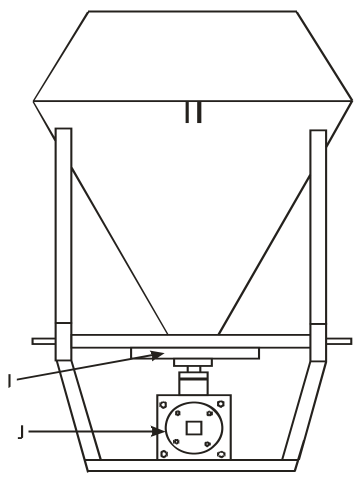

Fig.3: Front View

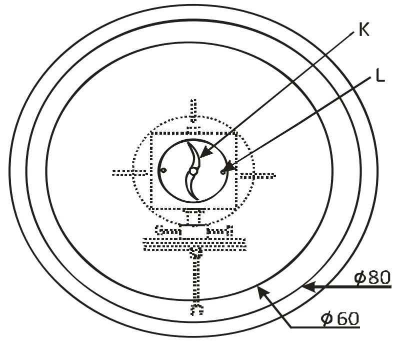

Fig.4: Plan View

PRINCIPLE OF OPERATION

With the various parts of the machine been assembled, the developed machine was then tested without any fertilizer or seed poured into the hopper. This was done to study the behaviour of the machine.

A known mass of granular fertilizer was then poured into the hopper and covered. With the PTO working, the agitator stirs the fertilizer in order to allow the fertilizer move freely under gravity onto the spreading disc for even distribution. The centrifugal force developed by the spreading disc makes any fertilizer granule that drops on it to be directed tangentially away from the center of the spreading disc thereby enhancing even pattern distribution of the fertilizer. With the tractor in motion, the fertilizer was evenly dispersed on the field.

MACHINE EVALUATION

500 kg NPK granular fertilizer (15:15:15) was purchased from a major fertilizer distributor in Bida Local Government Area, Niger state. The fertilizer was inspected to ensure that they were dry and granular so as to ensure maximum performance of the machine. With the tractor set in motion, the fertilizer was evenly dispersed on the field. The field experiments were conducted over one hectare of KGA rice farms Bida under the supervision of Desfabeng Company Limited. The machine was tested at four different ground speeds of 5, 10, 15 and 20 km/hr and the time taken was recorded using a stop watch. The capacities of the machine were calculated at different speeds with the corresponding distribution pattern evaluated and results tabulated in table 1. Each of the experiment was done in triplicate.

i) ***Time taken*:** The time taken for the machine to complete operation in 1 ha of land was recorded with a stop watch that reads both minutes and seconds.

ii) ***Effective and total width of swath*:** Effective width (WE) of the fertilizer spreader was measured by placing collection trays 0.5 m × 0.5m in a row 0.3 m apart from each other perpendicular to the direction of travel according to the ASAE 341.2 standardized collection tray method as described by Lawrence and Yule (2005).

iii) ***Effective Field capacity and efficiency of spreader*:** Effective field capacity (EFC) of the spreader was calculated in ha/day using equation 16 by considering 75% field efficiency and effective swath width of the spreader as 10m. The effective capacity was also calculated in ha/hr via dividing an hour (60 minutes) by the time taken for the tractor and spreader to cover one hectare of land.

iv) ***Fertilizer spreading pattern and uniformity*:** Spreading uniformity was determined by placing a row of collection trays (0.5 m x 0.5 m), 0.3 m apart from each other at right angles to the direction of travel. Fertilizer from each collection tray was collected and placed in polythene bags and labelled. The samples were immediately weighed over digital scale and further poured into graduated test tubes as shown in Figure 5. The spread pattern is easily seen when the trays are emptied into tubes

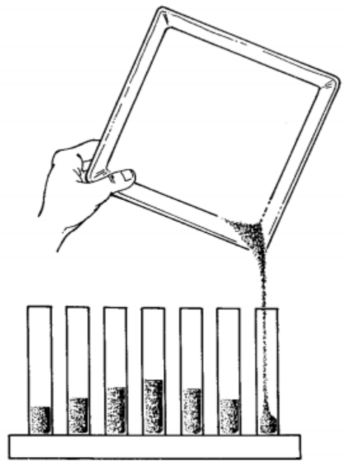

Fig.5. Spread Pattern Using Test Tube Method

Plate 1: Fertilizer being applied in the field

RESULTS AND DISCUSSION

The results obtained from the field test of the centrifugal fertilizer application on a hectare of land is presented in table 1.

Table 1: Machine performance using NPK fertilizer for 1 ha of land at varying speeds

Speed(km/hr)	Replications	Time (mins)	Machine Capacity	Average Time(mins)	Average Capacity	Distribution pattern
5	1	16.03	3.74	16.00	3.75	More fertilizer in the center tray. Thus, giving a pyramidal Pattern
	2	15.97	3.76			
	3	16.00	3.75			
10	1	7.98	7.52	8.00	7.50	Evenly distributed with a curved pyramidal pattern at the apex
	2	8.03	7.47			
	3	7.98	7.52			
15	1	5.25	11.43	5.3	11.25	Evenly distributed with an oval spread pattern
	2	5.42	11.07			
	3	5.33	11.25			
20	1	3.92	15.31	4.0	15.00	Not evenly distributed due to high speed
	2	4.07	14.74			
	3	4.02	14.93			

i) Time taken

As presented in table 1, four different ground speeds of 5, 10, 15 and 20 km/hr were used to test the fertilizer spreader. The time taken for the spreader to cover one hectare of land was estimated using a stop watch. The result in table 1 reveals that increase in the forward speed of the spreader leads to a reduction in the time taken for the spreader to cover a hectare of land. Thus, as the speed of the tractor increases from 5 km/hr to 20 km/hr, the time taken reduces from an average time of 16 minutes to 4 minutes. It therefore means that the speed of operation is inversely proportional to the time taken to accomplish the desired task.

ii) Machine Capacity

The average effective capacity gives an index of the application rate of the fertilizer. The average effective capacity as shown in table 1 reveals that at a tractor forward speed of 5 km/hr the average capacity obtained was 3.75 ha/hr. From field test conducted, the low speed resulted to an increase in application rate of 350 kg/ha. This increase in application rate would in turn hasten the growth of weeds and further impede the proper growth of crops. At an operating speed of 10 km/hr, the corresponding field capacity obtained was 7.5 ha/hr. At this speed and effective capacity, the application rate was still high at 290 kg/ha. At 15km/hr operating speed, an effective capacity of 11.25 ha/hr was obtained. At this operating speed and effective capacity, the application rate from the field test conducted was 250 kg/ha which is in agreement with the required application rate for rice crop as reported by Parish (2006). When the tractor was operating at 20 km/hr, the effective capacity was 15 ha/hr and the application rate obtained was 180 kg/ha which means insufficient nutrient supplement needed for the proper growth and development of the rice crop.

iii) Fertilizer distribution pattern

Using the tray method and later transferring the collected weighed samples into graduated test tubes, it was observed as recorded in table 1 that at a forward speed of 5 km/hr, a pyramidal pattern was obtained when the collected samples were emptied into the test tubes. At a forward speed of 10 km/hr, a pyramidal pattern with a convex apex was obtained. At an operating speed of 15 km/hr, the fertilizer was evenly distributed thereby giving an oval spread pattern which is in agreement with the spread pattern reported by Mahmood *et al.* (2014) as an acceptable spread pattern. At 20 km/hr, the fertilizer was not evenly distributed due to high speed.

CONCLUSION

A tractor drawn centrifugal fertilizer applicator which makes use of centrifugal force to broadcast fertilizer on the farm was developed and tested. From the test result on the fabrication and testing of the machine, the following conclusions were made:

i) The machine was able to effectively distribute fertilizer on the farm in an efficient and uniform manner at an optimum application rate of 250 kg/ha. Thus, eliminating time wastage and drudgery associated with manual method of fertilizer application.

ii) The effective spread width during the operation of the machine on the farm was found to be ten meters (10 m).

iii) The forward speed of the tractor that gave the most uniform and even spread was recorded at 15 km/hr. At this operating speed, the required application rate of 250 kg/ha was achieved at an effective capacity of 11.25 ha/hr. Increase in forward speed leads to a corresponding increase in the effective field capacity and a decrease in the application rate and time taken to cover one hectare

iv) At the optimum forward speed of 15 km/hr, the machine was found to have an effective capacity of 90 hectares per day which an entirely manual method would require large labour force to accomplish within a day.

v) The machine should be operated at an optimum forward speed of 15 km/hr as it would help alleviate the drudgeries encountered with manual methods.

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DEVELOPMENT OF AN AUTOMATED HYBRID SOLAR AND BIOMASS MORINGA LEAVES DRYER

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ABSTRACT

An automated hybrid solar moringa leaves dryer was designed, fabricated and tested. The machine is capable of drying moringa leaves using either solar energy or heat generated from biomass burning it operates between temperature ranges of 30^{o}C to 49^{o}C. The machine's major component parts include drying chamber, solar collector, transparent glass, biomass heating unit, drying trays, solar panel, fans, battery, temperature sensor, temperature control system and the solar controller. The machine can dry 20kg of wet moringa leaves in 5.35 hours when using solar energy and 3.20 hours when using biomass heating system. The test results revealed that fresh moringa leaves was dried from moisture content of 80.22% to 9.5% with drying temperature of 31±4.5^o and to 9.11 % with drying temperature of 49^o when solar energy and biomass heating system were used respectively. The machine has the advantage of producing hygienic and high quality dried moringa leaf.

Key Word: *Automated, biomass, hybrid, moringa, leaves, solar*

INTRODUCTION

Moringa oleifera leaves powder is becoming more popular because of its various socio-economic and health benefits. The leaves are extremely valuable source of nutrition for people of all ages. Nutritional analysis indicates that Moringa leaves contain essential disease preventing nutrients. They are an exceptionally good source of vitamin A, vitamins B, and C, minerals, and the sulphur-containing amino acids methionine and cysteine (Marcu, 2005). The composition of the amino acids in the leaf protein is well balanced since the dried leaves are concentrated; they contain higher amount of many of these nutrients. But if the moringa leaves are not carefully processed, they would definitely lose their potency and quality. Therefore, its processing is faced with numerous challenges. In Nigeria most of the moringa products processors lack efficient equipment and technical knowhow to develop a better means of processing moringa leaves to powder. The current processes involved in processing of moringa powder are energy exhausting and time demanding above all the products are mostly adulterated, counterfeit and of poor quality (Marcu, 2005). Chris (2010), reported some of the problem faced by moringa dealers to include: the attitude of buyers towards the local food supplements in general is poor as it is perceived as poor quality products. It is considered by most people as inferior products compared to imported alternatives. Lack of production technology to add value and flavour denies it the market advantages which could accrue to its nutrition potential. About 82% of the dealers and consumers complained about the lack standard production methods and quality control. The texture of the product differs between different processors. Hence, the design, fabrication and testing of moringa leaf powder processing equipment capable of providing acceptable, hygienic and good quality moringa leaf powder is of immense significance in alleviating some of the shortcoming associated with moringa leaf powder production. Thus, this presentation is on design, fabrication and testing of an automatic hybrid moringa leaves solar dryer.

MATERIALS AND METHODS

Materials Selection

Stainless steel materials were selected for construction of part of the equipment that will get in direct contact with the product in other to avoid contamination.

Description of the Machine

The automated hybrid dryer is made of the following components part

Battery

An average marine deep cycle battery was considered adequate since it has an advantage over other types of battery based on discharge and recharge ability.

Drying Chamber
This is made of stainless steel plate (1mm) and galvanize sheet (1mm), with glass fibre as an isolating materials between them. The chamber is made up of 0.9m x 0.9 x 0.8m dimension it contains an exhaust outlet portion at the upper part of the door as shown in Plate 2.

Solar Collector
The solar collector is 1.6m length and 0.8m width. It is made to be adjustable in order to vary the angle of tilt. It was designed to be heated by solar radiation from upper part or by artificial source of heat at the bottom. It has a space of 5 cm between the collector and transparent glass; this is to allow the passage of pre-heated air to the drying chamber.

Transparent Glass
This is transparent with thickness of 5mm. It allows the passage of solar radiations to the collector.

Solar Collector
This is cubical in shape it is made with 2mm mild steel material and then painted black to have heat absorption quality. The upper part is covered with transplant glass sheet (5mm thick). The bottom portion is fitted with two non-corrosive galvanize sheets and between them is the glass fibre, above this plate air space of 5mm was allowed in order to allow free circulation of heat energy generated by biomass heater to the back of the solar collector. It was designed to be adjustable between the angles of 10^0 to 30^0 this is to allow utilization of the solar system anywhere in Nigeria.

Biomass Heating Unit
This is attached at the bottom centre of the solar collector. It is cylindrical in shape bottom of the drying diameter which allows pre-heated air coming from solar collector to pass through the moringa leaves.

Drying Trays
These are 3 numbers each made with stainless steel mash and plate. They are 0.7m x 0.7m in dimensions. The trays are position inside the drying chamber in such a way that gap (space) for free air circulation is allowed round the trays.

Solar Panel
It was designed to be adjustable and it is mounted on top of the drying chamber. The solar panel used is 72 watt solar panel (plate 3). A marine deep cycle battery that has the advantage of discharging and recharging ability was used. The battery serves as power accumulator in a case where solar drying will take place over night in this case it needs to work for almost 18 hours without charging, this calls for selection of a large size battery of 18 ampere capacity.

Fans
These are four in number, two of which exhaust fans are fixed at the bottom of the drying chamber and covered at the end with filtering screen, while the other two were fixed at the front of the air collector for blowing of hot air to the drying chamber.

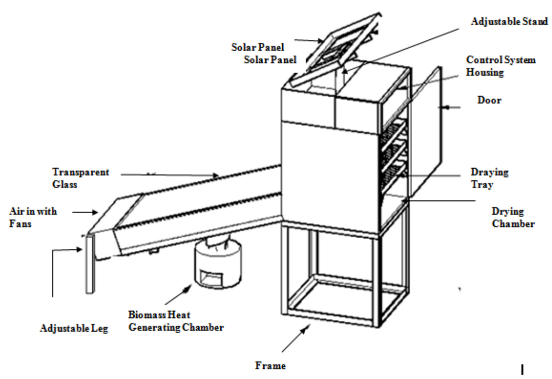

Figure 1: Automated Hybrid Solar Dryer

Design considerations
The following factors were considered in design of the dryer; quantity and inconsistency of products to be dried over a specified period of time; average ambient temperature and relative humidity for Bida area; initial moisture content of fresh products; and final moisture content considered safe for dried products. Ease of loading and unloading of the product, sources of heat generation, heat and mass transfer; and heat conservation during the drying process. Also considered were adjustment of the collector so as to allow varied collector angle, adjustment of the solar panel and strong support for the dryer frame, Consideration was also given the speed of air flow through the trays which must not be too high to cause the products to be blown off the drying trays. Spaces were allowed round the trays in order to allow circulation of the hot air (Adesoji and Omotara, 2014).

Design Computation

Angle of Tilt of the Solar Dryer

This is the angle of inclination of the collector it was determined using method reported by Alamu, Nwaokocha, And Adunola (2010).

$$\alpha = 10^0 + \text{lat } \beta \quad (1)$$

Where α is angle of tilt (Degree) and lat β is the latitude of the location

The latitude of Nigeria is between 4^0 and 14^0N. Therefore the angle was designed to be adjustable by substituting values of latitude into equation 1, the angle ranged between 10 and 30^0

Isolation on collector surface area

The isolation for Bida that is average daily radiation H on horizontal surface was obtained as 1250w/m^2 and average effective ratio of solar energy on tilted surface to that on the horizontal surface R = 1.0035

Thus, isolation on the collector surface was obtained as follows as reported Alamu, *et al.* (2010)

$$IC = HR \quad (2)$$

Where IC is isolation on the collector

H is average daily radiation H on horizontal surface

R is average effective ratio of solar energy on tilted surface to that on the horizontal surface

Mass Flow Rate of Air

The mass flow rate of air was determined by taking the average air speed and was calculated as reported Alamu, *et al.* (2010)

$$V_a = 0.13m/s \quad (3)$$

The air gap height was taken as 5cm = 0.05m, the width to be 80cm = 0.8m

Thus, volumetric flow rate of air

$$V_a^I = V_a \times h \times w \quad (4)$$

Thus, mass flow rate of air

$$M_a = V_a^I \times \rho_a \quad (5)$$

Where M_a is mass flow rate of air

V_a^I is volumetric flow rate of air

ρ_a is density of air taken as 1.28kg/m^3

h is height of the collector opening (m)

w is width of the collector opening (m)

Area of the Collector

The Area of the collector Ac was obtained as reported by Alamu, *et al.* (2010).

$$Ac = \frac{Ma\ x\ Cp\ x\ \Delta t}{0.5\ x\ IC} \quad (6)$$

Where Ac is the area of the collector (m^2)

Ma is mass flow rate of air (kg/m^3)

Cp is specific heat capacity of air

Δt is the temperature difference

IC is insolation on the collector surface (W/m^2)

In other to overcome losses that may occur 4 times the calculated area was used.

$$L = \frac{Acs}{B} \quad (7)$$

Where L is in length as the solar collector

Acs is the total area of the collector used

B is in Breadth as in collector

Base Isolator Thickness for the Collector

The rate of heat loss from air is equal to the rate of heat conduction through the insulation. The following equation holds for the purpose of design (Alamu, *et al.,* 2010)

$$\text{Ta} = \left(\frac{K \times AC \times (T_0 - T_1)}{(FMaCp\ (T_0 - T_1)}\right) \quad (8)$$

Where Ta is the thickness of the collector base (m)

K is thermal conductivity of fiber glass (0.037 m^{-1} k^{-1})

AC is area of the collector (m^2)

F = is factor given as 10%

Ma is mass flow rate of air (Kg/ m^3)

Cp is specific heat capacity of air

T_0 = 60^0C and T_1 = T_a = 30^0 approximately

Heat losses from the Solar Collector

The heat losses from the solar collector is give as reported by

$$Ic\ Ac\ Ta = Qu + QL + QS \quad (9)$$

But Qs is the energy stored which is considered negligible therefore

$$IC\ Ac\ Ta = Qu + QL \quad (10)$$

Thus QL the heat energy losses

$$QL = Ic\ Ac\ \tau\alpha - Qu \quad (11)$$

$$Qu = M_a C_p (T_O - T_1) = M_a C_p \Delta T \quad (12)$$

$$QL = UL\ Ac\ \Delta T \quad (13)$$

$$UL\ Ac\ \Delta T = Ic\ Ac\ \tau\alpha - M_a C_p \Delta T$$

$$UL = \frac{Ic\ Ac\ \tau\alpha - M_a C_p \Delta T}{Ac\ \Delta T}$$

Where Ac is the area of the collector (m^2)

IC is insolation on the collector surface (W/m^2)

Ta is the thickness of the collector base (m)

Qs is the energy stored which is considered negligible

τ *and* α are constant given as 0.86 and 0.9 respectively

Design and selection of size and type of fan to convey the drying air

The fan size was determined by calculating the volumetric flow rate of the drying air which was given by Adesoji and Omotara (2014) as:

$$M_v = M_{air} \times V_{sv} \quad (14)$$

where, M_v is the volumetric flow rate of the drying air in m^3/s,

M_{air} is mass of the air in kg

V_{sv} is the specific volume of the drying air in m^3 kg^{-1}

Energy required for drying

The quantity of heat energy required is determined as reported by Adesoji and Omotara (2014)

$$Q_h = M_{air}(h_2 - h_1) \quad (15)$$

where, Q_h is amount of heat energy in kJ s-1

M_{air} is air mass flow rate in kg s^{-1}

h_1 is specific enthalpy of air at inlet in kJ kg^{-1} air

h_2 is specific enthalpy of air at the drying chamber in kJ/ kg air.

Quantity of Biomass needed for combustion

The quantity of biomass needed to be burned in the combustion chamber was determined using equation reported by Adesoji and Omotara (2014)

$$Q_B = \frac{Q_h}{C_B} \quad (16)$$

where, Q_B is quantity of biomass needed for combustion in kg

Q_h is amount of heat energy required for drying in kJ

C_B is calorific value of charcoal in kJ/ kg.

Design of Solar system

Amount of energy estimated to circulate air inside the hybrid solar dryer and for controlling the solar dryer temperature if the system works for 24 hours is given as

$$A_E = 12watt \times Nd \quad (17)$$

Where A_E the amount of energy is required (watts)

Nd is number of hours the machine operate in a day

Size of the solar panel

Base on five hour daily light at least in Nigeria. The calculation of solar panel needed for the solar dryer is given as

$$S_Z = \frac{A_E}{5\ hour} \quad (18)$$

Where S_Z the solar panel needed (watts)

A_E the amount of energy is required (watts)

Solar Battery

The capacity of the battery was obtain as follows

$$S_C = \frac{S_Z}{12\ volt} = \quad (19)$$

Where S_c the capacity of the solar panel (Ah) and S_Z is the solar panel needed (watts)

Plate I: Side View of the Hybrid Solar Dryer

Plate II: Drying Chamber

Plate III: Furnace

Mode of Operations of the Plants

The greenhouse effect was adopted as the main working principles of this hybrid solar dryer. The sources of heat for the dryer are indirect solar energy and heat generated from heating of biomass materials. The heat energy from any of the two sources (depend on the one in usage) heat up the fresh air entering from atmosphere through air inlet and is passed through the bottom of the drying chamber. The hot air extract moisture from moringa leaves and it is exhausted through the air outlet. As the hot air passed into the drying chamber the temperature of the chamber increases, as it reaches the pre-set temperature of 49^0C the temperature sensor inside the drying chamber will send a signal to the control system which in turn activate the hot air extractor fan situated at the bottom of the drying chamber. The fan blows in filtered air into the chamber which cools the temperature of the chamber. As the temperature decrease to 30^0C the temperature sensor is reactivated again and sends a signal to the control system which in turn deactivate the extractor fan. This process continues automatically until moisture content of the leave is reduced to the desired moisture content.

Sample preparation

The leaflets were striped from the leaf petiole, diseased and damaged leaves were discarded. The leaflet were washed using the developed washer with potable water to remove dirt; the leaves are washed again in 1% saline solution (NaCl) for 5 minutes to remove microbes. The leaves were further washed with 70% ethanol which was also washed twice with distilled water. Draining of excess water from the leaves was carried out by spreading the leaves on perforated trays made with stainless steel inside the draining chamber. The leaves were dried to the maximum recommended moisture content of 9% using the automated solar dryer. The dried leaves were milled and sieved using the developed stainless steel hammer mill. The moringa leaf powder was finally dry to moisture content below 7.5%.

Proximate Composition

The Proximate composition including moisture, fat, crude protein, ash, and carbohydrate contents of the leave powder were evaluated at the National Cereal Research Institute Badeggi, Bida, Niger State. The protein and ash contents were determined using the method of AOAC (2000). The moisture, fat and crude fibre contents were determined using the method described by AOAC (2005), while carbohydrate was by difference as reported Alakali, Kucha, and Rabiu (2015).

RESULTS AND DISCUSSION

The automated hybrid moringa leave power processing machine was design, constructed and performance testing was also carried out. The result of the performance evaluation carried out on the machine is presented below

Effect of drying temperature on proximate composition

The proximate composition of fresh, solar dried and biomass dried *Moringa oleifera* leaves samples are presented in Table 1.

Table 1: Proximate Composition of Fresh and Dried Moringa Leaves

Parameter	Fresh Moringa Leaves	Solar energy (Dried for ave. time 5.35 hours)	Biomass energy (Dried for ave. time 3.20 hours)
Moisture content	80.22±1.2	9.50±0.37	9.11±0.09
Fat	1.03±0.08	2.18±0.13	2.08±0.18
Ash	1.59±0.17	4.76±0.05	5.02±0.08
Fibre	2.9±0.06	16.72±0.08	16.93±0.06
Protein	9.95±0.15	30.16±0.21	27.46±0.23
Carbohydrate	4.31±0.23	36.68±1.29	48.51±1.32

The results show that all the parameters changed when the leaves were dried either using the solar or the biomass heat generating unit. From figure 2, the fresh moringa has higher moisture content of 80.22%, this value is higher than that in samples dried using solar energy and biomass heat generating with values of 9.5 and 9.11 % respectively.

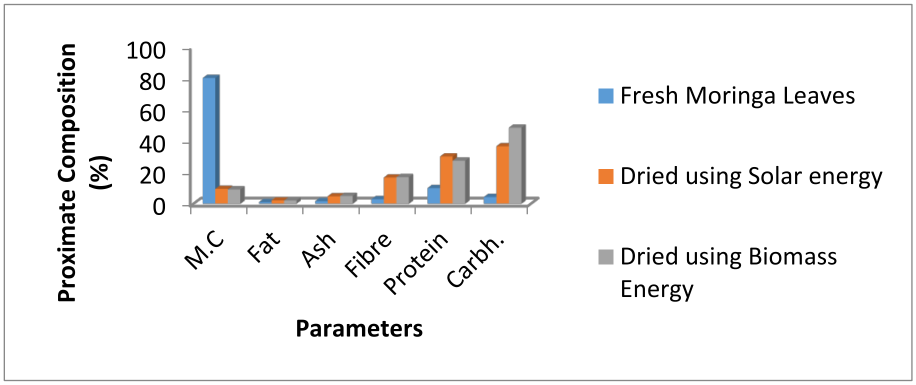

Figure 2: Relationship between Drying Methods and Proximate Composition of Mringa Leaves Powder

The fresh moringa leaves is lower in fat, ash, fibre, protein and carbohydrate. This could be as result its high moisture content. The solar method with drying temperature of 31±4.5 has high value of fat and protein contents of 2.18% and 30.16% respectively. This is in lined with the report of Kumar, Kari and Mohammad (2014), where mild drying conditions with lower temperature may improve the product quality but decrease the drying rate. Samples dried using biomass heat generating unit are higher in ash and carbohydrate contents with values of 5.02% and 48.51% respectively.

CONCLUSION

This paper presents the design, construction and preliminary testing of an automated hybrid solar dryer for drying moringa leaves. The results of preliminary tests of the machine revealed that fresh moringa leaves was dried from moisture content of 80.22% to 9.5% and 9.11 % when solar energy and biomass heating system were used respectively. The solar method with drying temperature of 31±4.5^o has the highest value of fat and protein contents of 2.18% and 30.16% respectively while samples dried using biomass heat generating unit with drying temperature of 49^o are higher in ash and carbohydrate contents with values of 5.02% and 48.51% respectively.

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DYNAMICS OF THE FUNCTIONAL PARAMETERS OF AN AUTOMATED MACHINE ON SOYA MILK YIELD

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ABSTRACT

The dynamic of the functional parameters of an automated grain drinks processing machine on yield of soya milk was investigated in this study. Response Surface Methodology (RSM) was used to develop polynomial regression model and investigate the effect of changes in blending blade, basket orientation and speed of rotation on yield of the milk using central composite rotatable design (CCRD). The result reveals that blade type and speed of rotation have significant ($p\leq 0.05$) effect on yield of the milk while basket orientation has insignificant ($p\leq 0.05$) effect. It was observed that the experimental data fitted well. The value of adequate precision of 19.55 also showed that the model equation can be used to navigate within the experimental range. Numerical optimization carried out produced optimum values at basket orientation of 44.25°, 3-blade assembly, speed of 1400 revolution per minute with corresponding milk yield of 98.2 %.

Key Word: *Blade type, basket orientation, speed, optimization, yield, milk*.

INTRODUCTION

In order to develop alternative machine for production of hygienic grain drinks from different varieties of soaked grains, effects of blade configuration, basket orientation and speed on yield of the grain milk were studied. The production of grain drinks from grains can be accomplished using different equipment (Simolowo, 2011). According to Gbabo *et al.,* (2012) burr mill and small household blender are mostly used in Nigeria. For dimensioning the machine and their component, several factors should be taken into consideration, from hygiene of the product, time taken in the production process, to tediousness of the operation (Simolowo, 2011).

The introduction of new technology which enable the combination of the basic operations of blending of the soaked grains, mixing of the slurry, extraction of the milk and expelling of the paste out of the machine all in single unit, as well as the automation of these operation makes the process more attractive.

The automated grain drink processing machine makes the production process of grain beverages production more attractive, more efficient compared with the existing method which involves different equipment for different operation. The innovation is also relevant when the goal is to produce hygienic drink which is free from contamination and of high quality. This paper presents of optimization of functional parameters of the machine based on yield of grain milk

MATERIALS AND METHODS

Experimental Setup

For performing the experiment on optimization of functional machine parameters based on yield of soya milk, an automated grain drink processing machine was used as shown in Plate I. The machine functional parameters which include blade type, basket orientation and speed were studied. Each of these factors was design to have five different levels as shown in Table 1. The soya milk and paste obtained from processing soya beans using the developed automated grain drinks processing machine are shown in plate II and III.

Plate I: Automated Grain Drinks Processing Machine

(A) (B)

Plate II: Soya Milk Flow from Blending Chamber to; (A) Temporary Milk Tank and (B) Out of the Machine

(A) (B)

Plate III: Soya Paste Expelled out; (A) Paste Collector (B) Packed Out of the Machine

Material preparation

The soya bean (TGX 1954-IFXTGX 1835-10E) was obtain from Kure Market in Minna, it was cleaned, sorted and soaked before processing using the developed machine as recommended by Gaffa *et al.,* (2003) and as shown in Plate II and II.

Experimental Design

In this investigation three factors and five levels were studied as shown in table 1. Based on preliminary investigation and review of literature the high and low values were selected as reported by Gbabo *et al.* (2012) and Hassan *et al.* (2011). The factors levels were utilized for conduction design of experiment as shown in Table 1.

Table 1: Matrix Transformation of Five Level- Three Factors Central Composite Rotatable Design of the Experiment

Run order	Coded X_1	Values X_2	X_3	Real Blade Configuration	Values Basket Orientation	Speed of Rotation
1	-	-	-	3	30	1000
2	+	-	-	5	30	1000
3	-	+	-	3	50	1000
4	+	+	-	5	50	1000
5	-	-	+	3	30	1400
6	+	-	+	5	30	1400
7	-	+	+	3	50	1400
8	+	+	+	5	50	1400
9	-1.682	0	0	2	40	1200
10	+1.682	0	0	6	40	1200
11	0	-1.682	0	4	23	1200
12	0	+1.682	0	4	57	1200
13	0	0	-1.682	4	40	864
14	0	0	+1.682	4	40	1536
15	0	0	0	4	40	1200
16	0	0	0	4	40	1200
17	0	0	0	4	40	1200
18	0	0	0	4	40	1200
19	0	0	0	4	40	1200
20	0	0	0	4	40	1200

Note: *X_1= Blade Type, X_2= Conical Basket Orientation, X_3= Combine Speed of Blade and Basket, -1.682 and +1.682 = Axial Values of X_1, X_2 and X_3 (Anuonye, 2006).*

Statistical and Optimization Analysis

Design Expert Software Version 7.0.0 was used for the regression and graphical analysis. Analysis of variance was also carried out at 5 % significant level (Myers *et al.,* (2004). Optimization is the process of finding the best solution for a system or operation. The main purpose of optimization is to achieve optimum conditions for the operation of a system or machine. In this study the optimization analysis were carried out as reported by Anounye (2006).

Optimization Technique

Design expert ® 7.0.0. software was employed using numerical technique for the optimization of independent variables and the dependent variables in this study. By applying the desirability functions method in RSM, numbers of solutions were obtained for the optimum covering criteria with desirability close to 1 and the first solution with desirability closest to 1 was selected.

Conducting the Experiments

The experiment was conducted following the design matrix, and the yield of milk was computed as follows;

Yield of the Milk

This is the quantity of the aqueous liquid produced by the machine and was determined as reported by Onuorah *et al.*(2007). It is given as

$$Y_M = \frac{A}{MT} \text{ x } 100 \qquad (1)$$

where, Y_M = the Yield of the Milk (%)

A = the amount of the material passed through the sieve (kg)

MT = the total weight of the material fed into the machine (kg)

RESULTS AND DISCUSSION

Yield of the Milk

The yield of the milk is percentage ratio of weight of the aqueous liquid produced by the machine to total weight of material fed into the machine and it was evaluated using the formula reported by Onuorah *el al*. (2007) (equation 1).

The relationship between independent variables; blade configuration, basket orientation and speed with yield of the milk was presented in Table 2. It was observed that the yield of the milk ranged from 91.47 % to 98.2 %. The highest value of 98.2 % was obtained from combination of 3 blades assembly, basket with half angle of 30° and speed of 1400 r.p.m, while the least yield of milk of 91.47 % was obtained from interaction between 4 blades assembly, basket with half angle of 40° and speed of 864 r.p.m.

Table 2: Matrix Transformation of Five Level- Three Factors Central Composite Rotatable Design of the Experiment

Run order	Real Blade Configuration	Values Basket Orientation	Speed of Rotation	Yield of Milk (%)
1	3	30	1000	94.72
2	5	30	1000	94.14
3	3	50	1000	95.3
4	5	50	1000	94.95
5	3	30	1400	95.53
6	5	30	1400	95.07
7	3	50	1400	97.85
8	5	50	1400	92.63
9	2	40	1200	95.41
10	6	40	1200	97.5
11	4	23	1200	98.2
12	4	57	1200	97.16
13	4	40	864	95.65
14	4	40	1536	95.88
15	4	40	1200	95.53
16	4	40	1200	92.17
17	4	40	1200	97.16
18	4	40	1200	91.93
19	4	40	1200	93.79
20	4	40	1200	91.47

Statistical Analysis

The result of statistical analysis of variance (ANOVA) of the experimental is shown in Table 3. The significant model terms were identified at 95% significance level.

Calibration of the Model

The model F – value of 31.94 implies that the model is significant. There was only 0.01% chance that a Model F value this large could occurred due to noise. The value of Probability > F less than 0.0500 indicated that model terms were also significant. In this case A, C, A^2, and C^2 were significant model terms. It is observed that C (speed) had more significant effect on yield of the aqueous milk with coefficient of estimate of 1.745 followed by blade configuration of -1.30546.

The "Lack of Fit F-value" of 0.05 implies that the Lack of Fit is not significant relative to the pure error. There was a 99.72% chance that a "Lack of Fit F-value" this large could occur due to noise. The non-significant lack of fit is good for model to be able to predict the response (Aworanti *et al.,* 2013). The coefficient of determination R value of 0.9831 indicated that the model was able to predict 98.31 % of the variance and only 1.69 % of the total variance was not explained by the model. The coefficient of correlation R- Squared value of 0.9664 was high though large value of R^2 does not always suggest that the regression model is a good one because it will increase when a variable is added regardless of whether the additional variable is statistically significant or not Xin and Saka (2008). Hence predicted and adjusted R^2 were suggested to be used to check the model adequacy. It was also observed that the Predicted R – Squared of 0.9415 was in reasonable agreement with the Adjusted R – Squared of 0.9361 which indicated that the experimental data fitted better. The value of adequate precision of 19.54661 obtained which was above the minimum value of 4 was reported by Salam *et al.* (2014). This indicated an adequate signal which showed that the model can be used to navigate the design space (Salam *et al.,* 2014).

Table 3: Regression Analysis of Response of Yield of the Milk

Source	Coefficient of	Standard	F – value	P- value Prob >F	R-	
Model	95.82549	0.2028	31.94282	< 0.0001	0.9664	Significant
A-Blade Confg. (No.)	-1.30546	0.134553	94.13304	< 0.0001		
B-Basket Orient.	-0.07349	0.134553	0.298301	0.5969		
C-Speed (r.p.m.)	1.745	0.134553	168.1914	< 0.0001		
AB	0.14625	0.175802	0.69206	0.4249		
AC	-0.31875	0.175802	3.2874	0.0999		
BC	-0.00125	0.175802	5.06E-05	0.9945		
A^2	-0.35258	0.130984	7.245867	0.0226		
B^2	-0.20939	0.130984	2.555626	0.1410		
C^2	-0.49754	0.130984	14.42855	0.0035		
Lack of Fit			0.051826	0.9972		not

Regressed Model Equation

$$Y_M) = 95.83 - 1.31A - 0.073B + 1.75C + 0.15AB - 0.32AC - 1.250 \times 10^{-3}BC - 0.35A^2 - 0.21B^2 - 0.50C^2 \quad (1)$$

Where, Y_M = Yield of Milk (%), A = is the blade type (Number), B = is the basket orientation (Degree) and C = is the speed of blending (r.p.m)

The model equation was improved by removing the insignificant model terms. Values greater than 0.1000 implies that the model terms are not significant (that is B, AB, AC, BC, B^2 were not significant) and since these terms are insignificant the models were reduced to equations 2 from 1, in order to improve the models (Aworanti *et al.,* 2013).

Fitted Model Equation

$$\text{Yield of Milk (\%)} = 95.83 - 1.31A + 1.75C - 0.35A^2 \quad (2)$$

It is important to add that the variable C in the model has positive co-efficient implying a direct proportionality while A has negative co-efficient implying an indirect proportionality. That is independent increase in A decreased the yield of the milk while increase in C increased the yield of the milk.

Simulation and Validation of the Model

The model equation obtained was simulated and the yield of the milk was observed to be within the experimental range as shown in Table 3. The actual value of yield of the milk was in close agreement with the predicted value. This indicated close agreement between the predicted value and observed value validating the need for the model equation to be used to determine the optimum yield of milk at various operating conditions.

Table 3: Relationship Between Actual and Predicted Values of Yield of Milk

Standard Order	**Actual Value**	**Predicted Value**
1	94.14	94.22617
2	91.93	91.96024
3	93.79	93.78919
4	92.17	92.10826
5	98.2	98.35617
6	94.72	94.81524

7	97.85	97.91419
8	94.95	94.95826
9	97.16	97.02375
10	92.63	92.63271
11	95.53	95.35682
12	95.07	95.10963
13	91.47	91.4835
14	97.5	97.35296
15	95.41	95.82549
16	95.88	95.82549
17	97.16	95.82549
18	95.3	95.82549
19	95.65	95.82549
20	95.53	95.82549

Response Surface and Contour Plot for Yield of the Milk

The response surface and contour plot for the yield of the milk are presented in Figures 1 and 2. The yield of the milk increased from 92.2 % to 98.3 % as the speed of blending increased from 1000 r.p.m to 1400 r.p.m. This could be due to increase in cutting and shearing actions of the blade with increased in rotational speed. Jayesh (2009) had reported that speed of blending had a significant effect on size reduction of solid materials. Where, higher speed of blending resulted to more yield of the material than lower speed of blending. But the yield of the milk was observed to decrease from 98.3 % to 94.4 % with increased in blade configuration from 3 blades to 5 blades assembly with speed of 1400 r.p.m. This could be as result of decreased in contact between the blade and the grains with increased in configuration. This result agreed with the result of earlier findings by Rachel *et al.* (2007) where blade design was found to affect blending of materials. There was significant ($P \leq 0.05$) difference of 6.1 % in yield of the milk between speed of 1000 r.p.m and 1400 r.p.m. Also significant ($P \leq 0.05$) difference of 3.8 % was observed in yield of the milk from 3 and 5 blades assembly. The maximum yield of the milk of 98.3 % was obtained from combination of speed of 1400 r.p.m and 3 blades assembly. This value was observed to decrease to 97.5 % when the speed was increased to 1536 r.p.m and also decrease to 97.16 % when the blade number was reduced to 2 blades assembly. This could be as result of clogging of the sieve holes by fine particles (increase in segregation) produced by increased in speed of blending and decreased in blade configuration. This agreed with the result of an earlier study by Douglas (1997) where high speed of blending was found to produced finer particles that clogged together and blocked the sieve holes, thus prevent materials from passing through the holes.

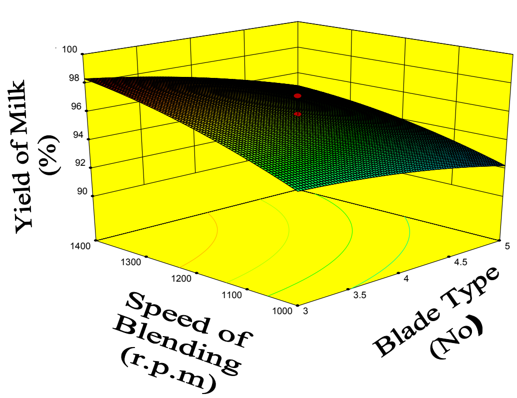

Figure 1: Response Surface of Yield of Milk

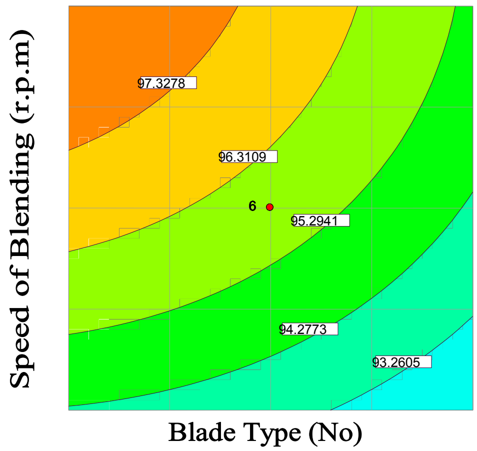

Figure 2: Contour Plot of Yield of Milk

3.2.4 Optimization of the Machine Functional Parameters

The ramp for the optimization is shown in Figure 3; it gives the optimum values of 3-blades assembly, basket of half angle of 44.25 º and speed of 1400 r.p.m., while for the responses; yield of milk was 98.2 %.

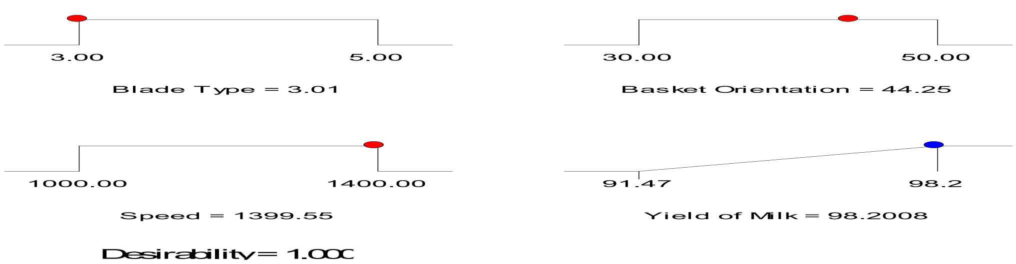

Figure 3: Ramp for Optimization of Machine Performance Parameters

CONCLUSIONS

The interaction effects between the machine parameters showed that yield of the milk increase with increased in speed of blending from 1000 r.p.m to 1400 r.p.m and also with decrease in blade type (number) from 5 blades assembly to 3 blades assembly. The basket orientation was found to have no significant effect on blending efficiency.

The developed mathematical models and individual coefficient were found to be significant while the Lack of fit was significant. The experimental values were found to fit better with close agreement between predicted r-squared and adjusted r-squared values. The model equations can be used to navigate within the experimental ranges with high adequate precision values of 19.55.

Optimization of the functional machine parameters was carried out using numerical optimization technique by applying desirability function method in rsm. The best optimal machine functional parameters of 3-blades assembly, basket of half angle of 44.25 º and speed of 1400 r.p.m., while for the yield of milk was 98.2 %,

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EVALUATION OF WATERMELON RIND AND STEVIA FOR THE PRODUCTION OF FRUIT JUICE CONCENTRATES

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ABSTRACT

This study reports the use of watermelon rinds formulated with stevia plant for the production of fruit juice concentrate. This is to ascertain the possibility of value addition to the nutritional compositions of the end products. Completely Randomised Design experimental setup was adopted. The samples was divided into six portions: fresh watermelon pulps (FWMP), fresh watermelon rind (FWMR), dried watermelon pulp (DWMP), dried watermelon rind (DWMR), grind stevia sample (DSPS) and the formulated concentrates (WRSC). The samples were analysed using standard laboratory procedures in triplicates and values were statistically analysed using SPSS statistical tool (16.0 version). Vitamin A, C and E in the final product are 0.18±0.02mg/100g, 0.11±0.01mg/100g and 0.12±0.02mg/100g respectively. Total phenol and flavonoid contents of the product increased significantly as it ranged between 0.03±0.02 to 0.57±0.00mg/100g and 0.01±0.00 to 0.07±0.00mg/100g respectively. Stevia sweetener is recommended for food processing industries as this will serves as substitute for sugar non-consuming patients.

Keyword: *Watermelon rind, stevia plant, fruit juice concentrate*

INTRODUCTION

The application of fruit and vegetable wastes for the production of edible substance has taken a boom to reduce environmental pollution. These residues consist of some nutritional components (Polyphenols and antioxidants) essential for human health. However, Larrosa *et al.,* (2002), in a study revealed that Agricultural and industrial residues are attractive sources of natural antioxidants and dietary fibre.

Watermelon (*Citrullus lanatus*) is one of the most widely cultivated crops around the world contains 6% of sugar and 91% of water by weight. Like other fruits, it is very rich sources of vitamins and also serves as other source of health beneficial nutritional constituents including phytonutrients (FAO, 2006). Study revealed that watermelon rinds are edible parts and can be used as vegetable for which citrulline in the sample gives it antioxidant effects that protect consumers from exposure to danger (Leong and Shui, 2002). Therapeutic effect of this fruit has been ascribed to antioxidant compounds (Lewinsohn *et al.,* 2005). However, researchers speculated that the rinds are capable of relaxing blood vessel such as cancer and cardiovascular disease (Rimando *et al.,* 2005).

Watermelon rinds are edible and contain many hidden nutrients, but most people avoid eating them due to their unappealing flavour. They are sometimes used as vegetables. In China, they are stir-fried, stewed or more often pickled. Pickled watermelon rind is commonly consumed in the Southern US (Rattray and Diana, 2012). Bushra, (2013) in a study reported that fresh watermelon contain 170.7 mg, 8.1mg and 0.05 mg of vitamin A, C and E with 19%, 13.5% and 0.5% recommended daily allowable intake (RDAI). Watermelon rind possess significant amount of moisture, ash, fat, protein and carbohydrates 10.61%, 13.09%, 2.44%, 11.17% and 56.00% (Al- Sayed and Ahmed, 2013) and rind contribute 30% of the total weight.

Rimando *et al.,* (2005), also revealed that 1-inch cube of watermelon rind contains 1.8 calories of which majority of the calories is constituted in the carbohydrates, with 0.32 g per serving. Further report stated that one serving provides 2 per cent of the daily recommended intake of vitamin C and 1 per cent of the vitamin B-6 required by human body every day. It is however, essential to find out the way of using watermelon rinds (so-called "wastes‟) for the formulation of different food products.

Stevia (*Rebaudiana*) is a nutrient rich natural sweetest plant of Asteraceae family used for sweeten tea and beverages centuries back in some part of the world (Ena *et al.,* 2013). The plant leaves naturally contain diterpene glycosides stevioside, rebaudiosides A-F, steviolbioside and dulcoside, which are responsible for its sweet taste and have commercial value all over the world as sugar substitute in foods, beverages or medicines. It is a magical plant which offers sweetness with fewer calories and does not show any side effects on human health after consumption. *Stevia* has many pharmacological and therapeutic applications as suggested by many preclinical and some clinical studies; these are nontoxic and possess antioxidant, antimicrobial, antifungal and anticarcinogenic activity (Ena *et al.,* 2013).

Stevia plant has been reported with a lots of economic importance which can be used as sweetening agent in products like biscuits, jams, chocolates, ice-creams, baked foods, soft drinks, soda, candies and also common beverages like dip tea, coffee and herbal tea that are targeted particularly at the diabetics and also the health conscious consumers (Jaroslav *et al.,* 2006). Toxicological studies indicated that secondary metabolites embedded in *Stevia* does not have adverse effect on human health and as such, no allergic reactions, teratogenic and arcinogenic effects have been observed after consuming stevia plant as sweetener (Pol *et al.,* 2007). Stevia plant required warm sunny atmosphere and grow well on sandy soil. However, the preferable and natural climatic weather condition is semi-humid subtropical temperature ranging between 21 to 43^{O}C on average of 24^{O}C (Huxley, 1992).

MATERIALS AND METHODS

Sample Collection and Preparation

Fresh samples of watermelon (sugar baby variety) of 1200±15g weight were procured from a local market in Bauchi, Bauchi State Nigeria. The stevia herb was purchased from a local vegetable market in Dass, also in Bauchi State. The watermelon was washed then the rind was peeled and separated from the washed fresh fruits (pulp), the sample were further cuts into pieces and spread in trays, dried at 50^{O}C for 72 hours using air oven. The sample was grind into fine powder using laboratory mill. The stevia plant was separated from undesirable materials such as sand and other particles, and then pounded to fine powder with the use of a mortar and pestle, samples were mixed and sieved. A tea spoon each from the prepared grind samples (grind stevia stem and grind watermelon rind) were properly stirred together, mixed in a ratio 1:1 proportion and diluted in a glass cup with water. Organoleptic properties were determined and the diluted liquid sample was observed for microbial growth for 92 hours. Other nutritional properties (Vitamin A, C and E among others) were evaluated in the Chemistry Laboratory II of the Department of Chemistry, Faculty of Science, Abubakar Tafawa Balewa University, Bauchi. Bauchi State. Some of the equipment used in this study include: a set of test tubes, beakers, a weighing balance, a graduated cylinder, an oven, sieves, a Soxhlet extractor and a UV-V spectrometer. Standard reagents were also used for the analysis. However, the dried concentrate was used for the evaluation of the nutritional constituents to ascertain the possibility of value addition in the sample mixture.

Experimental Setup

The experiment was fitted into a completely randomised design (CRD) experimental procedure. The watermelon parts were divided into two portions: fresh rind (A), fresh pulp (B), while the stevia was placed in a container tagged sample C. The content of samples A and B were cut separately into small sizes of length 8cm and breadth 3cm to ease the drying process. The samples were dried at temperatures and drying times of 50^{O}C and 72 hours respectively using the oven drying method until the dried (watermelon rind and dried watermelon pulp) samples were obtained. Vitamin A, vitamin E, vitamin C, total phenol content and the total quantity of flavonoids content in samples were determined in three replicates.

RESULTS AND DISCUSSION

The results obtained for samples after being assessed individually showed statistical variations in the nutritional contents (vitamins and phytonutrients contents) in each part (Table 1). This however, revealed that both fresh and dried rinds samples contained significantly lower values in their respective nutritional compositions than the fresh and dry pulp.

Table 1: Nutritional and some Phytonutrient Compositions of Watermelon Parts, Stevia Herb and Concentrate Formulation

Sample	Vitamin A (mg/100g)	Vitamin C (mg/100g)	Vitamin E (mg/100g)	Total Phenol Content (mg/100g)	Total Flavonoid content (mg/100g)
FWMP	0.21±0.00^{c}	0.33±0.00^{d}	0.48±0.00^{c}	0.03±0.00^{b}	0.01±0.00^{a}
FWMR	0.07±0.00^{a}	0.04±0.00^{a}	0.04±0.00^{a}	0.02±0.00^{a}	0.01±0.00^{a}
DWMP	0.53±0.00^{d}	0.82±0.00^{e}	0.48±0.00^{c}	0.03±0.00^{b}	0.03±0.00^{a}
DWMR	0.18±0.00^{b}	0.10±0.01^{b}	0.11±0.02^{b}	0.07±0.00^{a}	0.03±0.00^{a}
DSPS	0.06±0.00^{a}	0.15±0.00^{c}	0.10±0.01^{b}	0.57 ±0.00^{c}	0.07±0.00^{b}
WRSC	0.18±0.02^{b}	0.11±0.01^{ab}	0.12±0.02^{d}	0.10±0.02^{d}	0.03±0.03^{a}

* Values are expressed as mean ± SEM, n = 3, Values not sharing a common superscript letter differ significantly at $P < 0.05$

FWMP = Fresh Watermelon Pulp, FWMR = Fresh Watermelon Rind
DWMP = Dried Watermelon Pulp, DWMR = Dried Watermelon Rind
DSPS = Dried Stevia Plant Stem, WRSC = Watermelon Rind with Stevia Concentrate

Table 1, indicated that vitamin A content of fresh watermelon rind (0.07±0.01 mg/100g) was significantly lower than that of the fresh pulp (0.21±0.00 mg/100g), while the dry concentrates also revealed that the vitamin A content in the rind (0.18±0.00 mg/100g) was significantly lower than the dried pulp (0.53±0.00 mg/100g). Similar pattern were observed for vitamins C, vitamin E, Phenol and Flavonoid contents in this study.
The result of Vitamin A contents (0.07±0.00 mg/100g) in this study is significantly lower than the reported value of 1.71mg/100g reported by a researcher (Bushra, 2013). Variation in the value could be attributed to difference in the species and maturity stage of the watermelon sample used for the experiment. But the Vitamin E content (0.48±0.00 mg/100g) in this study is significantly higher than the reported value (0.05mg/100g) of the same researcher.
The result of vitamin C (0.11±0.01mg/100g) contents of the end products in this study is however significantly higher than the reported value of 0.081mg/100g by Bushra, (2013). This could be associated with the addition of the mixture of the stevia combination with the watermelon rind along the processing chain which signifies value addition to the juice concentrate. The vitamins contained in the stevia herb are lowest when compared to the watermelon pulp, this is similar for all nutritional content studied (Table 1).
Phytonutrients are described as natural bioactive compounds from plants with general benefits to human health (Erukainure *et al.,* 2010), Flavonoids and phenol contents quantified in this study (Table 1) were observed to be significantly high in the stevia herb (0.07±0.00 mg/100g) and (0.57 ±0.00 mg/100g) compare to in fresh and dried watermelon rind (0.03 ±0.00 mg/100g) and (0.07±0.02 mg/100g) respectively at ($p>0.05$).
The result of fruit juice concentrate formulated in this study was observed to maintain its vitamin A (0.18±0.02) contents while an appreciable increase in the vitamin C contents (0.11±0.01mg/ 100g)is an indication that the sample combination does not affect the nutritional contents of the product after formulation.

There were slight significant ($p<0.05$) reductions in vitamin E contents, total phenolic and total flavonoid contents of the formulated concentrate with values 0.12±0.02(mg/g), 0.10±0.02(mg/100g)and 0.03±0.03 (mg/100g) respectively. These could be attributed to prolong drying time and temperature along the processing chain.

Shelf Stability of the Product
The product concentrate when diluted with water was observed to change its initial taste after the second day (24 hours) and grow moulds from the fourth day (48 hours). This is however in line with the speculated precautions prescribed for all other fruit juice concentrates (Foster clark, Tiara, Jolly juice and Nutri C) after dissolved in water. These produce after dissolved in water also changes their respective taste after few hours.
However, the dried samples of the product concentrate maintained its normal physical characteristics after four months of storage in an air tight container under room temperature as shown in Tables 2 and 3.

Appearance / Month	Dried Concentrate	Diluted Product / day	Observation / day
November, 2015	No sign of spoilage	Day 1	Fresh/ No foul taste
December, 2015	No sign of spoilage	Day 2	Fresh
January, 2016	No sign of spoilage	Day 3	Foul taste
February, 2016	No sign of spoilage	Day 4	Growth of Moulds.

The mean score for colour, mouth feel, taste, consistency and overall acceptability preference to product concentrate obtained from ten (10) trained testers are presented in Table 3.

Table 3: Organoleptic Properties of Sample at Day 1 after4 Months of Product Storage

Sample	Mouth Feel	Taste	Consistency	Colour and Appearance	Overall Acceptability
Product Concentrate	6.40±1.07^{b} (Good)	4.90±1.07^{c} (Sour)	10.00±0.00^{b} (Good)	8.10±0.90^{b} (Fair)	3.60±0.98^{b} (Good)

Concentrate formulation was subjected to sensory evaluation after four (4) months of storage. Table 3 showed the mean organoleptic scores of ten (10) trained panellists' feelings. A significant Approximate number of 6.40±1.07

panellist attest to the mouth feel of the products after the forth months to be good while the 10.00±0.00 panellist supported that consistency of the product were both preferred and had good remarks, however the colour and taste received approximate values of 8 and 5 mean scores signifying a fair look and a sour taste respectively. An approximate number of 4 panellists enjoyed the overall acceptability of the end product to be good while the others are neither fair nor bitter.

CONCLUSION

The fresh and concentrated forms of the watermelon pulp and rind at similar weights as evaluated in this study reflected that the concentrated forms contained more vitamins and antioxidants. The rinds were also seen to contain a significantly lower concentration of nutrients than the pulp ($p<0.05$) and the stevia was found to have a higher level of antioxidants than the rind and pulp, although lower in vitamin content. The product concentrate was produced, and evaluated to have higher concentration than its constituents in the nutritional composition. The watermelon rinds were evaluated and found to contain some phytochemicals which are useful for pharmacological and agricultural purposes.

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DESIGN, FABRICATION AND TESTING OF A MOTORCYCLE MOUNTED HERBICIDE BOOM SPRAYER

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ABSTRACT

A motorcycle mounted herbicide boom sprayer with a capacity of 2 ha/hr was designed and fabricated in order to overcome some of the challenges associated with the existing equipment for weed control such as knapsack sprayer, tractor mounted boom sprayer etc. The machine was fabricated from locally available materials and comprises of the following parts: battery, spray pump, tank, hose, boom, nozzles and frame. Test results indicate that at 8, 10, 12 and 14 km/hr ground speeds, the spray application rates were 286, 270, 256 and 245L/ha respectively while the corresponding field capacities in ha/hr are 1.5, 1.8, 2.1 and 1.8 respectively. The field efficiencies obtained for the four different speeds are 78.2, 76.1, 72.1 and 75.4% respectively. Maintenance and replacement of parts used is easy since all the components are available locally.

Keywords: *Weeds, sprayer, herbicide, crop, farm*

INTRODUCTION

Weeds are plants that are seen as hazardous or injurious to people, animals or crops. These undesirable plants infest different crops thereby reducing yield by as much as 95% due to shading and competition for light and nutrients (Santos *et al.,* 1996). In an effort to reduce the activity of weeds on the farm, a lot of energy, time and resources are wasted, which could have been invested in other farm operations. As a result of the manual method of weeds removal been tedious and time consuming, various technical methods have been devised to control or eliminate weeds. Some of these methods include use of mechanical equipment, flooding, mulching and herbicide application using sprayers (Hamid *et al.,* 2011).

A sprayer is defined as a device that utilizes mechanical energy to atomize liquid chemical into a spray fog for pests, disease, insects or weed control in a given area of land (Prasad, 1994). Spray equipment vary in terms of mode and scale of application, ranging from knapsack sprayers to tractor operated boom sprayers. However, the knapsack sprayer has their shortcomings of drudgery, limitation in application rate (200L/ha) and field efficiency (56%) depending on the operator (Campbell and Altman, 1997). Also the tractor operated boom sprayer have their disadvantages such as high cost of the equipment and cost of operation and maintenance.

In view of the shortcomings associated with the existing methods of applying herbicides on the farm, this work "design, fabrication and testing of a motorcycle mounted herbicide boom sprayer" was conceived with a view of increasing the application rate limitation of the knapsack sprayer and at the same time solve the high cost problem of the tractor drawn boom sprayers.

MATERIALS AND METHOD

Design Considerations

In carrying out this design work, the followings were put into consideration

i. Capacity of the chemical reservoir (plastic tank).
ii. The height of the boom and nozzle from the ground.
iii. The rate of herbicide discharge.
iv. Head losses.
v. Compactness and availability of construction materials.

Design Calculations

Determination of the Rate of Herbicide Discharge

The rate of herbicide discharge was determined as given by equation 1.

$$Q = A.V \qquad \text{(Rajput, 2006)} \qquad (1)$$

Where,
Q = discharge (m^3/sec)
A = Area of cross-section of the hose pipe (m^2)
V = Velocity of the liquid (m/sec) .

Determination of Head loss in the hosepipe
Due to friction in the hose pipe, head losses are inevitable. This was calculated from equation 2

$h_f = \frac{4fl}{D*2g} * v^2$ (Rajput, 2006) (2)

Where,
h_f = Head lost in the hosepipe
f = Friction factor
L = Length of the hosepipe (m)
D = Diameter of the hosepipe (m)
G = acceleration due to gravity (m/s^2)

Determination of power delivered by the pump
The power delivered by the pump was determined by equation 3.
$P = wQH_p$ (Rajput, 2006) (3)
P = Power delivered by the pump (W)
w = Fluid static weight (kg)
Q = Pump flow rate (m^3/s)
H_p = Head delivery by pump (m).

Determination of the Velocity of the liquid chemical in the Hose pipe
The velocity of liquid travelling in the hose was calculated using equation 4.

$V_O = \frac{Q}{A}$ (Nakayama and Boucher, 2000)

(4)

$V_O =$ Velocity of the fluid (m/s)

Q = the pump flow rate (m^3/s)

$A = \frac{\pi D^2}{4}$

$D = Internal\ diameter\ of\ the\ hose\ (m)$

Determination of the Tank Capacity
The tank was considered as a cuboid and as such, the capacity was calculated using equation 5.
V_t = L x W x H (Omeni *et al.,* 1997) (5)
Where,
V_t = Volumetric capacity of the tank (m^3)
L = Length of the tank (m)
W = Width of the tank (m)
H = Height of the tank (m)

Machine Description
The followings are the component of the motorcycle herbicides sprayer.

Tank: This is a rectangular 25 litres capacity plastic tank. It holds the liquid chemical temporarily before delivery on the farm.
Hose: These are fluid pathways provided to connect the bottom and top openings of the tank so as to release the herbicide and to return excess herbicide to the tank.
Strainer: This is a mesh made of very fine silk of 0.05mm diameter provided in the nozzle to prevent dirt from clogging the tip or orifices of the nozzle. The meshes are loosely inserted in the nozzles so that they can easily be cleaned occasionally when they are dirty or clogged.

Spray pump: This is a 12 volt DC pump. It sucks the liquid from the tank at low pressure by means of a hose and releases it to the nozzles through the boom at a very high pressure.

Battery: This is the source of power for the pump. It is a 12 volt, 7 amps rechargeable battery.

Nozzles: The nozzles help to atomize the chemical solution into droplets and deliver the liquid in a desirable spray pattern to the target object.

Boom: This is a 1.75 mm diameter PVC pipe used in connecting the four nozzles with the aid of screw extensions. A hose is used to link the center of the boom to the tank. .

Machine frame: The machine frame is made of 2 inches rectangular light pipe with dimensions, 35mm x 25mm x 55mm (length, breadth and height) and a 2mm thick bottom mild steel plate on which the tank seats.

Principle Of Operation

The various parts of the machine were coupled together and the tank was filled with liquid chemical. The strainer was placed at the inlet of the tank to remove impurities that may likely block the nozzles. With the motorcycle set in motion and the switch connecting the pump and the battery turned on, spraying was actuated and continuously spraying was maintained by the constant motion of the motorcycle

MACHINE EVALUATION

The machine was tested as shown in plates 1 and 2 at four different ground speeds of 8, 10, 12 and 14 km/hr with a view of determining the spray application rate, field capacity, and field efficiency. Each of the experiment was done in triplicate and the results obtained are tabulated in table 1

Plate 1: Spraying proces

Plate 2: Spray overlap from adjacent nozzles

Spray application rate (L/ha)

The spray application rate was calculated using equation 6 in order to know how many litres of chemical that will be needed per hectare.

$$\text{Application rate (L/ha)} = \frac{600 * \text{Total sprayer output } (L/min)}{\text{Swath width}(m) * \text{travel speed } (km/h)} \quad (6)$$

Field capacity

The field capacity is the number of hectare that can be sprayed per unit time. It was evaluated by equation 7.

$$\text{Field capacity (FC)} = \frac{\text{Width}(ft) * \text{Speed } (mph)}{8.25} \quad (7)$$

Field efficiency (FE%)

Field efficiency is defined as the percentage of time the machine operates at its full rated speed and width while in the field and it was calculated using equation 8.

$$\text{Efficiency (E\%)} = \frac{A_c}{A_t} \times 100 \quad (8)$$

Where,

A_c = Area covered with chemical

A_t = Total area of field travelled

RESULTS AND DISCUSSIONS

Table 1: Average Machine performance at varied motorcycle speeds

Motorcycle speed (km/h)	Spray application rate (L/ha)	Field capacity (ha/h)	Field efficiency (%)
8.0	286	1.5	78.2
10.0	270	1.8	76.1
12.0	256	2.1	72.1

Spray Application Rate

From table 1, the result shows that the spray application rate depends on the speed of the motorcycle such that the lowest speed 8 km/hr had the highest application rate of 286 L/hr while the highest speed recorded the lowest application rate of 245 L/hr. This means that the slower the motorcycle speed, the higher the application rate and vice versa.

Field capacity

The result presented in table 1, shows that the field capacity is directly proportional to the motorcycle speed. The highest motorcycle speed, 14 km/hr recorded the highest field capacity of 2.8ha/hr and the least field capacity of 1.5 ha/hr was observed for the lowest speed of 8km/hr.

Field efficiency

The field efficiency as shown in table 1 reduces with increase in the motorcycle speed. The major reason for this reduction is due to wind effect. As the speed increases, the higher the chance of the spray to be prone to wind drift.

CONCLUSION

The motorcycle mounted herbicide boom sprayer was designed, fabricated, and tested. From the test result on the fabrication and testing of the machine, the following conclusions were made:

i) The optimum application rate of the motorcycle mounted sprayer was found to be 270 L/ha with an average field efficiency of 76.1%. This indicates a 35 % increase in application rate and 34 % increase in efficiency compared to conventional knapsack sprayer (200L/ha application rate and 56% efficiency).
ii) Field capacity of the machine increased with speed.
iii) The motorcycle mounted sprayer reduced the risk of chemical exposure to man since it is sprayed behind the operator.
iv) Also, the cost of maintaining the machine is low compared to tractor mounted sprayer

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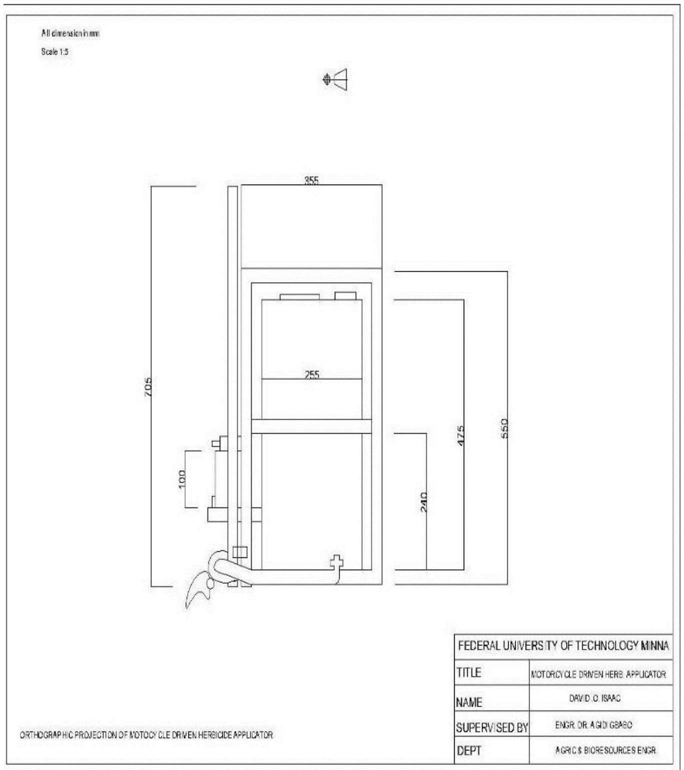
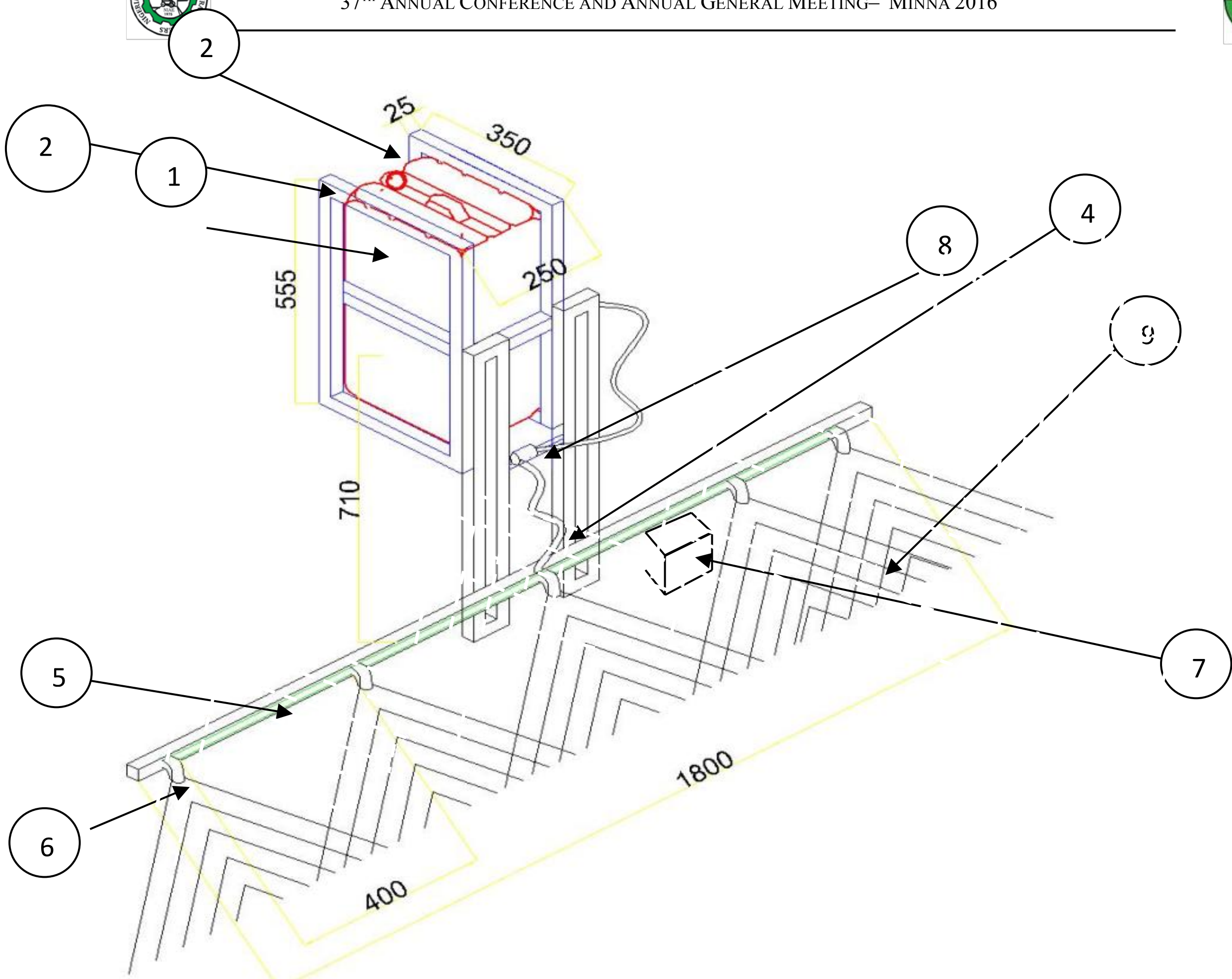


Isometric view of motorcycle mounted herbicide boom sprayer



1	TANK
2	FRAME
3	ADJUSTABLE ARM
4	HOSE
5	BOOM
6	NOZZLE
7	BATTERY
8	PUMP
9	SPRAY (OVERLAP)

DEVELOPMENT AND OPTIMIZATION OF OPERATIONAL PARAMETERS OF A GAS-FIRED BAKING OVEN

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ABSTRACT
In this study an indigenous gas-fired bread baking oven at affordable cost for small-scale entrepreneur was developed. It is an insulated rectangular box-like chamber, made of galvanized -steel sheets and having a total dimension of $920\ mm \times 650\ mm \times 600\ mm$. *The oven characteristics were evaluated in terms of the baking capacity, baking efficiency and weight loss of the baked bread. The physical properties of the baked breads were measured and analyzed using Duncan multiple range test of one way ANOVA at significant level of* $p<0.05$. *These properties were optimized to determine the optimum baking temperature using 3D surface response plot of Statistical Release 7. The baking capacity, baking efficiency, weight loss and optimum baking temperature were: 12.5 kg/hr, 87.8%, 12.5 g, 200-220 °C, respectively. The physical properties of baked bread dough were found to correspond with the imported product (control sample). These results showed that, the developed gas-fired oven can be adopted for baking of bread at domestic and commercial levels.*

***Keywords*:** small-scale entrepreneur, heat exchanger, baking compartments, optimum baking temperature, physical properties.

INTRODUCTION

Almost in every continent, bread has become one of the most widely consumed non-indigenous foods and it is the second most widely staple food after rice (Abdelghafor *et al.* 2011). More importantly, it is a ready to eat convenient food in Africa for both urban and rural communities. It is made from wheat flour dough that is cultured with yeast, proofed and baked inside oven (Komlaga *et al.* 2012). There are many combinations and proportions of type of flour and other ingredients, likewise different traditional recipes, which resulted to wide varieties of breads, likewise in terms of shapes, sizes and texture (Shittu *et al.* 2007). In addition to bread, baking is used to prepare biscuit, cakes, pastries, pies, cookies and crackers. Baking oven is a complex simultaneous heat and mass transfer process equipment commonly applied in food industries. An oven can be simply described as a thermal insulated chamber used for the heating, baking, cooking, or drying of food substances (Mondal and Datta, 2008). During baking, the driving force of heat transfer is the temperature gradient while that of mass diffusion is concentration difference. However, both occur simultaneously within the food product from the outer part to the inner part of the food material. Basil (2014) reported that the moisture migration in the food material occurs mainly by convection and conduction, less by radiation; hence product looses moisture as baking continued. He also reported that for the effective baking, heat losses should be minimal. Hence, in Nigeria, indigenous baking ovens are wood fired or electric types that were made from mud, metals and non-metals. Their shortcomings are: longer baking time, non-homogenous heat distribution and thermal energy losses which resulted to increase in the cost of production, likewise air pollution (Aborisade and Adewuyi, 2014).

In Nigeria, increasing population, rapid urbanization, and changing food habits have resulted to preference for ready to eat convenient foods such as bread, biscuits, and other baked products, despite the increase in their prices (Ogunjobi and Ogunwole, 2010; Adebowale *et al*. 2012). Unfortunately in Nigeria, the large-scale bakers utilize the imported ovens, which are unaffordable to small-scale or household bakers (Aborisade and Adewuyi, 2014). Presently, irregular supply of electricity in Nigeria has rendered electric baking oven unproductive across the all level of operations. Therefore there is a need for the development of an indigenous gas-fired bread baking oven, with the enormous availability of liquefied gas in Nigeria. It was reported that gas-fired baking oven enhances flavor and uniform distribution of heat transfer better than any type of oven (Okafor, 2014; Genitha *et al.* 2014). Aborisade and Adewuyi (2014) also reported that the gas-fired oven is cheaper to run than diesel-fired oven, more so that it produced less greenhouse gas which resulted to global warming effect. Hence, the aim of this work is to develop and evaluate a gas-fired bread baking oven for small-scale entrepreneur at affordable cost using local contents.

MATERIALS AND METHODS

Materials

The materials of construction were locally sourced and procured at Owode-Onirin Iron Market, Ikorodu Road and International Industrial Market Alaba, Lagos. The major materials are: galvanized-steel sheets of varying thickness for the fabrication of inner frame, outer cover and baking compartments, seamless steel pipe for gas line and heat exchangers, fiber glass as insulator, angle iron for stands, regulator and thermocouples as transducers. The main components of the oven are the frame, door, baking compartment, heat exchanger and burner, gas pipeline, and chimney. The supporting frame is made of mild-steel angle iron. Some design considerations for materials selection are: food compatibility factor, thermal conductivity value, corrosion resistance, availability and cost. The dimensions of angle iron for the supporting frame were selected based on the total load capacity in term of its dead-load value and bending moment. The thermal resistivity value of the lagging material for the insulated walls was considered in terms of affordability and availability factors.

Design calculations

Volume of the baking compartment and oven capacity

The capacity of the oven is directly proportional to the number of bread loaves/batch and its dimensions (size of the baking pan and the dough weight).
Assume average weight of bread = 250 g as design basis, having volume of 1.17×10^{-3} m^3
Bread surface area = 0.018 m^2. The surface area occupied by 20 loaves of bread = 0.36 m^2.
Two baking compartments dimensions are then established as follows:
The Surface area of baking tray for each compartment = 0.2 m^2
Therefore, the surface area of each baking compartment = 0.20 m^2
The vertical height of the baking compartment proposed = 0.18 m
Therefore, Capacity of the oven = 0.036 m^3

Volume of the heat exchanger

The efficiency of the heat transfer depends on the volume of the heat exchanger and atomizing efficiency of the burners. Hence, the volume of heat exchanger is calculated as:

$$V = l \times b \times h \quad (1)$$

Where, l = length of the baking chamber (450 mm)
b = width of the baking chamber (400 mm), h = height of the baking chamber (120 mm)
Volume = 0.036 m^3

Energy generated by the heat source (gas burner)

Energy generated= Heat gained by food products + heat radiated to the environment of the heating chamber + heat conducted through metal surfaces.

$$H_g = H_p + H_c + H_m \quad \text{(Mayilsamy and Rudramoorthy, 2006)} \quad (2)$$

Where: H_g = the quantity of heat produced by the gas burner
H_p = the quantity of heat gained by food product (Bread dough)
H_c = the quantity of heat radiated to the heating chamber
H_m = the quantity of heat conducted through lateral walls (galvanized steel sheet)

$$H_p = M_p C_p \Delta T \quad \text{(Mayilsamy and Rudramoorthy, 2006)} \quad (3)$$

Where: M_p = Mass of food product
C_p = Specific heat capacity of food product (Bread dough = 2890J/kgK) (Zheleva and Kambourova, 2005)
ΔT_p = Change in temperature that occurred
Baking of the dough piece for 30 minutes with 20 bread dough pieces with an average weight of 250 g, hence total weight of dough is 5.0 kg, Hence, H_p = 4.3MJ

Energy radiated

$$H_c = \delta (T_1^4 - T_2^4) \quad \text{(Mayilsamy and Rudramoorthy, 2006)} \quad (4)$$

Where: δ = The constant of Stefan-Boltzmann (5.669×10^{-8} W/m^2K^4)
T_1 = Initial temperature of surrounding air, T_2 = Final temperature of surrounding air
H_c = 9.45 MJ

***Thermal conductivity to the two baking* chamber**

$H_m = \frac{KA(T_1 - T_2)}{L}$ (Kreith and Boehm, 1999). (5)

Where: K = Carbon steel conductivity (54 Wm/K), A = Area of the baking chamber = 0.18 m^2
L = distance between the dough and the heating element (0.120 m)
H_m = 28139.4 J/sec m^2 for 30.0 min. = 50.7 MJ/m^2 for the two compartments = 101.4 MJ/ m^2, for the baking compartment surface area of 0.36 m^2 , H_m= 36.5 MJ

The gas energy generated by butane gas
The calorific value of Butane = 45.752 MJ/kg
Total butane consumed for 30 min. = 1.25 kg
Total energy generated by butane as input = 57.19 MJ

Description of the major working components
The assembly drawing and exploded views of the oven are shown in Figs. 1 and 2, respectively.

The inner frame outer cover
This is made of galvanized steel sheet of 2.5 mm thickness internally and 1 mm externally. All the six walls were lagged with glass wool, having coefficients of thermal conductivity of 0.45 W/m^{o}C. The gas-fired oven is a rectangular box-like chamber of : $920\ mm \times 650\ mm \times 600\ mm$ shown in Fig. 3. The oven was designed such that the bread dough is loaded on the top surface of the two baking compartments. Each baking compartment has its own heat exchanger at the top and bottom for the effective heat and mass transfer during baking of bread dough.

Gas burner
This is made of seamless steel pipe of Ө 25 mm. It was fabricated into a u-shape, drilled along its longitudinal length of 350 mm with 2.0 mm drill bit size to form a burner. A gas nozzle of 0.95 size was fitted to the inlet part of the burner, while the outlet part was closed to retain gas pressure for effective atomization. There is an opening for air admittance with a shutter to regulate fuel and air stoichiometric ratio that will enhance lean combustion.

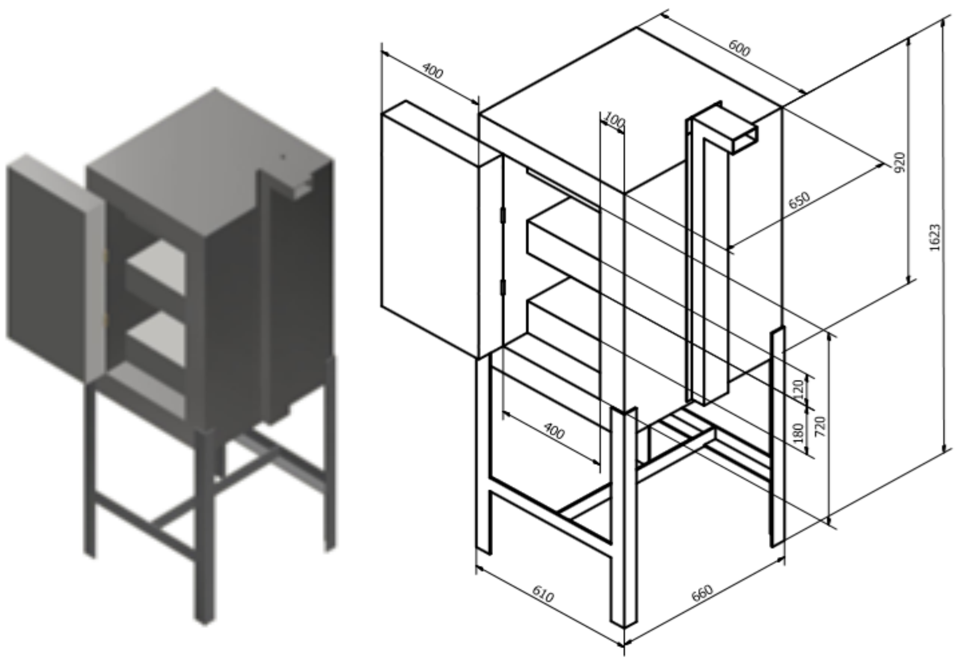
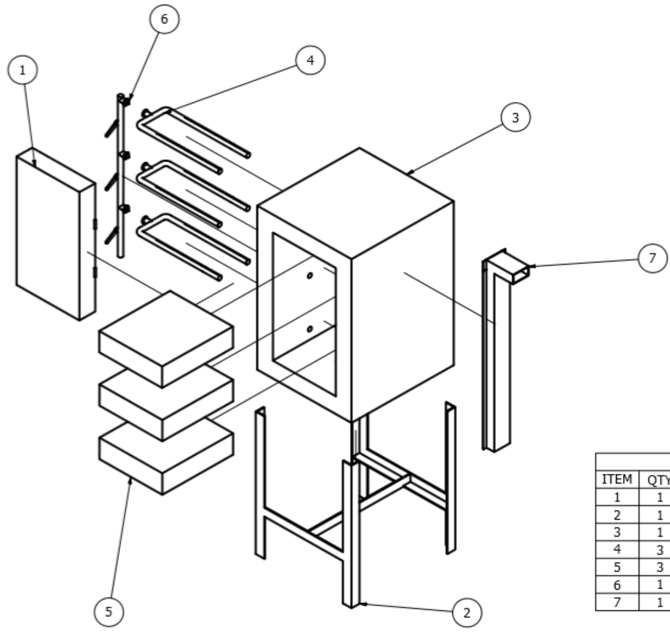


Figure 1: Solid view and Assembly drawing of the gas fired oven



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Door	Stainless steel insulated
2	1	Stand.	steel mild
3	1	Body	Stainless steel insulated
4	3	Burner	steel mild
5	3	Gas combustion chamber	Stainless steel insulated
6	1	Gas delivery line	steel mild
7	1	Chimney	Stainless steel

Figure 2: Exploded view of the oven

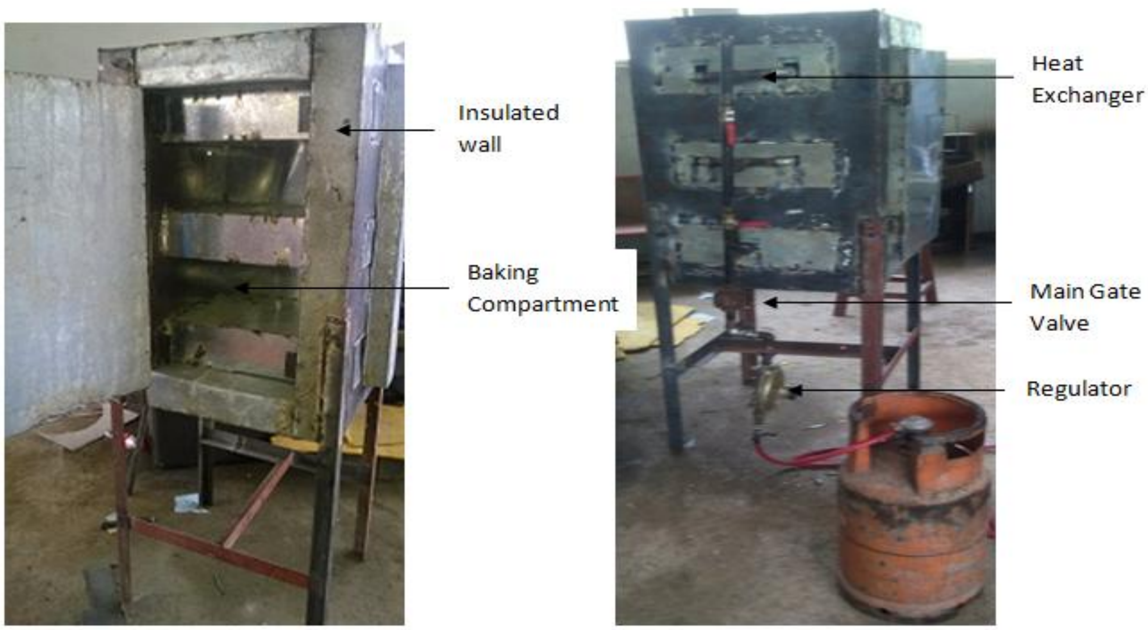


Figure 3: Fabricated gas-fired bread baking oven

The three gas burners were arranged inside the three heat exchangers vertically, with the help of a gas pipe. Each burner has its control gate valve for the regulation of gas flow rate. During baking operation, butane is discharged from the gas cylinder which flows through the regulator to the main supply line then to the nozzle via a gas valve, and finally atomized through burner for combustion inside heat exchanger.

Heat exchanger

There are three heat exchangers in this gas-fired oven shown in Fig. 3 as gas combustion chambers. They are made of galvanized steel sheet of 2.0 mm thickness with these dimensions: 400 mm × 650 mm × 120 mm. The three heat exchangers are connected to a common chimney which helps to vent exhaust gas from the heat exchangers. During evaluation of the oven performance thermocouples were installed to measure the temperature values both at the out wall and baking compartments.

Baking compartment

There are two baking compartments, where baking tray is suspended. They are the outer part of heat exchangers, having dimensions of 400 mm × 450 mm × 180 mm as shown in Fig. 2. This baking oven has three heating exchangers for effective heat transfer from its bottom and top parts.

The door

Both inner and outer walls of the door are made of galvanized sheet material of 2.5 mm and 1.0 mm respectively. The dimension of the door is 100 mm × 450 mm × 720 mm. It was hinged to the inner frame of the oven at two points to enhance adequate suspension. The door is lagged with glass-wood to prevent heat loss to the environment and baker.

The supporting Frame

These are four legs that suspended the baking oven vertically. They are made of mild-steel angle iron of 75 mm × 75 mm × 3.0 mm.

Regulator

A gas regulator of 0 – 12 bar pressure value was installed to built-up gas pressure and to regulate the flow rate consistently on gas delivery line. It was located in between the gas cylinder regulator and the main gate valve.

Thermocouple

Four thermocouples were installed in each baking compartments and heat exchanger for measuring the temperature values during baking operation.

Dough preparation

The bread dough was prepared by mixing 2.8 kg of flour, 24.2 g of salt, 100 g of butter, 25 g of yeast, 3.0 litre of water and 50 g of sugar using a planetary dough mixer for 5 min. The dough was then divided into required measurements and kneaded into a ball shape. The kneaded dough was divided and weighed into 200, 250, 300, 350, 400, 450 (g) as one set. Three sets were made in triplicates, then moulded and placed inside clean and oiled baking-pans of six different sizes to develop moist surface. A set of six sizes of moulded dough was placed inside a proofer for 1 hour 30 min. at 45 ^{o}C. During the proofing process, alcohol is produced with carbon dioxide due to fermentation of sugar content by the yeast. This resulted to dough rising to almost a doubling height. After the proofing process, they were transferred and properly arranged on the baking tray then loaded inside oven and baked for 30 min at 180 ^{o}C temperature (Okafor, 2014). These procedures were observed for other two sets of six moulded dough at 200 and 220 ^{o}C baking temperature consecutively. The physical dimensions at an interval of 5 min. of loss in the weight and vertical height of dough were measured at a varying baking temperature.

Performance evaluation of the gas-fired Oven

After fabrication of the oven, the performance evaluation based on the machine characteristics was carried out to establish optimum baking temperature at constant time, likewise the baking efficiency and capacity of the oven.

Baking capacity

The number of pieces of the bread dough in each baking compartment depends on the arrangement of the food samples in the baking chamber. The baking capacity of the oven was determined by putting into consideration the size of the baking pan and the dough weight.

Baking efficiency

The Baking efficiency of the oven is calculated using the Equation. 6.

Baking efficiency, $\eta = \frac{Output energy}{Input energy} \times 100$ (Okafor, 2014). (6)

Weight Loss in the Food Samples

The weight loss in the food samples (bread dough) was calculated by subtracting the weight of the food sample after heating from the initial weight of the food sample. The percentage of moisture loss was obtained using Equation. 7.

Weight Loss = $\text{Initial Weight} - \text{Final weight}$

Percent Moisture Loss = $\frac{\text{Initial Weight} - \text{Final weight}}{\text{Initial Weight}} \times 100$ (7)

Oven spring

The sudden rise or rapidly expansion of dough during the first ten (10) minutes in the oven is called oven-spring. Several factors may influence oven-spring. The quantum of heat energy and increase in volume of dough, moisture content, carbon dioxide and ethanol evaporates. All this causes increase in internal pressure of dough and the dough rise rapidly in the initial stage of baking. The Yeast activity decreases as the dough warms and the yeast is inactivated at 55ºC (Khatkar, 2004). This oven-spring of the baked bread dough was measured in terms of vertical height using a digital vertical-height venial caliper (0 - 300 mm, Mutitoyus, Germany).

Physical properties of the food sample

For the effective investigation of the oven-spring of the baked bread, these other physical properties were evaluated in terms of surface area, specific volume, density and relative density. Each property was determined using the mathematical equations 8 - 12.

The surface area

The surface area = $2(lb + bh + lh)$ (8)

Volume =$lenght \times breadth \times height$ (9)

The density

Density= $\frac{mass}{volume}$ (Avadhanula, 2002): (10)

The specific volume

The specific volume= $\frac{volume}{mass}$ (Avadhanula, 2002)

(11)

Statistical analysis

The data of the physical properties of the baked bread dough of the developed oven and the imported proto-type (gas-fired baking oven in the Department of Food Science and Technology, ObafemiAwolowo University, Ile-Ife) was analyzed using Duncan multiple range test of one way ANOVA at significant level of p<0.05. The optimum baking temperature was also investigated and established using 3D surface response of STATISTICA Release 7.

RESULTS and DISCUSSION

Performance evaluation of the gas-fire bread baking oven

The developed gas-fired bread baking oven was evaluated at three levels of temperatures: 180, 200 and 220 ºC uninterruptedly during dough baking to establish the optimum baking temperature at a constant period of 30 min. During the baking process, the initial bread dough of white colour changed to varying degrees of brownness as baking temperature increased. The final product had an outer layer that is semi-rigid less fragile structure called the crust layer while the inner part of the dough had a crumb texture. Figure 4 a, b and c depicted level of browning reaction of baked dough at various temperatures. Both physical and chemical changes of dough occurred as result of effective heat and mass transfer due to several mechanisms such as convection, radiation, conduction, evaporation and condensation of steam. Generally, it was observed that starch gelatinization begins as baking temperature increases with subsequent amylase activity and gluten coagulation. The gluten matrix surrounding the individual cells transformed into a semi-rigid film structure and almost doubling oven-spring rate for every 10 °C increase of temperature. It was also observed that the rate of oven-spring was higher at 220 ºC baking temperature than other baking temperatures and that browning reaction increase as baking temperature increases (Fig. 4 a-c). It was established further that visible browning reaction was more pronounced at baking temperature of 220 ºC. This browning reaction is chiefly responsible for the development of the attractive bread flavor and typical browning coloration of the bread crust which enhances the firmness. These observations were in agreement with the reports of Hofmann and Lindenmeier, 2004; Khatkar, 2004 and Genitha *et al*., 2014.

(a) (b) (c)

Figure 4: Bread baking at various temperatures of (a) 180 ºC (b) 200ºC (c) 220 ºC

Baking capacity
The gas-fired baking oven has two baking compartments, in each compartment, a total of 10 pieces of bread dough in baking pans of size 145 mm × 90 mm × 60 mm was attained. The baking chamber of the fabricated gas-fired bread baking oven has a volume of 0.036 m^3, can bake 20 pieces of bread dough in one batch. Therefore, the gas-fired baking oven has maximum baking capacity of 12 kg/hr.

The baking efficiency
In Table 1, it was observed that baking efficiencies increased relatively to the increased in the baking temperatures. The optimum baking efficiency of the oven occurred at the baking temperature of 220 ºC most especially when the weight of dough was increased to 450 g. This may be due to the increased in the surface area of the bread dough to absorb maximum thermal energy dissipated from the heat exchangers. The baking efficiency of the gas-fired bread baking oven was obtained using calorific value of the butane as liquefied petroleum gas estimated as 87.8 % as shown in Table 1.

Heat loss in the oven
The heat loss from the oven to the environment was estimated to be 6.95 MJ after considering the heat absorbed by the bread dough, heat radiated to the environment of the heating chamber and the heat conducted through metal surfaces.

The weight loss

The result of the weight loss during the baking process of the bread dough at different baking temperatures (180, 200 and 220°C) is showed in Fig. 5. However, it can be seen from the Fig. 5 that as the baking temperature increased the weight loss increased linearly. Furthermore, it can be observed that in Fig. 5, the weight loss increased, with increased in time and baking temperature. More importantly in Fig. 5, it was also observed that at the increased of baking temperature from 180 to 220°C, there was a corresponding increased in weight loss from 7.9 to 12.5 g. Likewise in Fig. 5, the maximum weight loss at the baking temperature of 180 °C was 7.9 g, while that of 220 was 12.5 g. There was no much disparity between the weight loss in dough during the baking at 180 °C and 200°C. However, there was a tremendous weight loss at the baking temperature of 220 °C comparatively. Hence, as the baking time increased, moisture loss increased, which resulted to reduction in the final weight of the baked dough. The same observation was reported by Carvalho and Martins, 1993 and Genitha *et al*., 2014 on moisture loss and modeling heat transfer at the evaluation of the development gas-fired bread baking ovens. These results were also synonymous to previous research report of Bahnasawy and Khater, 2014 on moisture loss during baking of bread dough using gas-fired oven.

Table 1: Baking Efficiency of the gas–fired oven

	Baking Temperatures (°C)		
	180	**200**	**220**
Weight of Dough	**Baking Efficiency (%)**	**Baking Efficiency (%)**	**Baking Efficiency (%)**
200	85.45	85.80	86.80
250	85.47	86.85	86.85
300	85.49	86.95	87.90
350	85.62	87.25	88.25
400	85.75	87.50	88.30
450	86.00	87.80	88.70
Average Baking Efficiency (%)	85.63	87.02	87.80

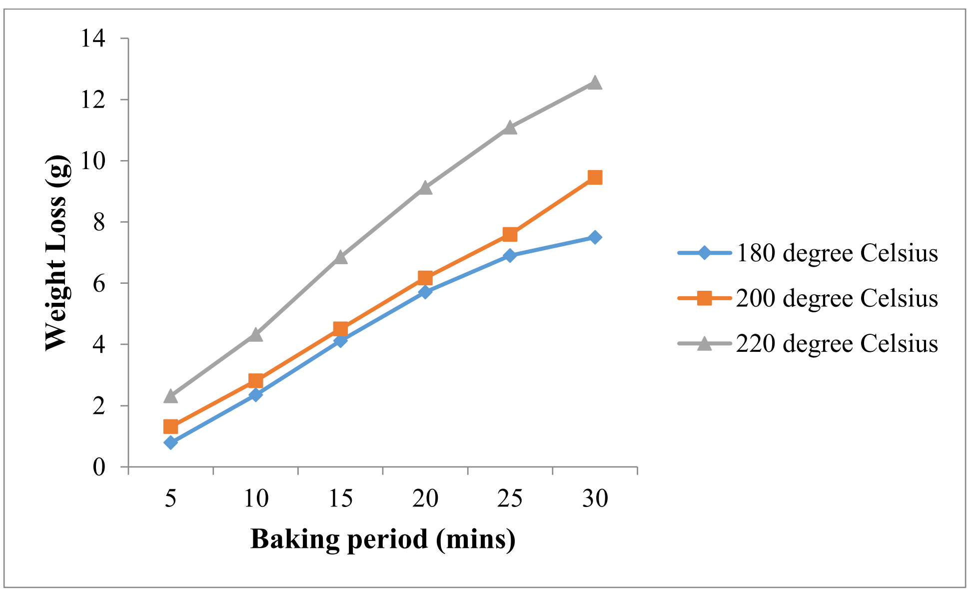


Figure 5: Weight loss of dough at various level of baking period

Physical properties of baked bread

The results of the physical properties of baked bread dough of 200, 250, 300, 350, 400 and 450 (g) in respect to the changes in their surface area, volume, density and specific volume at baking temperatures of 180, 200 and 220 (°C) were showed in Fig. 6 - 9. In Fig. 6, it is clearly demonstrated that at increased of the dough weight, the surface area of baked bread increased relatively to the increased of baking temperature.

The effect of baking temperature on the surface area of the baked bread

However, it can be seen from Fig. 6 that the maximum surface area of the baked dough occurred at the optimum baking temperature of 220 °C, with the minimum surface area at 180 °C. The quadratic regression modelling equation relating surface area of the baked bread to the baking temperature at six (6) different weights of dough is shown as Equation 12.

$$\textit{Surface Area} = 64.0189 + 1.4629X - 2.626Y - 0.0012X^2 + 0.0098XY + 0.0082Y^2 \quad (12)$$

Where : X= Weight of dough and Y= Baking temperature

In comparison of the baking efficiency of this newly developed oven to that of imported proto-type, the surface area of baked breads were compared with the control sample at 180 , 200 and 220 (°C) for 30 min. as showed in Tables 2 – 7. These results showed that the surface areas of the baked breads of newly developed oven were significantly different from the control sample at a level of p>0.05. The major reason was that the surface area of the control sample was found to be higher than the corresponding dough weight of 350 g baked by the newly developed gas-fired oven in Tables 2, 4 and 6.

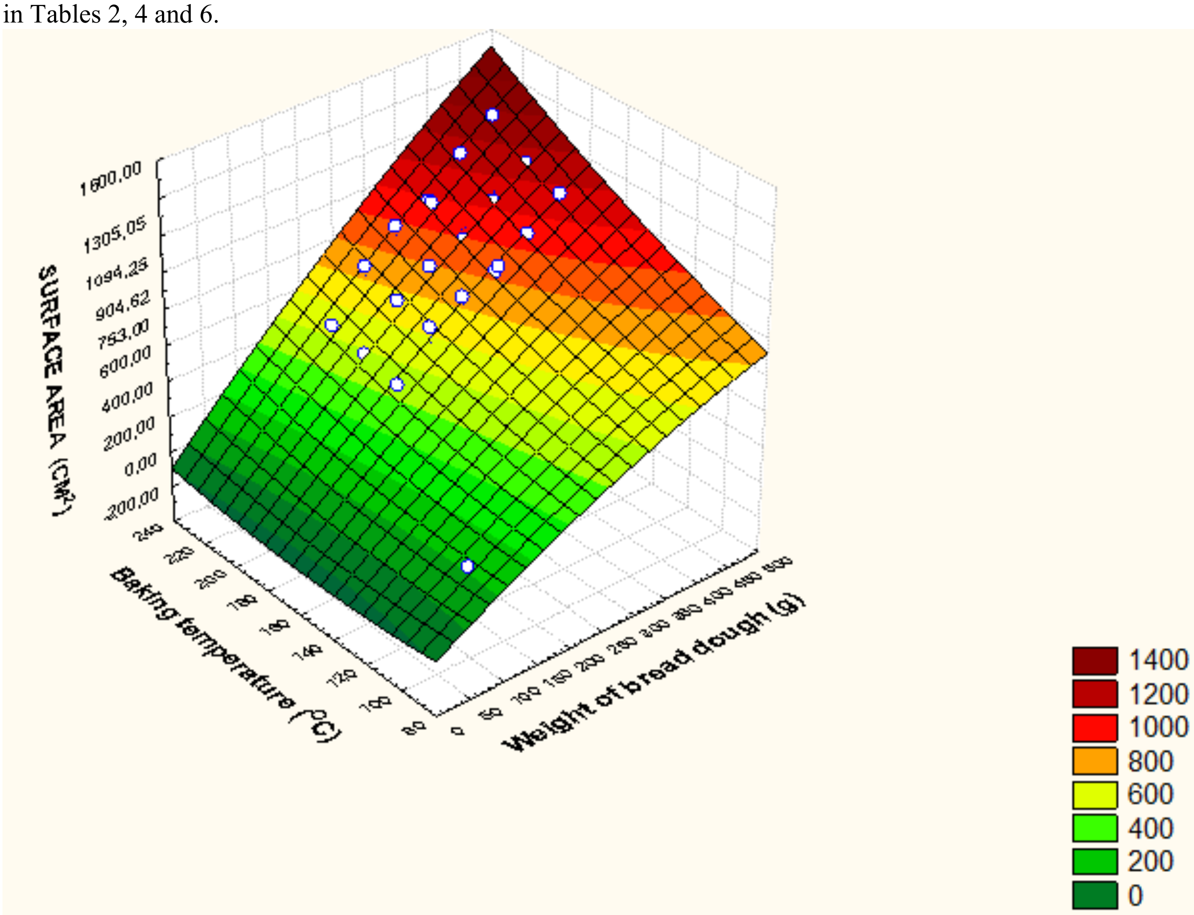


Figure 6: Graph of 3D surface plot of determining the optimum baking temperature at varying surface area of the baked bread.

Table 2: Physical Properties of Baked Dough at 180 °C for 30 min.

Weight of Un-baked Dough (g)	Surface Area (cm²)	Volume (cm³)	Density (g/cm³)	Specific Volume (cm³/g)
200	424.00a±0.00	533.00a±1.0	0.38e±0.00	2.67a±0.01
250	665.67b±0.57	1134.33b±0.58	0.22c±0.01	4.54c±0.01

300	753.09c±0.16	1375.94c±0.64	0.22c±0.01	4.58d±0.00
350	812.67d±0.05	1547.01d±0.05	0.23d±0.01	4.42b±0.01
400	948.17f±2.3	1953.00f±0.00	0.21b±0.00	4.88e±0.01
450	1094.25g±0.05	2425.55g±0.05	0.19a±0.00	5.39f±0.00
Control	828.67e±0.57	1595.33e±0.58	0.22c±0.01	4.58d±0.01

*N=3, *a,b,c Means of variables on the same column are significantly different at $p<0.05$*

Table 3: One-Way ANOVA of Physical Properties of Baked Dough at 180 °C for 30 min.

Physical Properties of Baked Dough		**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Surface Area (cm^2)	ween Groups	810667.86	6	135111.310	156794.49	.000
	Within Groups	12.06	14	.862		
	Total	810679.92	20			
Volume (cm^3)	Between Groups	6470261.43	6	1078376.904	4511138.44	.000
	Within Groups	3.35	14	.239		
	Total	6470264.77	20			
Density (g/cm^3)	Between Groups	.07	6	.012	840.00	.000
	Within Groups	.00	14	.000		
	Total	.07	20			
Specific Volume (cm^3/g)	Between Groups	12.78	6	2.129	49679.26	.000
	Within Groups	.00	14	.000		
	Total	12.78	20			

Table 4: Physical Properties of Baked Dough at 200 °C for 30 min.

Weight of Un-baked Dough (g)	Surface Area (cm^2)	Volume (cm^3)	Density (g/cm^3)	Specific Volume (cm^3/g)
200	467.00a±0.58	623.68a±0.07	0.32d±0.01	3.12a±0.00
250	688.67b±0.58	1197.02b±0.02	0.21c±0.01	4.79c±0.01
300	801.86c±0.15	1519c±0.05	0.21c±0.01	5.07e±0.00
350	853.37d±0.32	1667.77d±0.06	0.21c±0.01	4.77b±0.01
400	1031.52f±0.03	2228.09f±0.08	0.18b±0.01	5.57f±0.01
450	1147.73g±0.29	3240.64g±0.01	0.14a±0.00	7.20g±0.01
Control	863.88e±0.03	1700.83e±0.03	0.21c±0.01	4.88d±0.01

*N=3, *a,b,c Means of variables on the same column are significantly different at $p<0.05$*

Table 5: One-Way ANOVA of Physical Properties of Baked Dough at 200 °C for 30 min.

Physical Properties of Baked Dough		Sum of Squares	Df	Mean Square	F	Sig.
Surface Area (cm^2)	Between Groups	885811.78	6	147635.27	1337382.38	.000
	Within Groups	1.55	14	.11		
	Total	885813.32	20			
Volume (cm^3)	Between Groups	12259668.66	6	2043278.11	7.52	.000
	Within Groups	.04	14	.00		
	Total	12259668.70	20			
Density	Between Groups	.05	6	.01	270.00	.000
	Within Groups	.00	14	.00		
(g/cm^3)	Total	.05	20			
Specific Volume (cm^3)	Between Groups	26.50	6	4.42	115934.79	.000
	Within Groups	.00	14	.00		
	Total	26.50	20			

Table 6: Physical Properties of Baked Dough at 220 °C for 30 min.

Weight of Un-baked Dough (g)	Surface Area (cm^2)	Volume (cm^3)	Density (g/cm^3)	Specific Volume (cm^3/g)
200	512.00a±0.76	722.47a±0.06	0.32d±0.01	3.61a±0.00
250	765.37b±0.15	1396.53b±0.10	0.21c±0.01	5.60b±0.00

300	904.62c±0.03	1783.23c±0.02	0.20c±0.01	5.94e±0.00
350	975.49e±0.01	1990.22e±0.03	0.21c±0.01	5.69d±0.01
400	1162.89f±0.01	2674.63f±0.04	0.18b±0.01	6.69g±0.01
450	1305.05g±0.05	2957.56g±0.05	0.14a±0.01	6.57f±0.01
Control	956.10d±0.10	1981.98d±0.01	0.21c±0.01	5.66c±0.00

*N=3, *a,b,c Means of variables on the same column are significantly different at p<0.05*

Table 7: Physical Properties of Baked Dough at 220 ºC for 30 min.

Physical Properties of Baked Dough		Sum of Squares	Df	Mean Square	F	Sig.
Surface Area (cm^2)	Between Groups	1336595.12	6	222765.853	2514827.92	.000
	Within Groups	1.24	14	.09		
	Total	1336596.36	20			
Volume (cm^3)	Between Groups	10142848.68	6	1690474.78	5.94	.000
	Within Groups	.04	14	.003		
	Total	10142848.72	20			
Density (g/cm^3)	Between Groups	.03	6	.01	.	.
	Within Groups	.00	14	.00		
	Total	.03	20			
Specific Vol. (cm^3/g)	Between Groups	18.52	6	3.09	72019.04	.000
	Within Groups	.00	14	.00		
	Total	18.52	20			

The effect of baking temperature on the volume of the baked bread

In the Fig. 7 of 3D surface plot of determining the optimum baking temperature at varying volumes of the baked bread, the maximum volume (oven spring) occurred at 210 ºC of the baking temperature. In all baking temperatures, there was corresponding increased in the oven spring of the baked bread. This optimum baking temperature was found to be within the range of the values (200 - 220± 3.3ºC) reported by Purlis and Salvadori, 2010, using electric static bread baking oven (Ariston FM 87-FC, Italy) under two different baking conditions of forced and natural convections. But higher in value when compared with gas-fired cake baking oven reported by Genitha *et al*., 2014. They reported that the effective oven spring occurs at the optimum baking temperature of 180ºC under the baking period of 28 min. The quadratic regression modeling equation expressing mathematical relationship of volume of the baked bread against the baking temperature at six (6) different weights of dough is shown as Equation 13.

$$Volume = 200.1419 - 6.8726X + 1.9004Y + 0.0094X^2 + 0.045XY + 0.0157Y^2 \quad (13)$$

Where : X= Weight of dough and Y= Baking temperature

Tables 2 – 7 showed the comparison of the physical properties of dough baked using the newly developed oven to that of imported proto-type, in terms of volume (oven spring) were compared with the control sample at 180, 200 and 220 (ºC) for 30 min. These results showed that the oven spring of the baked breads of newly developed oven were significantly different from the control sample at a level of p>0.05. It can be seen empirically that as the baking temperature increased from 200 to 220 ºC, the values of the oven spring of newly developed oven were found to be lower considerably compared with that of imported product.

The effect of baking temperature on the density of the baked bread

The effect of baking temperature on different weight of baked bread dough in related with density of finished product was showed in Fig 8. It can be observed that in Fig. 8, the maximum density of the baked bread occurred at 200 ºC. However, the optimum density of the baked bread that occurred consistently in respective of varying the dough weight can be deduced in Table 6 as 0.21 g/cm³. This was can be further established by considering the density value of baked bread using imported gas-fired oven which has the same value of 0.21 g/cm³. The quadratic regression modelling Equation 14, expressed the mathematical relationship of the density of the baked bread against the baking temperature at six (6) different weights of dough.

$$Density = 391.402 - 0.118X - 3.7279Y + 4.2946 \times 10^{-5}X^2 + 0.045XY + 0.089Y^2 \quad (14)$$

Where : X= Weight of dough and Y= Baking temperature

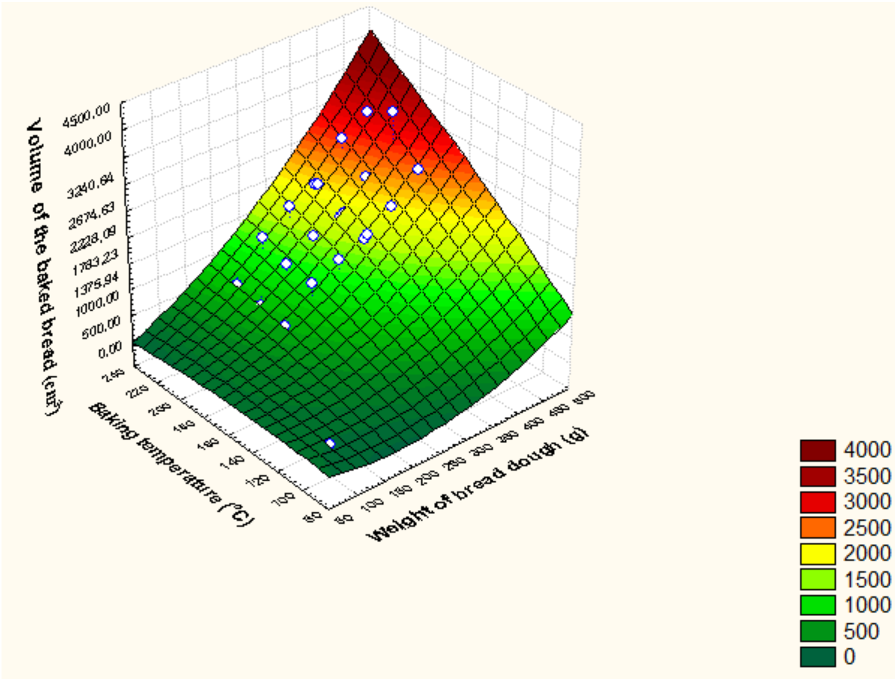


Figure 7: Graph of 3D surface plot of determining the optimum baking temperature at varying Volumes (Oven-Spring) of the baked bread.

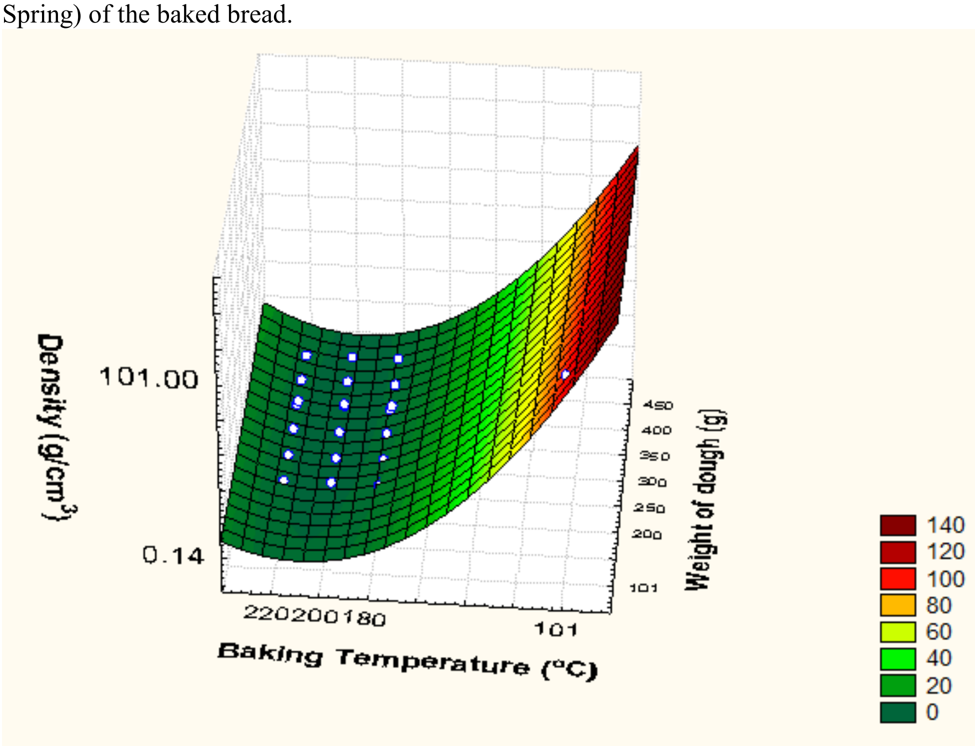


Figure 8: Graph of 3D surface plot of determining the optimum baking temperature at varying Volumes (Oven-Spring) of the baked bread.

The effect of baking temperature on the specific volume of the baked bread

The specific volume as one of the physical properties of baked bread was investigated to establish the optimum baking temperature on different weight bread dough. The result of this property was showed in Fig 9. It can be seen from the Fig. 9 graphically, that the maximum specific volume of the baked bread occurred at baking temperature of 200 ^oC. Hence, in Tables 2-7 the specific volume of the baked bread value at varying weights were significantly different at level of $p<0.05$ respective of increased in the baking temperature. The quadratic regression modelling Equation 15 expressed the mathematical relationship of the specific volume of the baked bread against the baking temperature at six (6) different weights of dough.

$$\textit{Specific Volume} = 389.93 - 0.1032X - 3.738Y + 2.1219 \times 10^{-5}X^2 + 0.0005\,XY + 0.009Y^2 \quad (15)$$

Where : X= Weight of dough and Y= Baking temperature.

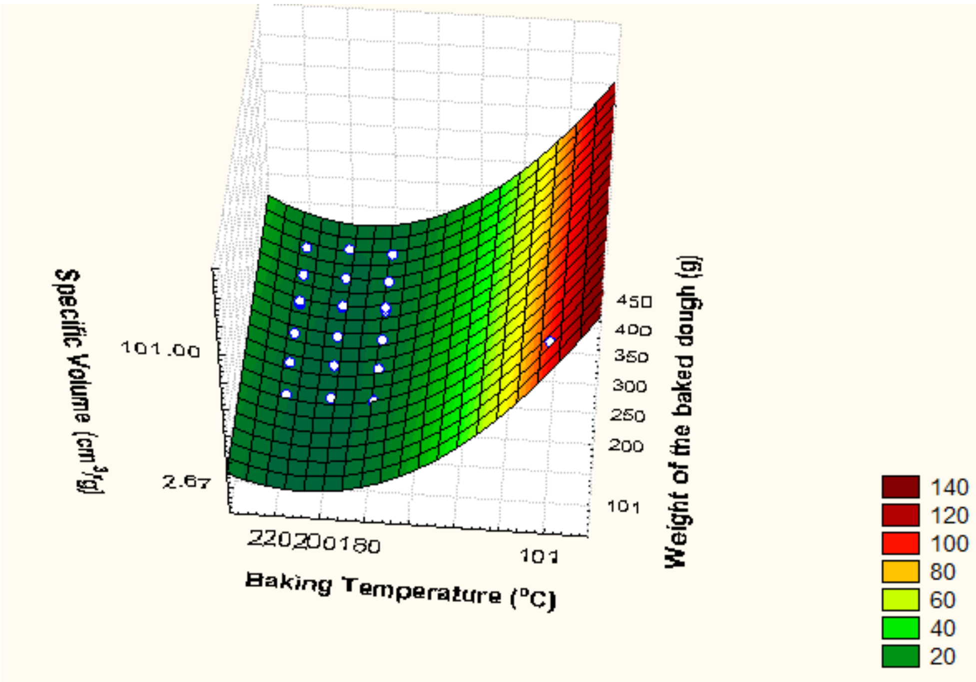


Figure 9: Graph of 3D surface plot of determining the optimum baking temperature at varying Specific Volumes (Oven- Spring) of the baked bread.

CONCLUSIONS

Gas-fired baking oven was designed, constructed and evaluated by considering the baking oven characteristics such as baking capacity, baking efficiency, weight loss and optimum baking temperature and physical properties. The physical properties of baked bread compared with that of imported gas-fired oven (control) were significantly different from each other at level of ($p<0.05$), but with optimum baking temperature between 200 – 220 ^oC. Therefore, the newly developed oven can be used for the baking of dough both at domestic and industrial level.

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THE SIGNIFICANCE OF RE-CALIBRATION OF IMPORTED FARM MACHINERY FOR EFFECTIVE FIELD OPERATIONS IN NIGERIA

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ABSTRACT
This study reported the effect of re-calibration of some imported farm machinery introduced into Nigeria due to variability of peculiar factors. Therefore, for optimum performance of the imported farm machinery, timely calibration with standardized instruments prior to field operation is inevitable. Hence, the study, investigates the effective method that will support accurate calibration of farm machinery in Nigeria. Precision pneumatic planter and boom sprayer were selected for this study. Static and dynamic methods of calibration of farm machinery were adopted. Parameters measured were: wheel speed, gear combination, tractor speed and pump pressure to determine optimum seed planting and herbicides discharge rates for both the pneumatic planter and boom sprayer respectively. Descriptive statistics was used for data analysis. The results showed that dynamic method was more accurate than static calibration method. The re-calibration parameters for precision pneumatic planter were 26/30 and 110 rev/min for gear combination and wheel speed; while that of boom sprayer were 1.3m/s and 6 bar for tractor speed and pump pressure respectively.

Keywords: *Re-calibration, static method, dynamic method, precision pneumatic planter, boom prayer.*

INTRODUCTION
Calibration is a scientific technique of gauging machine parameters for reliability, using accurate scale of reading or correlating instrument generally standardized by the regulatory bodies for accuracy. It involves timely presetting of farm machinery by careful checking the accuracy of the working components such as metering unit and vacuum pump pressure (for grain planter); and vertical height of the boom, nozzle defect and size likewise speed of the tractor and pump pressure (for boom prayer) against deviation from known specifications of the manufacturer. More importantly, it involves optimizing, the manufacturer's specification to machine performance. Inconsistent calibration, prior to field operation has been reported to be the major factor responsible for low crop yield and in-effective application of herbicide and fertilizer (Stephen and Daniel, 2008). Variability of seed sizes, plant population, physical properties of seeds, soil fertility, texture and climatic condition, abrasion rate of the working components of machine and equipment from season to season are some of the reasons why it is essential to re-calibrate imported machinery. Ideally, the manufacturers of farm machinery usually accompany their machine with application charts, but in reality these specifications may not be practicable but relative to the location where this equipment will be used. Adekoya and Buchele (1988) reported on the calibration of punch/stick planter that is suitable for effective planting operation on tilled and untilled soil. They also noted that seed-rate is proportional to soil dynamics in most tropical region. Dauda*et al.* (1988) reported some challenges associated with accurate calibration and concluded that the only way for uniform planting is regular calibration and consideration of relevant factors associated with crop production. Stephen and Daniel (2008) highlighted the calibration procedures for grain drill planter. They justified calibration of farm machinery as the only way of eradicating ununiform stand. It has been postulated by many other previous researchers that variation in seed size and shape can impaired planter performance, most especially when plate type of metering unit is used, unlike vacuum disc type which tolerates a range of seed size and shape (Heyns, 1989; Zulin*et al.,* 1991, Murray *et al*. 2006). Singh *et al*. (1985) manufactured a ridge planter for winter maize; it was noted that working depth variation is inversely proportional to the amount of water content in the soil. Copwell and Koroma (1981) also reported the modification of the manual planter for Soya bean and other related seeds while Kumar *et al.* (1986) re-calibrated grain seeder by modifying metering unit for optimum performance. The objective of calibrating boom sprayer was to ensure accurate quantity of herbicides discharge per hectare at a given pressure and speed.

Price *et al*. (1997) reported on some fundamental procedures that are highly essential for an effective calibration of band sprayer. They also reported the factors that may affect the boom sprayer calibration considered prior to the field investigation include: PTO speed, operating pressure, nozzle size and shape, nozzle spacing, vertical height of the boom, direction of the convention wind force, and climate condition. This study investigated and established effective methods that will enhance accurate re-calibration of farm machinery in Nigeria. It will further increase the technical capability of Agricultural Engineers, Agricultural Engineering Technologists, Mechanization supervisors, machinery operators, individual farmer and other stakeholders in the agricultural sector on how best to calibrate imported machinery and equipment to suit our local conditions that will enhances effective application.

MATERIALS AND METHODS

Machines Source

A precision pneumatic planter, model MTE 320, code: G90806311 (6 rows, fix frame with Telescopic type) manufactured by MaschioGaspardo, Italy and boom sprayer, model 3WC-500 (Tank capacity: 500 litres, Spray width: 12 m, numbers of spray head: 24 and rated pressure: 8 bar) manufactured by Alibaba, Italy were selected for this study. They were mounted at each time of field study on Steyr tractor 780 models, through the 3-hitch point linkages, while its PTO shaft engaged to that of the tractor. The field and dynamic calibration methods were investigated at the Department of Agricultural and Bio-Environmental Engineering demonstration farm, Auchi Polytechnic, Auchi, Edo State, Nigeria. The field static calibration of pneumatic boom sprayer was carried as shown in Figure 1. Both methods were carried out on the planter and sprayer using procedures described below.

Figure 1: Static calibration method of boom sprayer at the Department of Agricultural and Bio-Environmental Engineering, Auchi Polytechnic, Auchi, Edo State, Nigeria.

Methods

Static calibration method for the precision pneumatic planter using manufacturer's specifications

The recommended calibration chart of the planter manufacturer was used to investigate the accuracy of the specified seed discharge rates. The specified gear-combinations of 24/36 teeth were selected with corresponding seed discharge rate of 50 kg/ha. The inter-row spacing of 0.8 m and crop space interval of 0.2 m were observed in conformity with manufacturer's specification. The tractor engine was kick started, while the planter gang was raised above the ground level to measure the planter trailed tyre circumference. The hoppers were filled with viable maize seeds, while delivery chutes to the coulters were detached. The cellophane bag was attached to each of the metering unit outlet for the collection of discharged seeds. The aspirator was engaged at a low speed of the engine while the trailed tyres were suspended and made to rotate manually for 20 revolutions. Then the cellophane bags were removed to measure discharged grains using calibrated weighing scale (Sartorius 1600 electronic digital weighing balance of least count of 0.001 g). The data obtained were recorded as shown in Table 1. This procedure was replicated six times and the mean seeds discharge rate was determined using descriptive statistics. This procedure is referred to as un-calibrated static method.

Computation of parameters for static calibration method using manufacturer's specifications

Disc plate used: 20 cm in diameter with 50 holes.
The gear combination: Drive sprocket = 24 teeth and Driven sprocket = 36 teeth
Average weight of seed collected = $\overline{w} = \frac{\sum_{i=1}^{n} wi}{ni} = \frac{75.7}{6}$ = 12.62 g (Table 1)
Average weight of seed sowed for that specified area = 6 x 12.6 = 75.72g
Circumference of the tyre = 194.86 cm
Total length of the field covered = 20 x 194.86(cm) = 3.897 m
Area expected to cover = $15.6m^2$, for I ha, discharge rate = 48.5 kg/ha (Table 1)
From the manufacturer's calibration chart, the seed rate for maize of 80 cm inter-row spacing and 200 mm crop stand to each other, suppose to discharge 50 kg/ha. Meanwhile, the mean sowing rate per hectare was found to fall below the manufacturer's specification, may be due to the differences in maize grain sizes in Nigeria. Since 48.5 kg/ha is less than manufacturers' specification, then this planter was re-calibrated using gear combinations: 24/30 to 26/30 teeth as shown below:

Re-calibration of the precision pneumatic planterusing static calibration method
This method was investigated by replacing former gear combination (24/36) with another two sets of gear combinations (24/30 and 26/30) teeth consecutively in six replications as shown in Table 1, to determine the optimum discharge seed rate. The former procedures were observed and data collected were depicted in Table 1. The data was analyzed using descriptive statistics and the percentages of deviation from the specification of the manufacturers' calibration chart were established.

Table 1: Static calibration method for the precision pneumatic planter

Parameters	Manufacturer's Specification	Re- Calibrated Values	
Experiment /Trial		1	2
Gear combination	24/36	24/30	26/30
Speed of wheel (rev/min)	80	100	110
Average Weight of seeds discharged/hopper (g)	12.60±0.12	13.02±0.12	13.38±0.16
Summation of seeds discharged (g)	75.7	78.2	80.3
Weight of seeds discharged (kg/ha)	48.5	50.1	51.5
Percentage of deviation from specified discharge rate (%) (Assuming %germination rate of 98%)	-5.0	-1.8	+0.4

Computation of the precision pneumatic planter using static method
By computation the first trial of gear combination 24/30 teeth was found to be within the manufacturer's specifications, while the second trial was above. This can be clearly demonstrated by considering the plant population rate expected when the viability percentage of seed is considered. From Table 1, the percentage of deviation from the specified discharge rate, with assumption of 98% germination rate on the gear combinations: 24/36, 24/30 and 26/30 are -0.5%, -01.8% and 0.4%, respectively. This result established that 24/30 gear combination has minimum wastage of seeds.

Field/Dynamic calibration method of the precision pneumatic planter
The static method was measured in kilogram per hectare of seed planted. But this method was measured by considering seed population per hectare (total number of seeds discharge per hectare).
The procedures were enumerated as follows:
1. Physical counting of the total number of seeds per 1 kg was established by considering corresponding weight of 100 (15.2 g equivalent to 100 seeds).
2. 1 kg of the same seeds was loaded inside 6 hoppers in six replications. The number of seeds in each hopper was estimated to be 6614 seeds.
3. 100 m of a distance length of experimental field was demarcated and prepared for planting operation.
4. Cellophane bag was attached to each delivery tube to collect seeds.
5. Initially manufacturers' specification was confirmed using two methods demonstrated below as un-calibrated and calibrated methods.

Field/Dynamic calibration method of the precision pneumatic planter using manufacturer's specifications

A gear combination of 24/36 and row spacing of 200 mm specified by the manufacturer for the type of vegetation were observed. These specifications were confirmed using procedures highlighted below.

1. A specified tractor speed of 15 km/h was selected.
2. The planter was engaged from initial point demarcated and the tractor was made to run with a constant speed selected through a distance of 100 m.
3. Area covered was calculated as (4x100) m^2 (only 4 hoppers were used in 6 replicates) for accuracy
4. The weight of discharged seeds per each hopper collected using cellophane bags were measured and recorded as shown in Table 2.

Average weight of seeds collected $= \frac{\sum_{i=1}^{n} wi}{ni} = \frac{1896.42}{6} = 316.07$ g

Total weight of seeds for 400 m^2 Area = 1896 g, for 1 ha, seed rate = 47.4 kg/ha = 313561 seeds/ha

Hence 324,074 seeds were expected. Therefore, 313561 seeds/hectare was found to be inadequate (This was far below specified plant population of the planter's manufacturer).

Re-calibration of the precision pneumatic planter using field/dynamic method

First trial

Another set of gear combination of 24/30 was selected to increase the seed discharge rates. Calibrated tachometer was used to select speed of 100 rpm of the tyres. Mathematically, the new seeds sowing rate becomes 49.00 kg/ha. The spacing within row of 220 mm was observed. Using the procedures in sections 2.5 and 2.6, the population of seeds discharge was counted to be 322,368 seeds. This value was found to be lower than the manufacturer's specification (Table 2).

Second trial

The new set of gear combination of 26/30 was selected and procedures earlier stated above were observed. The weights of seeds discharged from the individual metering unit, the average weight and discharge rate /ha were recorded as shown in Table 2. The discharge rate /ha of this second trial was found to be more accurate and closer in value to that of the manufacturer's specifications.

Table 2: Dynamic calibration method for the precision pneumatic planter

Parameters	Manufacturer's Specification	Re-Calibrated	
Experiment/Trial		1	2
Gear combination	24/36	24/30	26/30
Speed of wheel (rev/min)	80	100	110
Mean weight of discharged seed (g)	316.07.±2.76	326.75±3.50	338.97±3.33
Summation of seeds discharged (g)	1892.0	1960.5	2033.8
Weight of seeds discharged (kg/ha)	47.4	49.0	50.8
Percentage of deviation from specified discharge rate (assuming %germination rate of 98%)	-7.1	-4.0	0.0

Calibration of the boom prayer

There are several methods that can be adopted, but only two methods were considered in this study namely: static and dynamic methods.

Static calibration method for the boom sprayer

A capacity of 500 litres (l) tank of boom sprayer was mounted on the tractor through the 3-point hitch linkage. The following procedures were observed as stated below:

Ca1ibration Procedures:

The boom sprayer tank was filled with water for economic reason, only to the ¾ of the tank capacity). The effective boom width was calculated; likewise the vertical height of the nozzle tip to the surface ground was selected as 0.6 m to avoid drift. Then the total numbers of nozzles were counted to be 19. Thereafter, nozzles inter-spacing was measured

as n = 0.50 m, while the delivery pressure was set to be 8 bar and the directional valve of first link to the right hand side of boom was opened for spraying. The maximum length of the first nozzle without considering partial wetted area was measured to be 0.6 m and the effective width of each nozzle was calculated as shown below.
The effective boom width = n x 19 nozzles + 1.2 (m) = 0.5 x 19 + 1.2 (m) = 10.7 m
By Sino Agro Chemical Industry Limited, Jiangsu, China (manufacturer of Force-Up herbicide) specified mixture application rate of 200 l/ha maximum, with chemical concentrate of 6 l/ha for perennial and broad leaves. To achieve this, the following trials were observed.

Static calibration method of the boom sprayer using manufacturer's specifications
The tractor speed of 5 km/h was selected and regulated through tractor speedometer. The discharge pressure of 8 bar selected as specified by the manufacturer was adopted for the study. The herbicide solution discharge/nozzle collected using plastic measuring beaker for 60 seconds period of spraying at static condition was measured and recorded.
Average discharge/ nozzle= 0.93 l (Table 3). For 20 nozzles in a boom = 20 x 0.93(l) =18.65 l
+Speed selected= 5 km/hr =1.3 m/s
The effective boom width = 10.7 m, demarcated length = 100 m
Area covered = 10.7 x 100 (m^2) = 1070 m^2.
Actual time for 1070 m^2 was calculated = 77 s
Theoretical time = 719.6 s, Discharge rate/min = 18.65 l
Hence, application rate/ha = 223.68 l/ha as shown in Table 3. This application rate fall below the manufacturers' specification, therefore further investigation was carried out.

Re-calibrationof the boom sprayer using static method

First trial
The initial tractor speed of 5 km/h was maintained, while discharge pressure was reduced to 7 bars. Nozzles of numbers 2 and 3 were replaced to achieve a maximum of 10% deviation from discharge rate in all nozzles. The calibration procedures on section 2.4.1 and 2.4.2 above were observed. These following data were collected at 60 s, using analog stop-watch. Average discharge per nozzle, discharge rate/ha and deviation from the manufacturer's specification were shown in Table 3.

Second trial
The same procedures were observed as stated above but delivery pressure was changed to 6 bar. The following data were collected as shown in Table 3. The average discharge rate per nozzle was 0.84 l. Hence total discharge rate for 719.6 s = 201.37 l/ha. Hence 6 bars pressure was found to be appropriate and preferred, due to reduction in the pump pressure.

Table 3: Static calibration method of the boom sprayer

Parameters	Manufacturer's Specifications	Calibrated	Calibrated
Experiment/Trial		1	2
Speed of the tractor (km/h)	30	25	30
Pressure selected (bar)	8.00	7.00	6.00
Mean discharge/nozzle (l/nozzle)	0.93±0.06	0.81±0.01	0.84±0.01
Discharge/ha (l/ha)	223.68	193.81	201.37
Deviation from manufacturer's specification (l/ha)	23.68	-6.19	1.37

Dynamic calibration method for the boom sprayer using manufacturer's specifications
The same facilities utilized in static calibration method were adopted, while procedures specified for field operation were observed as shown below:
***Step 1*:** The boom sprayer tank was filled with ordinary water to the graduated levelmark of 500 l on the tank.
Step 2:A demarcated distance of 100 m was measured with measuring tape.
Step 3:The boom of the sprayer was set on the starting point of 100 m distance length demarcated.
Step 4: The speed of 5 km/h was regulated using the tractor speedometer. Directional valve was adjusted to 6 bars, by opening non- return valve through a pressure gauge.
Step 5: At the starting point of movement, the valves were opened and then closed at the end of 100 m spraying operation.

Step 6: The total volume of water discharged was determined by re-filling the tank back to the initial volume of 500 l capacity. The total volume of water discharged was found to be 18.67 l.
Step 7: The rate of discharge/ha was determined using this Equation 1 depicted below:

$$Qh= \frac{V}{Wb} \text{ x } L \qquad (1)$$

Where: Qh = discharge rate (l/ha), V = volume of water used (l), Wb = effective width of the boom, L= distance demarcated (meters), of the boom. From the experimental data, application or discharge rate/ha = 174.50 l/ha as shown in Table 4 (This was found to be below specified application rate).

Re-calibration of the boom prayer using dynamic method

First trial
The discharge pressure was adjusted to 7 bar (to increase the discharge rate) under the same setting of speed and nozzle size to achieve the desired volume, procedures in section 2.9 were observed The data collected were shown in Table 4. The average discharge rate per nozzle was 1.03 l and total volume of discharge for 100 m was 20.64 l. However, using equation 1 above, hence the application rate = 192.90 l/ha (This a little lower than the specification).

Second trial
The discharge pressure was adjusted to 8 bars (to increase the discharge rate) under the same setting of speed and nozzle size to achieve increase in discharge rate. The data collected were shown in Table 4, while the average discharge rate per nozzle was 1.07 l. The total volume of water discharged at the new increase in pressure value of the pump was found to be 21.41 l at the end of 100 m distance. Using equation 1 above, the application rate was found to be 200.09 l/ha (Table 4) (This is more appropriate for cost effective application).

Table 4: Dynamic calibration method of the boom sprayer

Parameters	Manufacturer's Specification	Calibrated	Calibrated
Experiment/Trial		1	2
Speed of the tractor (km/h)	30	25	30
Pressure selected (bar)	6.00	7.00	8.00
Mean discharge/nozzle (l/nozzle)	0.93±0.06	1.03±0.01	1.07±0.07
Discharge/ha (l/ha)	174.5	192.90	200.09
Deviation from manufacturer's specification (l/ha)	-25.5	-7.1	0.09

RESULTS AND DISCUSSION

In Table 1 shows the results of the un-calibrated static method. The seed discharge rate was 48.5 kg/ha instead of 50 kg/ha specified by the manufacturer. Therefore, the specified gear combination of 24/36 teeth and speed of the wheel of 80 rev/min were not acceptable due to the physical properties of maize grains cultivated in Edo State of Nigeria. However, at the first trial of re-calibration, the wheel speed was increased to 100 rev/min and gear combination of 24/30 teeth, the seeds discharge rate obtained was 50.1 kg/ha. Hence, at further increase of the wheel speed to 110 rev/min, the corresponding seeds discharge rate obtained was 51.5 kg/ha, which was almost the same with the recommended specification of 50.0 kg/ha discharge rate, when 98% of germination percentage was considered. Furthermore, it was observed that from the Table 1, the re-calibration of the second trial, the seeds discharge rate was higher than specified discharge rate by 0.4% which is highly insignificant comparedto un-calibrated condition of 5% losses in plant population. Therefore, for reliability purpose the parameters for the second trial were found to be more appropriate for re-calibration of precision pneumatic planter under static method. From Table 2, the result of un-calibrated dynamic method of precision pneumatic planter shows the seed discharge rate of 47.4 kg/ha, at the wheel speed of 80 rev/min and gear combination of 24/36 specified by the manufacturer. This result indicates that those calibrated parameters specified by the manufacturer could not enhance productivity in Nigeria. At the first trial of re-calibration, with the increase of wheel speed to100 rev/min and gear combination increase to 24/30 teeth, the seeds discharge rate was found to be 49.0 kg/ha, which was not adequate enough. The second trial was embarked upon by increasing the wheel speed to 110 rev/min., while the gear combination was change to 24/30 teeth to increase the gear ratio that enhances the speed of the metering unit. The result of this second trial was found to be 50.8 kg/ha which is more accurate than previous settings. According to agronomic specification of 98% germination rate of sowed seeds is expected, hence 98% of 50.8 kg/ha is 50.0 kg/ha. However, the percentages of deviations from the manufacturer specification were found to be -7.1%, 4.0% and 0.0% for un-calibrated, first and second trial of dynamic methods, respectively. Invariably, it was observed that in both static and dynamic methods, un-calibrated specifications of planter manufacturer could not be used in Nigeria because of the variability in axial dimensions and bulk density of seeds cultivated in Nigeria. Hence, by considering the power train of this planter, the pneumatic wheel of the planter propelled the aspirator through a gear box and the suction power of this aspirator determines the seed terminal velocity and drag force that retain the seed on the seed plate inside the vacuum chamber of the metering unit of the planter. The disparity in axial dimensions and bulk density of cereal crops across the globe had been reported by previous researchers as a result of variability in climatic conditions, soil fertility, soil structure and texture (Oni and Olaoye, 2001; Simonyan *et al*., 2007). This variability had been reported to leads to differences in their morphology, associated with heterogeneous composition of their cell walls which varies even in-between the same cultivar (Ogunsina *et al*., 2008; Morakinyo and Bamgboye, 2015). Therefore, it implies that re-calibration of precision pneumatic planter is highly essential for effective performance in any location in Nigeria. The results from Tables 1 and 2 showed that the dynamic calibration method is more accurate, economical and effective than static calibration method in terms of deviation percentages from the specification of the manufacturer. This result established that timely re-calibration is highly essential to increase the performance efficiency of farm machinery regardless of the manufacturers' specification.

The results of static and dynamic methods of boom sprayer were shown in Tables 3 and 4. In Table 3, the result of un-calibrated static method depicted that discharge rate of 223.68 l/ha, based on the manufacturer's specifications of 8 bar pump pressure and 30 km/h of the tractor speed. This discharge rate was far above the recommended value of 200 l/ha. To achieve this, the sprayer was re-calibrated by reducing the pump pressure to 7 bar, a new discharge rate of 193.81 l/ha was obtained, which was closer to the recommended value. However, further reduction of the pump pressure to 6 bar at 30km/h of the tractor speed gave more accurate discharge rate of 201.37 l/ha. The deviations from the manufacturers' specification were: 23.68, -6.19 and 1.37 (l) for un-calibrated, first and second trials methods respectively. As shown in Table 4, during the un-calibrated dynamic method, it was found that the discharge rate was 174.50 l/ha based on the manufacturers' specification of 6 bar pump pressure and 1.2 m/s tractor speed. Hence, this discharge rate was found to be inadequate. The calibrated trials of 7 bar and 1.2 m/s; 8 bar and 1.3 m/s gave corresponding discharge rate of 192.90 and 200.09 (l/ha) respectively. Their levels of deviations from the manufacturers' specification were -25.5, -7.1 and 0.09 (l/ha) respectively for un-calibrated, first and second methods of dynamic calibration of boom sprayer. This result shows that utilizing the manufacturer chart for boom sprayer calibration could have resulted to wastage of 25.5 l/ha of herbicide solution which will be highly un-economical. The justification for re-calibrating the imported boom sprayer has been validated based on the above deduction. It was observed that decrease in the pump pressure from 8 to 6 (bar) was required for static calibration method, while reverse was the case for dynamic calibration method. In both methods, modifications of the manufacturers' specifications were essential for effective application of the boom sprayer. The disparity from the manufacturers' specification may be due to chemical concentration, climatic and environmental factors (that may have been resulted to defect in nozzle orifice area and water pump) (Robert et al, 2004). More importantly, the planter and boom sprayer were manufactured from the temperate region while Nigeria is located in the tropical region. The observation was affirmed by ASABE Standard, (2008) which reported that the discharge rate of granular materials on specific area during field application depends on nozzle orifice, pump or rotor speed, tractor speed, physical properties of the granule, climatic conditions (relative humidity rainfall and wind drift), field terrain and soil condition. Hence, dynamic calibration is more accurate, economical and pragmatic than static calibration method by comparing Table 3 to that of Table 4. From these results, this study has established the crucial need to re-calibrate some imported farm machinery into Nigeria to enhance their performance and productivity.

CONCLUSION

The effect of re-calibration of farm machinery prior to any field operation, using appropriate method and procedures have been investigated in this study as the most critical operation. To achieve optimum performance of farm machinery and adequate crop yield, re-calibration must not be neglected but regularly carried out at the beginning of every farming operation or when change in crop physical properties is obvious. The result revealed that, failure to re-calibrate precision pneumatic planter may lead to loss of plant population between 5-7% which consequently could have reduce crop yield. Likewise for boom sprayer about 23.68 -25.5 l/ha may have been wasted or inadequate using manufacturer's specification for static and dynamic method respectively. In addition, as the machine gets older, discharge rates from the metering unit of planter may not be accurate as they were expected; therefore re-calibration will be highly essential. More importantly, re-calibration enhances routine repair and maintenance, increase machinery durability, efficiency, reliability and reduce breakdown hour and cost of maintenance. This study therefore recommends dynamic method of re-calibration for all imported farm machinery on regular basis and if they are frequently engaged it should be done at an interval of 50 h for optimum performance to avoid errors.

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ADAPTATION OF A RUBBER ROLL RICE HULLER FOR MILLING TWO PADDY CULTIVARS IN SOUTHWESTERN NIGERIA

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ABSTRACT

Milling of paddy to highly nutritious brown rice is yet to be fully mechanized in Nigeria. The adaptation of the steel friction roll rice huller for the milling of some paddy cultivars in Nigeria pose some challenges such as low milling efficiency and high breakage. In order to have sustainable technological development in local rice mills, the conventional rubber rolls huller was modified by varying the gear velocity ratio to enhance machine characteristics for the two paddy cultivars (Ofadaand Swamp). The physical properties of two parboiled paddy cultivars in southwest geographical zone of Nigeria were studied for design modifications. The experimental design of 2 × 3 × 3 factorial block design was adopted. The optimum velocity gear ratio and parboiling temperature for each cultivar were investigated in terms of milling capacity, milling efficiency and breaking percentage. The triplicate data of machine characteristics were subjected to Univariate analysis of variance (3-way ANOVA method) and parameter estimates test to determine their significant differences (p<0.05). The results shown that optimum velocity gear ratio and parboiling temperature that enhanced machine characteristics were 1:1.3 and 70 °C respectively. Furthermore, the results showed that at the interaction of these optimum parameters, the maximum hulling capacity, hulling efficiency and minimum breakage percentage were 55.5 kg/h, 87.92% and 3.2%; 56.80 kg/h, 91.08% and 2.8% for Ofada and Swamp paddies, respectively. In between cultivars, the machine characteristics differences were insignificant at level of p<0.05.

***Keywords*: Milling, Compressive force, Gear speed ratio, Paddy, Rubber rolls,.

INTRODUCTION

Rice represents a major staple food item and a widely traded food product all over the world. The top ten rice producing countries include China, India, Indonesia, Bangladesh, Vietnam, Thailand, Philippines, Myanmar, Brazil and Cambodia (FAO, 2013). Nigeria is the second largest importer of rice and 17th rice producing country in the world, importing about two million metric tons per year from China and Thailand (FAO 2013). Oyeleye (2014) reported that Nigeria produced about 2.3 million tons of rice and consumed about 5 million metric tons annually,leaving a deficit of 2.1 million metric tons totaling about N356 billion in 2013. A number of rice processing mills in Nigeria are located in Abakaliki, Afikpo, Adani, Omor, Ogoja, Bende (Ezedinma 2003). Major rice cultivars grown in these location include *Swamp* rice (local short grain)*ofada*, *Dias*, *Santana*, *Ashawa*, *Yarsawaba*,*Yarkuwa, Faro52 and,faro55* cultivars (Bayou 2009).

The conventional way to hull rice is to pass it between two rubber rollers rotating at a surface speed differential. This results in a normal pressure and shear stress which peels the husk from the kernel (Baker *et al*., 2012). Juliano (1985) reported that the husk accounts for 20% weight of paddy and protects the grain from insect and fungal attacks. Rice hulling, involve the removal of husk from paddy to obtain brown rice. Rice milling may be achieved by a one-step, two-step or multi-stage process. Previous design include the steel friction type which operates as one-step removes husk and bran in one pass and mills into white rice indicating a throughput of 50-55% and <30% head rice yield (IRRI 2009). In a two-step process, the husk and bran are removed separately by rubber and steel friction rollers respectively (IRRI 2009); whereas, the multi-stage milling is a combination of the aforementioned processes including a polishing unit to produce white rice (Juliano and Bechtel 1985). Bhattacharya (1980) observed that parboiling toughens the rice grains and reduces breakages during milling. However it suffices to mention that poor drying often reduces milling efficiency. Gbabo *et al*., (2008) found that variety, steam pressure and specific volume of the steam affect the head rice yield of milled and parboiled paddy. Firouzi *et al*. (2010); Jasim and Hassoon 2010; Baker *et al*. (2012) reported the use of two rubber rollers of the same diameter run at different speeds to remove husk from paddy by abrasive action. They reported that one roller is in fixed position, while the other is adjustable to attain desired clearance between the two rollers. Furthermore, the fixed roller derived its torque from driven roller (Firouzi *et al*., 2010) (This conventional rice huller has friction losses and low velocity ratio, having average milling efficiency of 64.3% as paddy cultivars varied. Garibaldi (1981) reported that the appropriate speed ratio in between fixed and adjustable rollers should not exceed 0.7 to 0.8 mm, while the peripheral speed difference should be 2 m/s.

Presently, in Nigeria apart from commercial rice milling industries, no huller exists which is suitable for our local rice cultivars except the one-step steel friction roll type by Engleberg which yields low quality white rice called *FARO 44* and *FARO 52* (Danbaba *et al*., 2013). In this work therefore, a modification of the conventional rubber roll rice huller was carried out with the view to improve machine performance and milling efficiency of two paddy cultivars commonly grown in Southwestern Nigeria for sustainable development in rice production.

MATERIALS AND METHODS

The conventional rubber roll rice huller was modified by yoking two rubber rollers with two different spur gears for increased frictional force and shear stress at a constant rate. Three sets of spur gears with ratios 1:1.6, 1:1.3 and 1:1.05 were produced and evaluated relative to the parboiling temperatures of paddy (60, 70 and 80ºC) (Danbaba et al. 2013). Two cultivars of freshly harvested paddy namely: *ofada* rice from Akure in Ondo State and swamp rice (Fig. 1) from Erin-Ijesa in Osun State were obtained at moisture contents of 14.5 and 14.3% (w.b) respectively. The physical properties such as: length, diameter, geometric mean diameter and mass, sphericity, porosity, bulk and true densities and angle of repose were determined.

Design modifications

The modification include the use of two spur gears to drive the rubber rolls at different speeds instead of varying the pulley size (Firouzi *et al*., 2010; Jasim and Hassoon 2010; Baker *et al*. 2012) to eliminating frictional losses and increasing shear force towards increasing hulling efficiency. Likewise, the feeding rate and hulling capacity was enhanced by increasing the length of rubber roll from 300 to 500 mm. Furthermore, rollers were orientated horizontally instead of inclination at an angle of 45 degrees which was previously reported by Firouzi *et al*. (2010) and Baker *et al*. (2012). Based on the foregoing, velocity ratio was selected by varying the gear ratio in three levels (1:1.6, 1:1.3 and 1:1.05). A gear train was designed considering a common center distance between two gears and varying the pitch circle diameters such that, they can both be engaged at a tooth depth of 15 mm. Hence three sets of two spur gears were made of high carbon-steel and heat -treated to 56 HRC. However, the optimum gear combination was established by replacing one set after another on parboiled paddies at 60, 70 and 80 ºC temperature, while evaluating their corresponding machine characteristics (Danbaba *et al*., 2013).

Milling

The paddy of both cultivars was soaked at 70 ºC for 6 h and they were parboiled using un-pressurize galvanized tank cooker at three levels of temperatures: 60, 70 and 80 ºC for 30 mins. The steamed paddies were dried to 11.5 % (w.b) moisture content using multi-purpose pilot tray drier (Gbabo and Ndagi 2014). Each cultivar was milled using modified prototype by replacing three set of spur gears one after another at a constant feeding rate of 0.5 kg/s.

(a) (b)

Fig. 1: (a) AnOfada Paddy, (b) A Swamp Paddy

Statistical analysis

The experimental design of 2 × 3 × 3 factorial block design was adopted based on two levels of cultivars: *ofada a*nd *swamp* and three levels of parboiling temperatures: 60, 70 and 80 ºC and three levels of spur gear ratio:1: 1.6, 1:1.3 and 1:1.05 in three replicates (54 samples of dried paddy were milled). The triplicate data of machine characteristics were subjected to Univariate analysis of variance (3-way ANOVA method) expressed as Mean ± Standard Deviation (M±SD). Parameter Estimates Test on the mean of each machine characteristic intercepting with independent variables (cultivars, parboiling temperatures and velocity gear ratios) was analyzed to indicate the level of significant differences ($p<0.05$). The optimum velocity gear ratio and parboiling temperature interaction suitable for both (*ofada and swamp*) paddy cultivars were investigated to enhance machine efficiencies.

Evaluation of machine parameters

Hulling Capacity *(Hc)* $=\left(\frac{Massofhulledbrownrice}{TimeTaken}\right)\left(\frac{kg}{hr}\right)$ 1

Hulling Efficiency *(He =)* $100\left(\frac{1-W2}{W1}\right)$ 2

Where: He= Hulling Efficiency (%),
W_1= Mass of paddy sample before hulling (g)
W_2= Mass of un-hulling paddy (g)

Breaking Percentage *(Br %)* = $100\left(\frac{W3}{W1}\right)$ 3

Where: Br% = Breaking percentage (%),
W_3= Mass of broken rice after hulling (g)
W_1= Mass of paddy sample before hulling (g)

Machine design

Hopper design

The shape of the hopper was a combination a frustum and a cuboids mounted vertically to enhance gravity discharge with angle of repose of 50° and its volume was expressed according to Chelecha (2003) as shown in Equation 1.

$V=\frac{h}{3}\left[A+A_1+\sqrt{A\times A_1}+C\right]$ (cm³) 4

Where: h = vertical height;
A = area of upper opening;
A_1 = area of the lower opening or delivery section;
C = area of cuboids.

$A=L\times B$ 5

Where: L = 58 cm, B = 50 cm, A = 58 x 50 $(cm)^2$ = 2900 cm^2

$A_1=L\times b$ 6

$h=Lsin\o$ 7

Where ø = angle of repose
h= height, L= length

$A_1=\frac{bh}{sin\O}$ 8

$=25\times\frac{36}{\sin 50}$, Where b = 25 cm, h = 36cm, Angle of repose of rice = 50^0

A_1=1174.87cm^2, V= 49664.5cm^3

Design of driven roller shaft

Maximum bending stress of steel = 105 N/mm² = $105\times10^6 N/m^2$. The bending stress, σ = $32\frac{32M}{\pi D^3}$= 105×10^6,where M = 28.84 Nm (Bending moment of driven shaft)

$105\times10^6\times\pi D^3$ = 32 × 28.84 Nm , D = 0.0144 m

Taken Factor of Safety under life load to be 3 (Khurmi and Gupta 2005), diameter of driven shaft = 3 × 0.0144 m = 42.2 mm. M = 14.81 Nm (Bending moment of drive shaft). Diameter of Drive shaft = 3 × 0.01128 m = 42.2 mm. For uniformity purpose = 35.0 mm diameter of mild steel was preferred for both driven and drive shafts.

$P=\frac{2\pi TN}{60}$ 9

Assuming N= 50 rpm, from the equation $T=\frac{\tau J}{R}$, where: τ = shear stress of the shaft = 40 MPa = 40 × 10^6 N/mm², R = radius, J = polar moment of inertia of the shaft $=\frac{\pi d^4}{32}$, Since the uniform diameter = 35 mm, J = $\frac{\pi(0.035^4)}{32}$, T = $40\times10^6\times1.28\times10^{-7}/R$, $R=0.035/2$ = 0.0175m. T = 303.28 Nm, P = (303.28 × 2π × 50) / 60 , P = 2 kW

Therefore 2 kW of power supply was recommended for the design.

Shear stress, $T_s=\frac{16T}{\pi d^3}$ 10

Compressive stress = $\frac{4f}{\pi d^2}$ 11

Power or the torque to be transmitted by the shaft, $P = \frac{2\pi TN}{60}$ 12

Description of machine working components

Hopper

It is a combination of frustum and cuboids in shape, made up of mild-steel plate of 2.0 mm thickness (Fig 2). It has upper and lower chambers of surface areas of 2900 and 1175 (cm^2) respectively with a vertical height of 360 mm. At its lower part a shutter was positioned to regulate the feeding rate of paddy into the milling chamber by gravity.

Rubber roll

They are two rollers made of polyurethane blends of adequate hardness value commonly used in wheat huller, having thermal stability up to 100 ^{o} C and Poisson's ratio of about 0.45 (Baker *et al*., 2012). They are of equal hollow cylinder with outer and inner diameters of 180 and 140 mm respectively, and total length of 350 mm. These rollers were suspended on roller bearings with the help of drive and driven shafts of Θ 35 × 540 and 470 (mm) in lengths respectively.

Milling chamber

It is made of mild-steel plate of 2.0 mm suspended on the frame. This unit enclosed both rubber rollers, having a slanted base corresponding to angle of repose of paddy that was predetermined. This milling chamber has neither blower nor aspirator for separation of hull from grains.

Drive and driven shafts

They are made of mild-steel rod of 35 mm diameter, suspended on the frame with the help of roller bearings (Fig. 3). The drive shaft has a cast iron double grove driven pulley of 225 mm in diameter connected to a pulley of 75 mm in diameter of an electric motor. The replaceable drive and driven spur gears are mounted on their corresponding shaft.

Machine frame

This is made up of angle iron of 60 × 60 × 5 mm. It has a dimension of 600 × 800 × 1300 mm (Figs. 2-4). It suspended milling chamber, roller bearing and electric motor for effective performance. The orthographic and isometric views of the modified rubber roll rice huller are shown in Fig. 2 and 3, respectively while the exploded view of the experimental machine and a prototype are shown in Figs. 4 and 5 respectively.

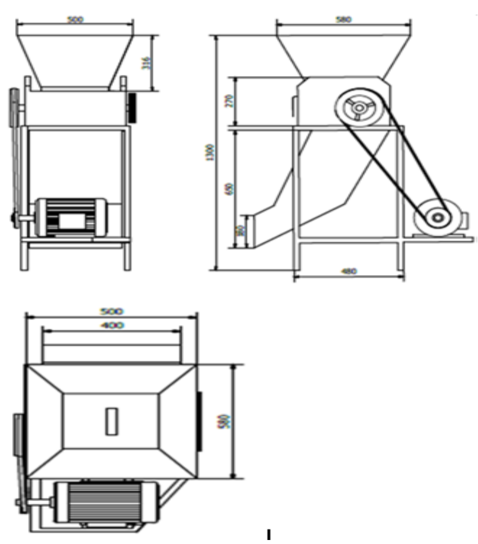

Fig. 2: Orthographic Projections of the experimental machine

Fig. 3 Isometric Projection of the experimental machine

PARTS LIST			
ITEM	QTY	PART NAME	MATERIAL
1	1	Hopper	Steel mild
2	1	Roller cover	Steel mild
3	1	Receiver with sleeve	Steel mild
4	1	Frame	Steel carbon
5	1	Electric motor	Purchased
6	1	Roller pulley	Steel carbon
7	2	Rubberized roller	Rubber
8	1	V-belt	Purchased
9	1	Spur Gear1	Steel carbon
10	1	Spur Gear2	Steel carbon
11	4	Bearing housing+roller bearing	Steel carbon

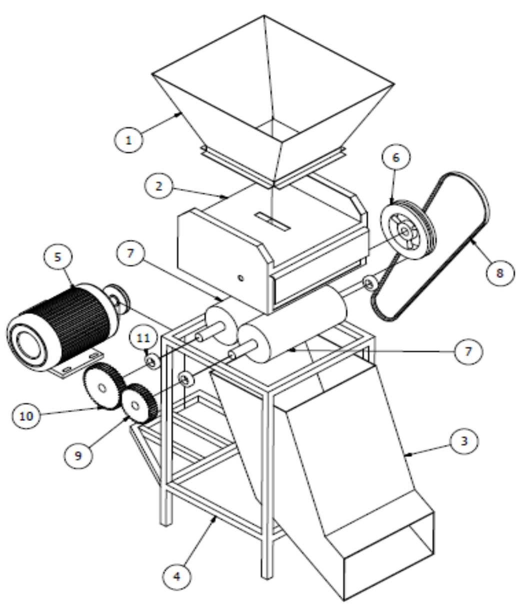

Fig. 4: An exploded view of the experimental machine

Fig. 5: Pictorial view

RESULTS AND DISCUSSION

Effect of physical properties of paddy on design and performance of the machine

A summary of the results of some physical properties of two cultivars of paddy measured is shown in Table 1. In Table 1, the average geometrical means diameter, sphericity and bulk density obtained were 3.88 mm, 0.38 and 535.75 kg/m^3; 3.94 mm, 0.41 and 511.54 kg/m^3 for *Ofada* and *Swamp* paddy cultivars, respectively. Almost the same values were reported by some previous researchers. Agu and Oluka (2013) reported some physical properties of *NERICA* paddy cultivars in Nigeria, such as geometrical means diameter, sphericity and bulk density to be: 3.56 mm, 0.36 and 640 kg/m^3; 3.62, 0.39 and 620 kg/m^3; 3.91 mm, 0.38 and 560 kg/m^3 for Faro 44, Faro 52 and Faro 57, respectively. Danbaba *et al*. (2013) also established some physical properties of paddy varieties in Nigeria, such as geometric means diameter and sphericity to be 3.70 mm and 0.39; 3.89 mm and 0.37 and 3.67 mm and 0.38 for Faro 44, Faro 52 and Faro 57, respectively. Table 1 shown that, there were disparities in the physical properties of *Ofada* and *Swamp* paddy cultivars in terms of axial dimensions, gravitational and frictional properties. These may be due to differences in their morphology, associated with heterogeneous composition of cell walls, shape, size and moisture content (Ogunsina et al. 2008; Morakinyo and Bamgboye 2014). From Table 1,*Ofada* paddy was found to be of higher values in axial dimension, gravitational and frictional properties than *Swamp* paddy but contrary to their sphericity values. This may be the major factor attributed to the higher value of the milling capacity and efficiency of *Swamp* paddy cultivar than that of *Ofada* paddy cultivar. It was also observed that the sphericity of the paddies influenced their angle of repose. The same observation was reported by Zarieforoush et al. (2010) on the two varieties of paddies: *Alikazeni* and *Hasheni* of 14.6 and 14.8 % (*w.b*) respectively. They also observed that, the engineering and varietal factors influenced the milling efficiencies. Dauda et al. (2012) also reported that the two paddies (*Faro52* and *Faro55*) soaked and parboiled under the same conditions showed disparities in machine characteristics due to their differences in some physical and mechanical properties. In this modification, the empirical values of the physical properties of these two paddy cultivars authenticate the selection of the optimum clearance in-between the two rollers of 1.2 mm which is lower than average geometrical mean diameter of both paddies (Table 1).

Effect of velocity gear ratio and parboiling temperature on hulling capacity

The results of the hulling capacities for *Ofada* and *Swamp* paddies at various parboiled temperature: 60, 70 and 80 ^oC and gear velocity ratio 1:1.6, 1:1.3 and 1:1.05 were shown in Figures 6 and 7 respectively. The result showed that, the maximum hulling capacity values were 55.5 kg/h and 56.8 kg/h for *Ofada* and *Swamp* paddies, respectively at the optimum parboiling temperature of 70 °C and velocity gear ratio of 1:1.3,. Hence, the minimum hulling capacities were obtained at parboiling temperature of 60 °C and velocity gear of 1:1.05 for both cultivars. It was also observed that increase in the parboiling temperature from 70 to 80 °C and velocity gear

Table 1: The mean of Physical Properties of Dried Parboiled Paddy of the Two Cultivars

Properties	Ofada	Swamp
Length (mm)	10.12 ± 1.88	9.45±1.60
Breadth (mm)	2.74± 0.20	3.28±0.16
Thickness (mm)	2.10 ±0.13	2.26±0.20
GMD(mm)	3.88±0.21	3.94±0.52
Sphericity	0.38 ±0.18	0.41±0.06
Porosity (%)	49.07±4.58	47.37±3.65
Angle of Repose (%)	20.02 ±3.20	18.50±2.30
Bulk Density ($\frac{kg}{m^3}$)	535.74±5.56	511.54±6.80
True Density ($\frac{kg}{m^3}$)	1052.00±15.70	971.93±8.67
Moisture Content (wb) (%)	14.5±0.21	14.3±3.5

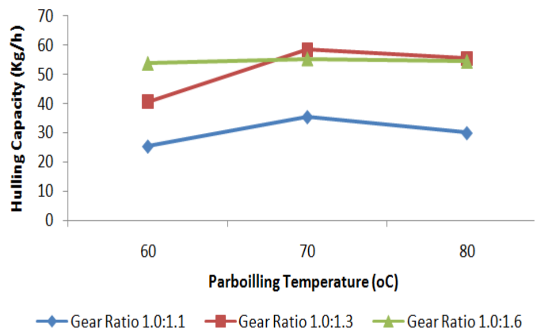

Fig 6. Graph of Hulling Capacity against Parboiling Temperature at Various Gear Ratio for *Ofada* Paddy

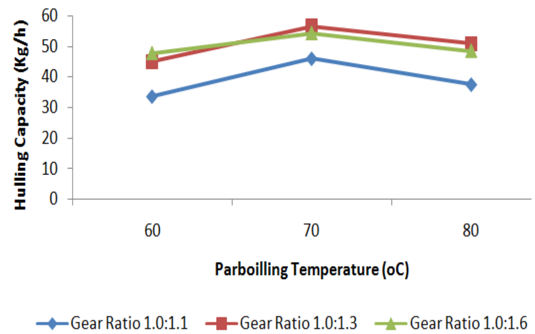

Fig 7. Graph of Hulling Capacity against Parboiling Temperature at Various Gear Ratio for *Swamp* Paddy

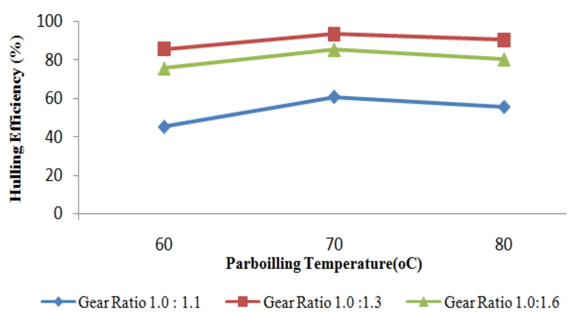

Fig 8. Graph of Hulling Efficiency against Parboiling Temperature at various Gear Ratio of *Ofada* Paddy

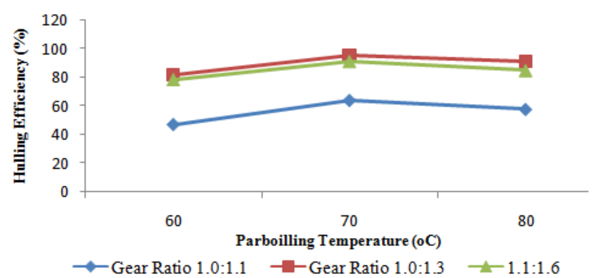

Fig 9. Graph of Hulling Efficiency against Parboiling Temperature at various Gear Ratio of *Swamp* Paddy

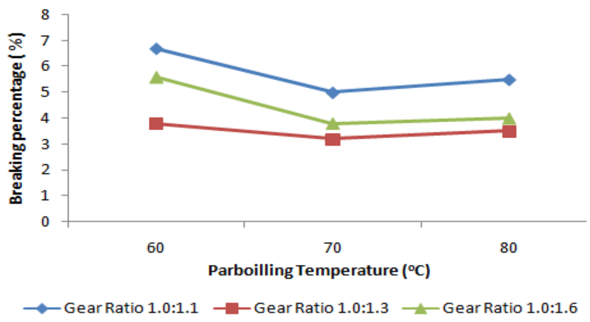

Fig 10. Graph of Breaking Percentage against Parboiling Temperature at various Gear Ratio of *Ofada* Paddy

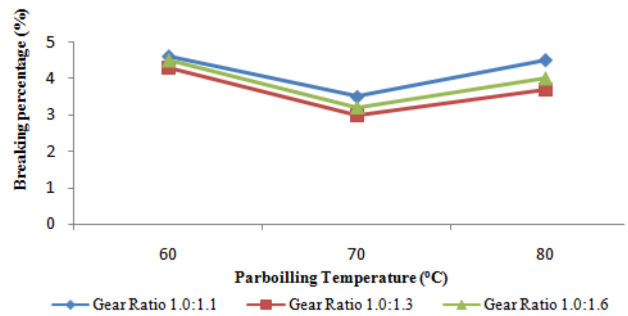

Fig 11. Graph of Breakage Percentage against Parboiling Temperature at various Gear Ratio of *Swamp* Paddy

ratio from 1:1.3 to 1: 1:1.6, the hulling capacity decreases in both paddy cultivars (Figures 6 and 7). The linear regression equation for predicting the hulling capacity Hcp is shown in Equation 1

$$Hcp = 58.007 - 1.841\beta_1 - 14.362\,\beta_2 - 18.228\,\beta_3 \quad (1)$$

Where: Hcp - Hulling capacity,
β_1- Paddy cultivars,
β_2 - Parboiling temperatures
β_3 - Gear ratio.

Table 2 shows the parameter estimates tests where the hulling capacity of *Ofada* cultivar is insignificantly different from that of *Swamp* paddy cultivar, likewise on gear ratio of 1.3 at level of $p>0.05$. However, the effect of varying the parboiling temperature from 60 to 80 °C resulted to significant differences in the hulling capacities of the machine for both cultivars. Hence the coefficient of determinations R^2 as degree of reliability tests in-between the hulling capacity and independent variables is 0.85. But within individual independent variables, the difference were significant ($p>0.05$). Hence, the optimum velocity gear ratio for maximum hulling capacity for both cultivars was 1:1.3 and at parboiling temperature of 70 °C (Figures 6 and 7).

Effect of velocity gear ratio and parboiling temperature on hulling efficiency

In Figures 8 and 9, the maximum hulling efficiencies measured were: 87.92.0% and 91.08% for *Ofada* and *Swamp* paddy cultivars respectively. These optimum values of the hulling efficiencies were obtained at velocity gear ratio of 1:1.3 and at the parboiling temperature of 70 °C. It was observed during hulling operation that there were no much differences in the hulling efficiencies at the velocity gear ratios 1:1.3 and that of 1:1.6 for *Swamp* paddy cultivar, unlike that of*Ofada* paddy cultivar (Figures 8 and 9). Their hulling efficiency differences may be due to their variability in engineering properties and varietal factors. It is shown in Figure 9, as the velocity gear ratio increased from 1:1.05 to 1:1.3 the hulling efficiency increased from 62.69% to 91.08%. The same trend was observed during the milling of *Ofada* paddy cultivar.

Table 2: Parameters Estimate Test between Independent and Hulling Capacity of Paddy

Parameter	B	Std. Error	T	Sig.	95% Confidence Interval	
					Lower Bound	**Upper Bound**
Intercept	58.007	1.342	43.211	.000	55.308	60.707
Ofada Cultivar	-1.841	1.096	-1.679	.100	-4.045	.363
Swamp Cultivar	0[a]	.	.	.	.	.
Parboiling temperature (60 °C)	-9.306	1.342	-6.932	.000	-12.005	-6.606
Parboiling temperature (70°C)	-4.956	1.342	-3.692	.001	-7.655	-2.256
Parboiling temperature (80°C)	0[a]	.	.	.	.	.
Gear Ratio (1.0)	-17.672	1.342	-13.165	.000	-20.371	-14.973
Gear Ratio (1.3)	-.556	1.342	-.414	.681	-3.255	2.144
Gear Ratio (1.6)	0[a]		.	.	. .	.

a. This parameter is set to zero because it is redundant, R = 0.85

Table 3: Parameters Estimate Test between Independent and Hulling Efficiency of the Paddy

Parameter	B	Std. Error	T	Sig.	95% Confidence Interval	
					Lower Bound	**Upper Bound**
Intercept	91.076	.715	127.418	.000	89.639	92.513
Ofada Cultivar	-3.159	.584	-5.413	.000	-4.333	-1.986
Swamp Cultivar	0[a]	.	.	.	.	.
Parboiling temperature (60 °C)	-12.328	.715	-17.247	.000	-13.765	-10.891
Parboiling temperature (70°C)	-4.244	.715	-5.938	.000	-5.682	-2.807
Parboiling temperature (80°C)	0[a]	.	.	.	.	.
Gear Ratio (1.0)	-28.383	.715	-39.709	.000	-29.820	-26.946
Gear Ratio (1.3)	5.894	.715	8.247	.000	4.457	7.332
Gear Ratio(1.6)	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant. R = 0.98

Table 4: Parameters Estimate Test between Independent and Breakage Percentage of the Paddy

Parameter	B	Std. Error	T	Sig.	95% Confidence Interval	
					Lower Bound	**Upper Bound**
Intercept	5.673	.260	21.843	.000	5.151	6.195
Ofada Cultivar	.790	.212	3.724	.001	.363	1.216
Swamp Cultivar	0[a]	.	.	.	.	.
Parboiling Temp. = 60°C	-1.104	.260	-4.253	.000	-1.627	-.582
Parboiling Temp = 70°C	-.785	.260	-3.023	.004	-1.307	-.263
Parboiling Temp = 80°C	0[a]	.	.	.	.	.
Gear =1.0	-2.579	.260	-9.932	.000	-3.102	-2.057
Gear =1.3	-1.618	.260	-6.231	.000	-2.141	-1.096
Gear=1.6	0[a]	.	.	.	.	.

a. This parameter is set to zero because it is redundant. R = 0.74

In Table 2 of parameter estimates tests between independent variable and hulling capacity on both cultivars were insignificant different to one another. But as the parboiling temperature increased from 60 to 80 °C, there was an increased in the values of milling capacity from one cultivar to another. In Figures 8 and 9, the percentage difference on the effect of velocity gear ratio was 34.28%, higher than that of the effect of the parboiling temperature of 12.33%. However, as the velocity gear ratio increased from 1:1.3 to 1:1.6, the hulling efficiency decreased from 91.08% to 85.72%, with the difference of 5.89% in Figure 9. In the same trend, as the parboiling temperature increased from 70 to 80 (°C), the hulling efficiencies decreased from 91.08% to 86.83% with the difference of 4.2%. From the above deductions, the aim of this work has been achieved, of determining the optimum velocity gear ratio and the parboiling temperature that could enhance the machine characteristics while milling *Ofada* and *Swamp* paddy cultivars in southwest of Nigeria. However, the linear regression equation for predicting the hulling efficiency H_{EF} is shown in Equation 2, while the coefficient of determinations R^2 as degree of reliability tests in-between hulling efficiency and independent variables is 0.98.

$H_{EF} = 91.08 - 3.16\beta_1 - 18.22\,\beta_2 – 22.50\,\beta_3$ (2)

Where: H_{EF} - Hulling efficiency,
β_1- Paddy cultivars,
β_2 - Parboiling temperatures
β_3 - Gear ratio.

In Table 3 of parameter estimates tests between independent variable and hulling efficiencies on both cultivars were significant different at a level of ($p<0.05$). Shitanda et al. (2008) noted the same observation, that milling efficiency of the three varieties of paddies increase from 89.31% to 91.33% when parboiled temperature increases from 60 to 75 (^oC). This result was in line with what other previous researchers reported, that machine characteristics of rice huller depend upon the varietal factors, speed of the machine and parboiling temperature (Gbado *et al*. 2008; Adekoyeni *et al*. 2012 and Dauda *et al*. 2012).

Effect of velocity gear ratio and parboiling temperature on breakage percentage

Figures 10 and 11, showed the results of the minimum breakage percentages of *Ofada* and *Swamp* brown rice grains as 3.2 and 2.8 (%) respectively, obtained at the velocity gear ratio of 1:1.3 and parboiling temperature of 70 ^oC. It was observed also that at the velocity gear ratio of 1:1.05 and parboiling temperature of 60 ^oC, the highest values of breakage percentages were obtained, while at the instance of velocity gear ratio of 1:1.6 and parboiling temperature of 80 ^oC, the breakage percentages of brown rice grain slightly became higher. These results showed that the optimum machine characteristics for *Ofada* and *Swamp* cultivars occurred when velocity gear ratio of 1:1.3 and the parboiling temperature of 70^oC were observed. Figures 10 and 11 revealed that, the maximum breakage percentage of *Ofada paddy* cultivar was 5.46%, while that of *Swamp* paddy cultivar was 4.67%. However, the minimum breakage percentages for both cultivars were 3.2 and 2.8% respectively. These observations were reported by some previous researchers. Seguy and Clement (1994) noted that the long and tiny paddy was more susceptible to breakage during hulling process than short and thick paddy. Likewise, Dauda *et al*. (2012) reported that speed of the steel friction roller influenced the hulling capacity and efficiency breakage percentages of paddies. However, the linear regression equation for predicting the breakage percentage B_{EF} is shown in Equation 3, while the coefficient of determinations R^2 as degree of reliability tests in-between breakage percentage and independent variables is 0.74.

$B_{EF} = 5.67 + 0.79\beta_1 - 1.89\,\beta_2 –4.19\,^{\beta3}$ (3)

Where: B_{EF} – Breakage efficiency,
β_1 - Paddy cultivars,
β_2 - Parboiling temperatures
β_3 - Gear ratio.

The coefficient of determinations R^2 as degree of reliability tests in-between the breakage efficiency and independent variables is 0.74. In Table 4 all independent variables were significantly different to each other, while considering the breakage efficiency of both cultivars at a level of $p<0.05$. Danbaba *et al*. (2013) investigated milling characteristics of steel friction roll rice huller on Faro 44, Faro 52 and Faro 57 paddy cultivars in Nigeria. They reported that hulling capacity, hulling efficiency and breakage percentage are: 70.4 kg/h, 79.27% and 19.27%; 68.37 kg/h, 80.41% and 15.72%; 69.16 kg/h, 80.45% and 14.46% for Faro 44, Faro 52 and Faro 57, respectively. In comparison of these machine characteristics to that of the modified rubber rolls huller of this study, it is clearly showed that the modify model is of better performance that steel roll huller. Therefore adopting this modified rubber rolls huller for the milling of *Ofada* and *Swamp* paddies will bring sustainable development and boost the production of rice in Southwest of Nigeria.

CONCLUSION

The convectional rubber roll rice huller had been modified to suit the milling of *Ofada* and *Swamp* paddies cultivars into brown rice grains in Southwest of Nigeria. From the result obtained, it was established that physical properties of paddies influenced the machine characteristics and the adoption of spur gears improve the machine performance and its efficiency compare to the pullet driven type. Furthermore, the evaluation results of the prototype evidently showed that the optimum parameters that enhance machine characteristics were velocity gear ratio 1: 1.3 and parboiling temperature of 70 ^oC.This design modification has increased milling efficiency of the convectional rubber roll huller previously reported by Zareiforoush *et al.* 2010 from an average of 64.3% to 89.5% as regard to their respective paddy cultivars (*alikazeni* and *hasheni; Ofada* and *Swamp*). Conclusively the modified rubber roll rice huller will enhance effective milling of *Ofada* and *Swamp* in South-western geographical zone of Nigeria. More importantly, other cultivars in Nigeria, having similar physical properties should be evaluated on this proto-type, for wider application and to enhance sustainability of adequate local rice production. This will go a long way reducing importation of parboiled rice in to the country, thereby sustain economic growth.

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SOIL AND WATER CONSERVATION

GROUNDWATER RECHARGE ESTIMATION AND TREND ANALYSIS USING HYDROLOGICAL AND SOIL MOISTURE BALANCE MODELS IN SEMI ARID REGION

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ABSTRACT

Groundwater recharge estimation becomes very important, particularly in a cultivated land mass owing to the roles played by groundwater in the area of agricultural productivity. This paper presents the estimation and trend analysis of groundwater recharge in Kwadna basin using modified soil moisture balance model between the years 1996 and 2016. A single layer soil water balance model coupled with hydrological models was used in the recharge estimation while statistical techniques were used in groundwater recharge trend analysis. The meteorological data used in the models were obtained from Nigeria Meteorological Agency, Minna for the entire study period. Potential evapotranspiration (ETp) on daily basis was also estimated using Hargreaves evapotranspiration equation. Soil properties like moisture content at both field capacity and wilting point, near surface storage, soil moisture deficit, and crop properties like crop rooting depth and crop growth stages were obtained from the past studies and information gathered from the farmers in the study area. The results showed that annual groundwater recharge varied from 156 mm in 2004 to 731 mm in 2012 which correlated positively with rainfall. The soil moisture balance model results indicated sufficient soil moisture for crops' use during the period of June to September each year when SMD<TAW. The groundwater recharge trend analysis recorded an increasing trend with statistical significance in the two statistical tests used. Thus, the higher groundwater recharge and its increase in trend observed was attributed to higher rainfall depth recorded within the study period in the study area.

Keywords: Groundwater recharge; Soil moisture deficit; Evapotranspiration; Trend analysis

INTRODUCTION

Estimating groundwater recharge in a region with vast agricultural production where potential evapotranspiration often exceeds annual rainfall becomes very crucial owing to the rate at which the cultivated crops require water for their growth. In such a situation, the shortage of water in the root zone, in particular, has been responsible for low yield in agricultural production. This, in other words, means that to ensure increase in agricultural production in the region, replenishment of groundwater lost to evaporation and evapotranspiration through rainfall and irrigation becomes very significant. This replenishment is, therefore, termed groundwater recharge. According to Shukla and Jaber (2006), groundwater recharge occurs when a portion of the water falling on the ground surface percolates through the soil and reaches the water table. This recharge, spatially and temporally, is influenced by several factors, among which are meteorology, characteristics of soil and underlying geology, vegetal cover, depth to the groundwater level and frequency of groundwater recharge (Eni and Nicholas 2014; Adeleke et al. 2015).

Groundwater is replenished when rainfall percolates below the soil zone (Cao et al. 2016; Dash et al. 2016). And as previously reported, according to Awulachew *et al*. (2009), with adequate rainfall and minimum surface runoff, substantial percentage of rainfall known as effective rainfall would get to the root zones and become available soil moisture to the plants. Substantial part of the effective rainfall will also recharge the groundwater table thereby raising the water table depth and enhance adequate available soil moisture at the root zones (Rushton et al. 2006; de Siva and Rushton, 2007; Miguez-Macho and Fan, 2012). This is further buttressed by Eni and Nicholas (2014) which established rainfall as the most important source of groundwater in Nigeria. Dean et al., (2015) and De Silva and Rushton (2007) further submitted that groundwater recharge is highly variable as a result of erratic rainfall patterns. This, therefore, underscores the fact that for proper water management in any basin with large scale agricultural production, there is need for proper understanding of rainfall patterns and groundwater recharge rates of the region. As pointed out by De Silva and Rushton (2007), this information on rainfall patterns and groundwater recharge rates are required as inputs to regional groundwater models and predictions of climate change impacts.

With all these attributes of groundwater recharge, many methods have been developed in estimating the groundwater recharge and checking fluctuations in water table levels. The easiest of these methods is to directly measure the water table levels using monitoring wells. The effectiveness of this approach has been hampered due to huge costs involved and effort required in monitoring the groundwater behaviour over a long period of time. Due to limited data and the difficulty of the recharge process, precise estimates are often very difficult. As a result of this limited data on groundwater recharge estimation for possible guide, there has been high degree of uncertainty among water resources engineers in the estimation of sustainable groundwater resources (de Silva and Rushton 2007).

Alternative methods for groundwater recharge estimation in Nigeria have been presented by (Eni and Nicholas 2014; Fan et al., 2014; Adeleke et al. 2015; Cuthbert et al., 2016). These approaches, though, provide insights into the process leading to groundwater recharge, but estimating routine recharge on daily basis for a long period of time becomes difficult. Water table fluctuation (WTF) method has also been used for groundwater estimation with some levels of success recorded (Rushton *et al*. 2006). According to Rushton *et al*. (2006) and Fan et al., (2014), using the water table fluctuation method, the rise in water table during the recharge season is multiplied by the specific yield to obtain a groundwater recharge. Saghravani *et al* (2015) compared WTF method with Chloride Mass Balance (CMB) method for recharge estimation. They concluded that direct recharge estimation using WTF method gives a better recharge estimation due to its wider application for a large area compared to CMB method which is just for a point area application. They also concluded that groundwater recharge estimation is a function of soil properties as the coastal area with heavy presence of sandy soils yielded higher recharge.

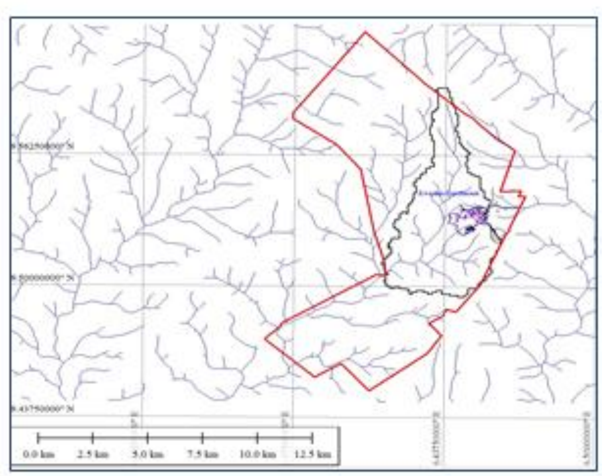
Groundwater recharge has also been correlated with rise in groundwater levels, according to Shamsudduha et al., (2009), which in other words means seasonal variation in water table levels as a result of variation in rainfall and intensive precipitation would have considerable effects on groundwater recharge (Mukherjee et al., 2007; Larsen et al., 2008; Norrman et al., 2008). This therefore calls for the need to check the trend in groundwater recharge to check the possible effects on crops and for the purpose of water resources management.

This study focused on groundwater recharge estimation in semi-arid region within a basin where the predominantly cultivated crops are peppers and corns which require adequate soil water availability for good yield. The study also appraised the trend in groundwater recharge within a period of fourteen years (2002 to 2015) using non-parametric method of trend analysis. Hydrological and soil moisture balance models which consider both the soil and crop properties were used for groundwater recharge estimation. The groundwater recharge was estimated in order to appraise the contribution of rainfall to the overall soil water need of the crops and to check the overall trend in groundwater recharge over some period of time. Consumptive use of soil water by the crops compared to the available soil moisture known as total available water (TAW) and readily available water (RAW) during the period of no recharge were also estimated on daily basis.

MATERIALS AND METHOD

Study area

The study area is Gidan Kwano Inland Valley located between Latitude 9^{o} 5000^{I} and 9^{o} 5625^{I} N and Longitude 6^{o} 373^{I} and 6^{o} 4375^{I} E (Figures 1 and 2). The valley is located at the western end of Minna, a North-Western town in Niger State, Nigeria within the permanent site of Federal University of Technology, Minna (Figure 1). The catchment area of the basin 30.79 km^{2}. The soil type on the study area was in a textural class of gravelly sand up to the depth of 80 - 90 cm. The area is characterized with low and erratic rainfall of between 1000 to 1200 mm as total annual rainfall with peaks in July and August.



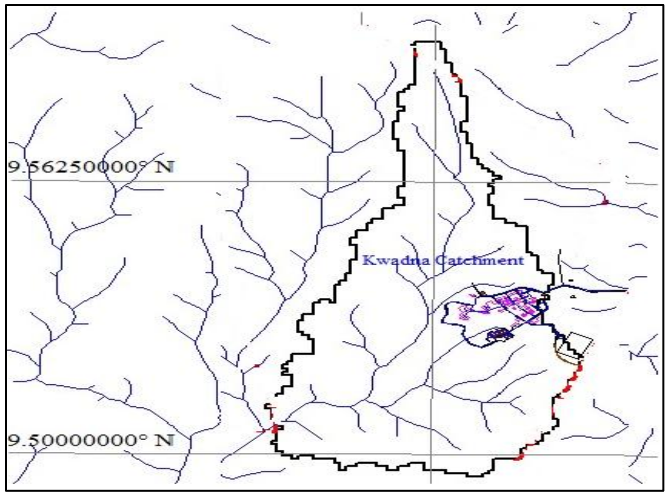


Figure 1: Location of Study Area (Kwadna basin)

The Model and its Computational Method

There are various models available for the estimation of groundwater potential recharge. There are conventional single layer model by Penman (1990), the CROPWAT model (Smith, 1992); the Balance model (Grema *et. al.* 1994), a two layer model developed to estimate daily soil water balance for cropped or un-cropped surface; and the four root layer model (FRLM) (Ragab et al., 1997). All the approaches listed above do not take into consideration routine recharge estimation. In order to achieve a routine recharge estimation and catchment-wide recharge estimates, a single layer modified soil water balance model with physical processes like rainfall, surface runoff, evapotranspiration, crop transpiration, root growth, soil water distribution following rain event and potential recharge is developed by Rushton (2003) and modified by De Silva and Rushton (2007). The conceptual and computational models of this approach are as shown in Figure 2.

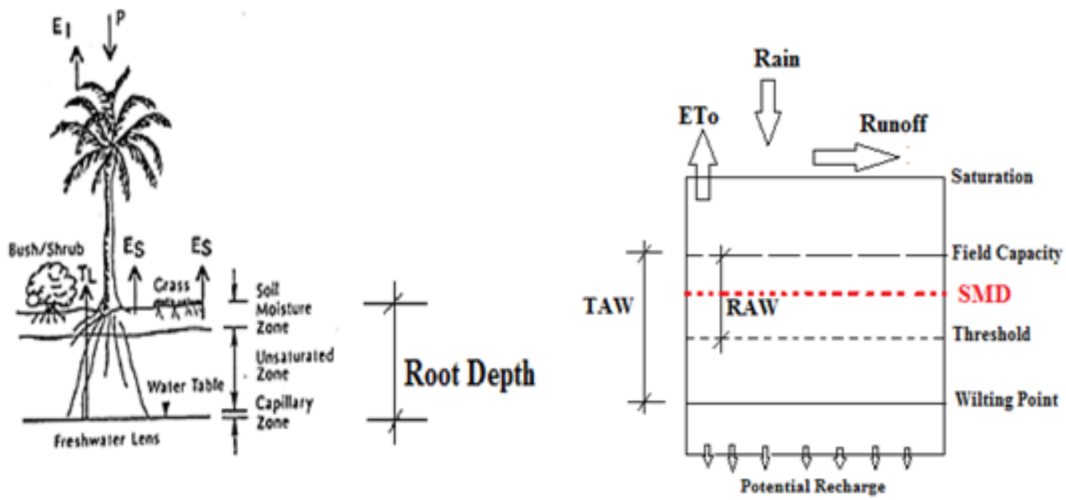


Figure 2: Conceptual and Computational Models of Soil Moisture Balance

This approach is based on the fact that soil becomes free draining when a certain soil condition called field capacity is reached. This is a soil condition which represents a point when additional water received by the soil drains through the soil to become groundwater recharge (Bradbury and Rushton, 1998). This type of recharge is categorized as direct recharge and the model has been used with huge success for potential recharge estimation in temperate climate, according to De Silva and Rushton (2007).

Reference evapotranspiration ETo

With the available maximum, minimum and mean temperature data with radiation, *Ra*, the Hargreaves method of evapotranspiration estimation was used in this study. The available daily maximum, minimum and mean temperature data for the study period with the obtained daily evapotranspiration values are presented in Appendix D.3. According to Droogers and Allen (2002), Hargreaves *ETo* equation is presented in [1]

$$\mathbf{ETo = 0.0023(T_{mean} + 17.8)\ (T_{max} - T_{min})^{0.5}\ Ra} \quad [1]$$

Where ***ETo*** represents the daily reference evapotranspiration (mm/day),
T_{max} and T_{min} = Maximum and minimum daily temperatures respectively (^oC)
T_{mean} = Mean Temperature (^oC)
Ra = Extraterrestrial radiation as 16.4 MJm^2/day

Soil moisture deficit

Initial soil moisture deficit ($SMD_{initial}$) which represents the soil moisture deficit at the beginning of the study was estimated as 49.8 mm using the method described in Adesiji (2012). The initial SMD was a function of moisture content at field capacity and wilting point which were estimated as 0.21 m^3/m^3 and 0.03 m^3/m^3 respectively (Adesiji, 2012).

Soil moisture deficit at the driest period (Initial SMD) is thus represented by the formula:

$$SMD_{initial} = [\theta_{fc} - \theta_{pwp}]\ Z_r \quad [2]$$

Where;
θ_{fc} = 0.21 m^3/m^3
θ_{pwp} = 0.03 m^3/m^3
Z_r = Maximum root depth (1.2 mm for peppers).

$$SMD' = SMD_{prev} + AE - AWE + NSS \quad [3]$$

Where;
SMD' = Present day SMD measured in mm
SMD_{prev} = Previous day SMD measured in mm
AE = Actual evapotranspiration measured in mm/day
AWE = Available water for evaporation measured in mm/day
AWE = Rainfall – Runoff + NSS, if SMD > 0

Where;
NSS = Near surface storage measured in mm
But, If SMDprev < 0, AWE = Rain – Runoff
NSS factor is the storage fraction of near surface storage represented by 0.45 by Rushton (2003).

Total available water and readily available water (TAW & RAW)

The value of total available water (TAW) is represented in eqn. [4].

$$TAW = (FC-WP)*1000*Zr, \quad [4]$$

Where;
FC = Moisture content at field capacity in m^3/m^3
WP= Moisture content at wilting point in m^3/m^3
Zr = maximum root depth in m as 0.9 m (as the oil palms are already mature)
Readily available water, RAW = TAW * ρ (ρ is a depletion factor constant between 0.2 and 0.7, Allen et al., 1998).

Groundwater Recharge Trend Analysis

Mann-Kendall trend detection technique, an example of non-parametric techniques, was used to identify the trend in groundwater recharge for the study period (2002-2015). Mann-Kendall (MK) statistical test (Mann 1945; Kendall 1975) is an example of non-parametric test also called Kendall's *t*-test which has been applied in many studies to identify whether monotonic trends exist in hydro-meteorological data like temperature, rainfall and streamflow. This test is often used because of its property that no assumption is needed about the data that need to be tested. In the trend test, the null hypothesis *Ho* is that there is no trend in the population from which the dataset is drawn and the sample of data $\{x_j, j = 1, 2, \ldots, n\}$ is independent and identically distributed. The alternative hypothesis *H*1 is that a trend exists in the dataset. The test statistic, Kendall's *S*, is defined as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j-k+1}^{n} Sign(x_j - x_k) \quad [5]$$

where x_j and x_k are the sequential data values,
n is the length of the dataset, and

$$Sign(x) = \begin{cases} 1 & if \quad x > 0 \\ 0 & if \quad x = o \\ -1 & if \quad x < 0 \end{cases} \qquad [6]$$

Under the null hypothesis, the statistic S is approximately normally distributed when $n \geq 8$ with zero mean and the variance is given as follows:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{t}^{n} t(t-1)(2t+5)}{18} \qquad [7]$$

where t is the extent of any given tie and denotes the summation over all ties. The standardized test statistic Z is computed by

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & for \quad S > 0 \\ 0 & for \quad S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & for \quad S < 0 \end{cases} \qquad [8]$$

The equation follows a standard normal distribution. For a two sided test for trends analysis, *Ho* should be accepted if $|Z| \leq 1.645$ at the 0.10 level of significance. A positive Z value indicates an upward trend, whereas a negative one indicates a downward trend. In other words, the hypothesis that there is no trend is rejected when the Z value computed in eqn. [8] is greater in absolute value than the critical value $Z\alpha$, at a chosen level of significance α, say 0.01 or 0.05. For the ease of using Mann-Kendall statistical test, TREND VI.0.2 was used in this study for groundwater recharge trend detection. The data set for the recharge is from 2002 to 2015.

RESULTS AND DISCUSSION

Recharge estimation

Figures 2 - 7 show the relationships between the soil moisture balance components for some selected years. Prominent among the components are rainfall, runoff, available water (TAW and RAW), soil moisture deficit, SMD and the groundwater recharge. In the presented cases annual groundwater recharge estimates ranged from 156 mm (13.9 % of annual rainfall) in 2004 to 731 mm (47.4 % of annual rainfall) in 2012. This expectedly correlated with annual rainfall pattern which recorded the highest rainfall depth in 2012 as 1543 mm. Surface runoff of 129 mm was recorded in 2014 while 169 mm was recorded in 2012. The groundwater recharge was recorded between the months of May and August in all the years. Table 1 shows the rainfall pattern, runoff, reference evapotranspiration, groundwater recharge and specific days the recharge was first recorded in the years under study.

Table 1: Annual values of measured hydrological parameters

Year	Annual Rainfall (mm)	Runoff mm	ETo mm	First Recharge Date	Recharge Mm
2002	1159	109	1696	June 19	455
2003	1048	106	2095	June 1	158
2004	1120	129	2117	June 1	156
2005	1088	151	2095	July 19	362
2006	1423	162	2048	May 21	389
2007	1382	145	2059	July 19	363
2008	1251	142	2066	May 26	334
2009	1297	197	2107	Aug. 17	296
2010	1223	123	2107	July 29	182
2011	1056	169	2189	Aug. 4	427

2012	1543	189	2095	May 30	731
2013	1140	169	2095	Aug. 4	427
2014	1232	139	2095	May 1	433
2015	1076	169	2095	Aug. 4	427

Soil moisture availability for Crop water use

From Figures 2 -7, total available water (TAW) and readily available water (RAW) are clearly defined and these two parameters, with soil moisture deficit (SMD), determined the availability of soil moisture for crop use. From a careful examination of Figures 2 - 7, it is apparent that between late June and Mid-September TAW and RAW reached peak levels which means there will be soil moisture availability for crop use, especially at the root zone (De Silva and Rushton, 2007). In other words, when SMD<RAW, there is sufficient soil moisture available for crop use and the actual evaporation (AE) occurs at the potential rate i.e. AE becomes the potential evaporation (PE). This is consistent with Bradbury and Rushton (1998). Consequently, the crop is likely to survive with this moisture availability with rainfall pattern kept constant. Excessive crop water use, which is also referred to as evapotranspiration (ETo), would lower both TAW, RAW, groundwater recharge and by extension, the surface runoff. This would mean there would be rise in SMD, which, if continued, would amount to excessive water stress within the root zone.

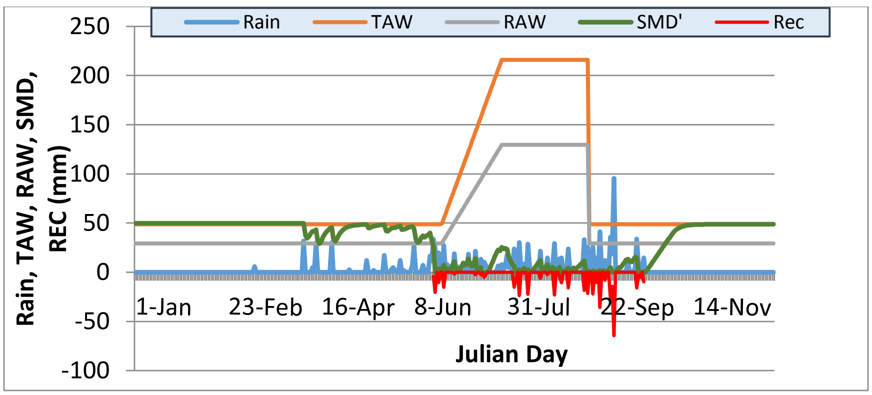


Figure 3: Soil Moisture Balance Components for 2002-Water year

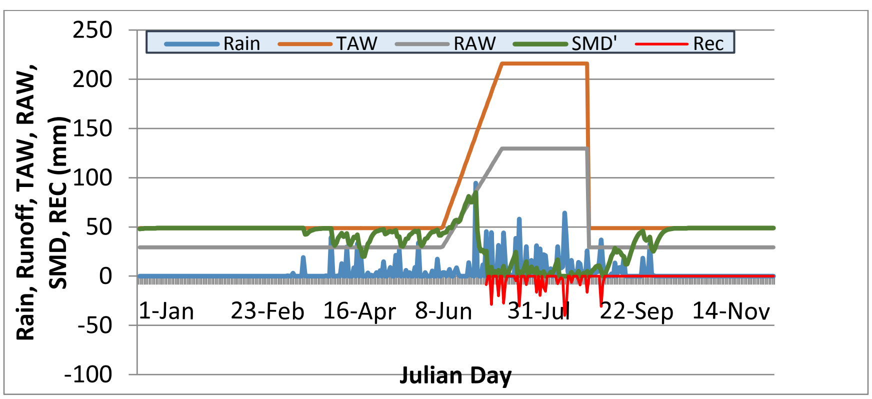


Figure 4: Soil Moisture Balance Components for 2005-Water year

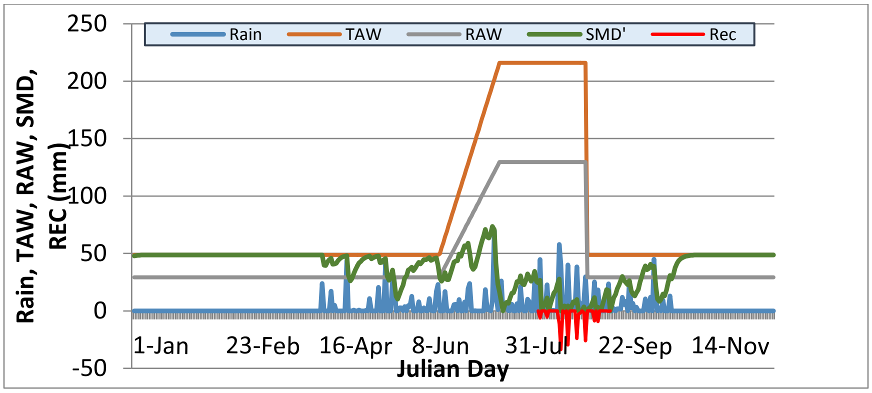


Figure 5: Soil Moisture Balance Components for 2010-Water year

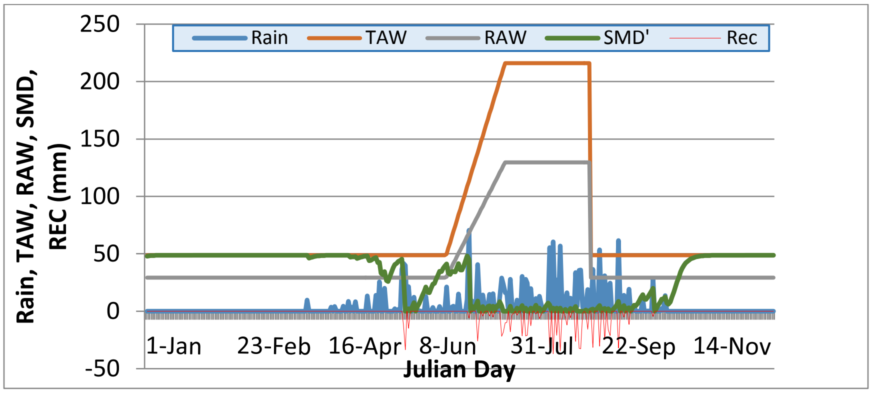


Figure 6: Soil Moisture Balance Components for 2012-Water year

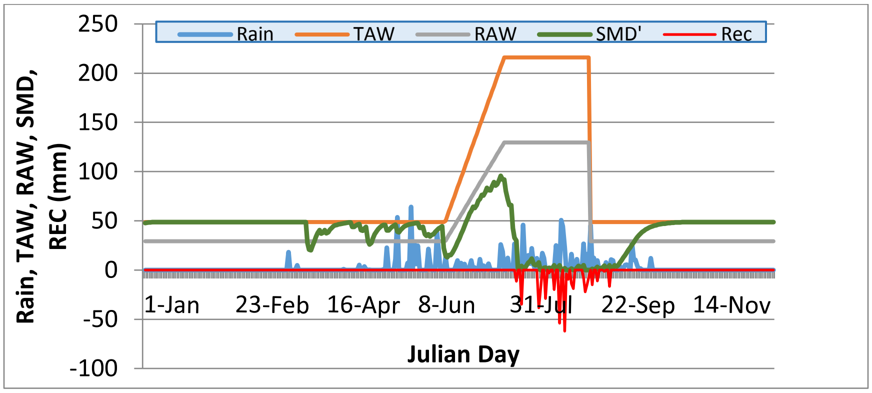


Figure 7: Soil Moisture Balance Components for 2015-Water year

Trend in groundwater recharge

The trend analysis results were as shown in Table 2 showing four different techniques used in checking any significance in groundwater recharge trends for the study period. Figure 8 showed the graphical representation of the trend analysis with increasing trend. The highest recharge (731 mm) was recorded in the year 2012 with the lowest in 2004 as 156 mm. From Table 2, critical values are compared with test statistics to check the statistical significance of the trend. From the four techniques used in the analysis, Mann-Kendall method and Spearman's Rho showed that there is statistical significance in groundwater recharge trend at significance levels of 0.05 and 0.01 respectively. The other statistical tests used: Linear Regression and Student's t-tests showed no statistical significance in groundwater recharge trend.

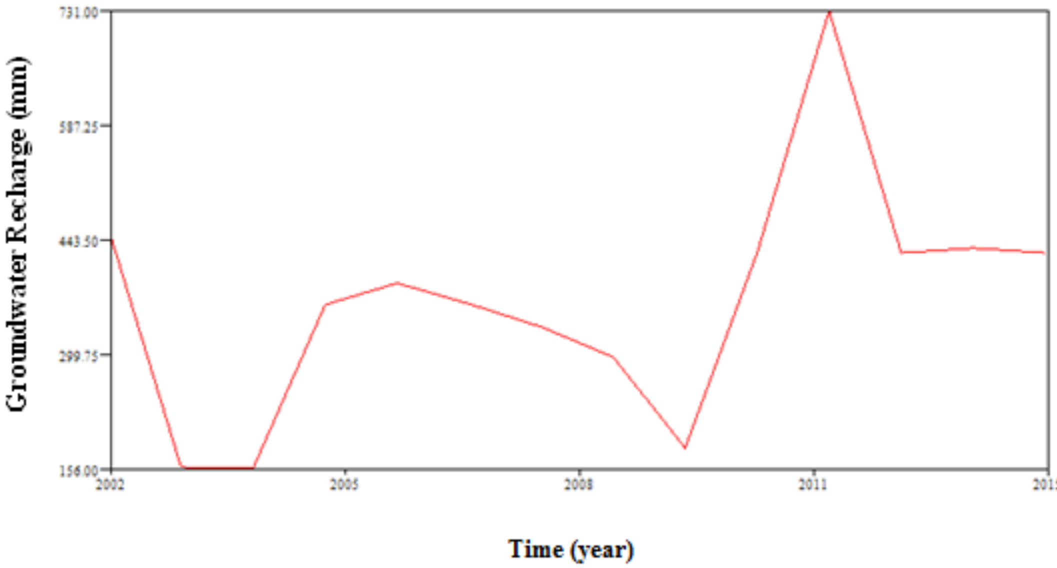


Figure 8: Graphical Output of Groundwater Recharge Trend Analysis (2002-2015)

Table 2: Results Output of trend analysis statistical testing

Statistical Method	Test statistic	Critical values (Statistical table) a=0.1	a=0.05	a=0.01	Result
Mann-Kendall	1.478	1.069	1.274	1.674	S (0.05)
Spearman's Rho	1.688	1.069	1.274	1.674	S (0.01)
Linear regression	1.761	1.782	2.179	3.055	NS
Student's t	-1.275	1.771	2.16	3.012	NS

CONCLUSION

Groundwater recharge quantity between the years 2002 to 2015 for Kwadna basin has been estimated using soil moisture balance model. Groundwater recharge trend analysis using trend detection techniques has also been carried out. From the study, rainfall was observed as the major factor determining the recharge quantity. The highest rainfall and groundwater recharge quantities were recorded the same year (2014) while the lowest was recorded in the year 2004. This shows rainfall determines majorly the amount of water recharging the basin. Hence, the farming period between May to September of each year under study recorded appreciable soil moisture availability (SMD<RAW) which explained the survival of the crops in the basin during these periods. This trend analysis generally gave an increasing trend which means there is accumulation of groundwater in the region for agricultural purposes in the basin.

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EVALUATION OF SOIL ERODIBILITY UNDER THREE DIFFERENT TILLAGE PRACTICES

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ABSTRACT

*A study was conducted to evaluate soil erodibility status under three different tillage practices. This study investigated the predictive capability of the K-value estimated by regression equation and nomograph. The tillage practices employed were tractor drawn, animal drawn and manual operations. The average results of K-value (erodibility) obtained for plot A, B and C were 0.12, 0.07 and 0.08**;** and 0.19, 0.15 and 0.16 respectively. For the two methods, tractor drawn operation (plot A) indicated higher K-value because the soil was more pulverized which accelerate aeration and porosity but at the same time exposing the top soil to action of erosion. This is due to finess of the soil particles are easily detached and transported by erosion especially at highly intense rainfall event. While plot B and C has the least K-value being the soil was poorly pulverized. The result between K_{eva} and K_{est} shows that they were linearly same with R^2 value of 1.0, 0.9, 0.9 and 0.8 for the four stages respectively. Therefore, Operation using tractor will favour crop growth but encourages erosion.*

Keywords: *Soil; Erodibility; Tillage; Erosion*.

INTRODUCTION:

Soil is one of the most precious natural resources. Proper soil management is a key to sustainable agricultural production. Soil management involves six essential practices: proper amount and type of tillage, maintenance of soil organic matter, maintenance of a proper nutrient supply for plants, avoidance of soil contamination, maintenance of the correct soil acidity, and control of soil loss (Hiscox, 2006). Erodibility can be defined as the susceptibility of a soil to erosion (Wischmeier and Smith, 1978). According to Levy *et al*., (2001) erodibility is the ability of a soil to resist or withstand erosion. Different soils have varying erodibility values which determine the way each soil responds to erosion, and this depends on the soil physical properties, including soil texture and organic matter (Levy *et al*., 2001). Soil erodibility is an important index used in evaluating the soil sensitivity to erosion, and its precise study and evaluation is important in understanding soil erosion regularity, predict soil loss and evaluate land productivity. According to Singh and Khera (2008), soil factor K (erodibility) represents both susceptibility of soil to erosion and the rate of runoff, as measured under the standard unit plot condition of 22.1m long with a 9 percent slope, maintained in continuous fallow, tilled up and down hill periodically to control weeds and break crusts that form on the surface of the soil. They observed that soil erodibility depends primarily on physical and chemical characteristics of the soil. According to Reichert *et al*., (2001), soil physical and chemical properties affect soil stability, which is an important soil property governing erodibility. However, Roose (1996), observed that soil erodibility can be seen in relation to percentage of sand content, percentage organic matter, soil structure and permeability. Organic matter is an important element in maintaining good physical conditions in the soil; it contains the entire soil reserve of nitrogen and significant amounts of other nutrients such as phosphorus and sulphur. Soil organic matter often plays a major role in aggregate stability, which affects soil erodibility (Tisdall and Oades, 1982, Oades, 1984). In addition, Singh and Khera (2008) observed that organic matter reduces erodibility because it reduces susceptibility of the soil to detachment, and it increases infiltration which reduces runoff and thus erosion. Soils high in clay have low K values, i.e. low erodibility index about 0.05 to 0.15, because they are resistant to detachment. Coarse textural soils such as sandy soils have low K values, about 0.05 to 0.2 because of low runoff even though these soils are easily detached. Medium textured soils such as the silt loam soils have a moderate K value, about 0.25 to 0.4, because they are moderately susceptible to detachment and produce moderate runoff. Soils having high silt content are most erodible of all soils. They are easily detached, tend to crust and produce high rates of runoff. Values of K for these soils tends to be greater than 0.5 (NRCS-USDA, 1958).

Soils generally have been known worldwide to have been affected by erosion, for that matter, the soils in Bayero University Kano (B.U.K) is not been an exception. Researchers (Onwualu and Anazodo, 1989; Yiljeb and Yusuf, 2000) are in agreement that land development (in agriculture) without due consideration to tillage practice could rapidly degrade the soil, causing a quick decline in productivity of the soil. The lack of knowledge of the erodibility status of the soils may hinder the individual from taking the right and adequate soil conservation and management procedure necessary in minimizing soil loss by erosion and increasing agricultural productivity. In the light of the foregoing, this study determine the erodibility status of each plot under different tillage practice and the best soil conservation management practice for minimizing erosion and increasing agricultural products.

MATERIALS AND METHODS

Location and Climate

The study was conducted at Department of Agricultural Engineering farm, Bayero University Kano which is located on (latitude 11˚ 58' 38''N. longitude 08˚ 02' 80''E) and the altitude is approximately 464m above sea level (Amir, 2011). The annual minimum and maximum temperature and relative humidity of the area are 20.9˚c, 32˚c and 51.36%, 52.05% and total amount of rainfall is 890.400692mm (Muhammad, 2014)

Experimental Set-up

The field layout is with a total area of 320m². The plot was divided into three sub-plots labelled A, B and C. In each of the sub-plot a different tillage system was carried out as considered under this study.
Sub-plot A. Involve the use of a tractor to carry out the tillage operation(s) and the size of the plot is $100m^2$.
Sub-plot B. Also involve the use of manual tilling operations with implements such as hoe, cutlass etc. The size of the plot is $100m^2$.
Sub-plot C. Also involve tillage using animal drawn implements for tilling operations. The size of the plot is $100m^2$.

Reconnaissance Survey

A reconnaissance survey was conducted aimed at selecting plot and demarcating the sub-plots. The first six (6) soil samples (pre season) was collected, two (2) each from three sub-plots. The collected soil samples were taken to soil laboratory for drying at room temperature. This procedure was repeated for next second, third and fourth soil sample collection.

Samples Collection

Two soil samples was collected using auger at the depth of 0-30cm from each of the sub-plots. The samples collected was put into a well label polythene bags to be transported to where it was dry at room temperature for two days after which it was taken to the soil science laboratory for soil texture and organic matter content analysis.
A total of twenty four (24) samples were collected in four (4) stages making six (6) per stage, which indicates two samples in each sub-plots.

- First stage: samples were collected before rain fully establish (pre-season) for laboratory soil analysis.
- Second stage: when the rain has fully established (early-season) another samples were collected for laboratory soil analysis.
- Third stage: when rain start to end for the season (mid-season), samples were collected for laboratory soil analysis.
- Fourth stage: this is the last stage; samples were collected when raining season has finished (late-season) for 2014 rainfall season.

Other materials to be used follow according to the requirements for the evaluation of the various parameters found in the Regression equation (Wischmeier and Smith, 1978) given below:

$$100\mathrm{K} = 2.1 \times 10^{-4} \times (12 - OM)\mathrm{M}^{1.14} + 3.25 \times (\mathrm{St} - 2) + 2.5 \times (\mathrm{Pt} - 3) \quad (1)$$

Where OM – Organic matter content %
M – Product of Silt and Silt + fine sand content
St - Soil structure code (very fine granular= 1, block= 4)
Pt - Permeability class (rapid= 1 to very slow= 6)

The soil erodibility factor (K-factor) is a quantitative description of the inherent erodibility of a particular soil; it is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. For a particular soil, the soil erodibility factor is the rate of erosion per unit erosion index from a standard plot. The factor reflects the fact that different soils erode at different rates when the other factors that affect erosion (e.g., infiltration rate, permeability, total water capacity, dispersion, rain splash, and abrasion) are the same. Texture is the principal factor affecting K_{fact}, but structure, organic matter, and permeability also contribute. The soil erodibility factor ranges in value from 0.02 to 0.69 (Goldman et al. 1986; Mitchell and Bubenzer 1980).

For estimating K in SI units (t ha hr / ha MJ mm) as given by Rosewell (1993) was used.

Estimation of Erodibility Using Erodibility Nomograph

The results that have been gotten from the laboratory work were used to evaluate erodibility by estimation using the Erodibility Nomograph, which is a standard chart for estimation of erodibility. The parameters to be used are product of Silt and Very Fine Sand + Silt content, Sand content, Organic Matter content, Soil Structure code, and Permeability class. The results from the Nomograph will then be compared with the ones gotten from the Regression equation (1) to see the method that will be better for use in evaluating the Erodibility in the plots.

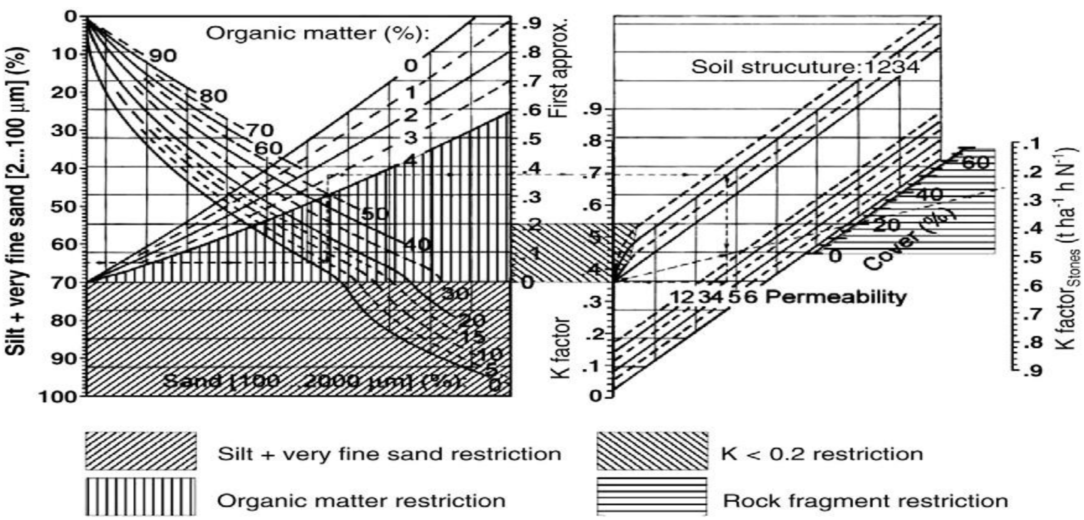

Fig. 1: Soil erodibility nomograph (Wischmeier *et al*, 1971)

RESULTS AND DISCUSSION

Table 1 shows the results of erodibility status of the experimental plot from stage one to stage four (i.e. from the beginning of rainy season to the end during 2014 raining season). The effect of management practice on soil erodibility factor (K), from beginning of rainy season to the end for all plots (A, B and C) shows a decrease in soil erodibility. This indicated that, as the raining season continues the more the soil become more erodible to erosion due to the fact that the soil becoming more moist and with crops which reduces the impact of rain drop.

Table 1: Soil erodibility status for all experimental plots for various stages (seasons)

Plot	Silt + Very Fine Sand %	Sand %	Clay %	Organic Matter %	Soil Structure	Permeability	Erodibility
				Pre-season			
A	23.06	66.74	10.20	0.70	4	3	0.13
B	19.41	74.39	6.20	0.69	4	3	0.10
C	21.96	71.84	6.20	0.55	4	2	0.09
				Early-season			
A	24.86	58.14	17.00	1.30	4	3	0.14
B	27.91	64.40	10.00	1.20	3	3	0.13
C	21.11	70.89	8.00	1.40	3	3	0.08
				Mid-season			
A	24.80	63.20	14.00	0.74	3	3	0.11
B	17.50	76.50	6.00	0.40	2	3	0.05
C	18.75	72.25	9.00	0.76	3	3	0.06

				Late-season			
A	25.76	56.92	17.32	0.74	3	2	0.09
B	20.06	75.62	4.32	0.64	2	3	0.04
C	21.46	72.22	6.32	0.52	2	2	0.05

Where; A - Tractor drawn, B - Manual operation, C - Animal drawn

Erodibility Status for Different Management Practice

The figure below shows that, tractor drawn operation has the highest erodibility status followed by the manual operation and lastly animal drawn operation. But at the last two stages, Animal drawn is higher than Manual operation.

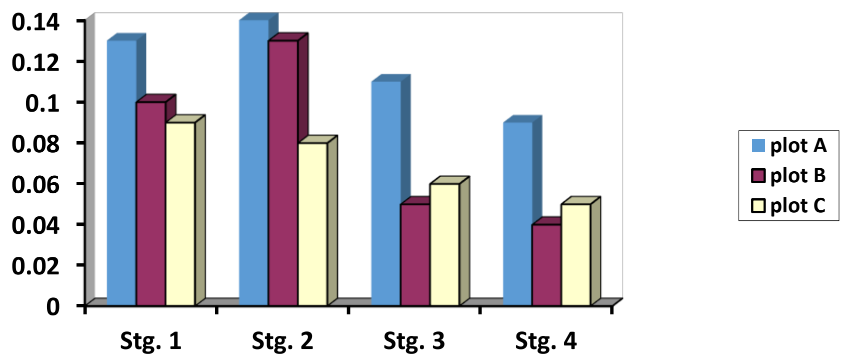

Fig. 2: Erodibility status for different management practice

Comparison Between Estimated and Evaluated Erodibility

Table 2 below show the results of estimated and evaluated erodibility obtained (i.e. using regression equation and nomograph).

Table 2: Soil erodibility values at different stages of rainy season

Stage	Plot	Kest	Keva
Pre-season	A	0.21	0.13
	B	0.18	0.10
	C	0.17	0.09
Early- season	A	0.22	0.14
	B	0.21	0.13
	C	0.14	0.08
Mid- season	A	0.18	0.11
	B	0.12	0.05
	C	0.14	0.06
Late-season	A	0.15	0.09
	B	0.11	0.04
	C	0.13	0.05

Where: Kest – Erodibility estimated from the NOMOGRAPH

Keva – Erodibility evaluated using REGRESSION FORMULA

Fig. 3 – 6 shows the relationship between estimated and evaluated erodibility. The graphs indicated that there were linear relationship between estimated and evaluated erodibility with R^2 value of 1.0, 0.9, 0.9 and 0.8 for the four stages respectively. This clearly indicated that any procedure can be followed in trying to evaluate the erodibility status of a given soil.

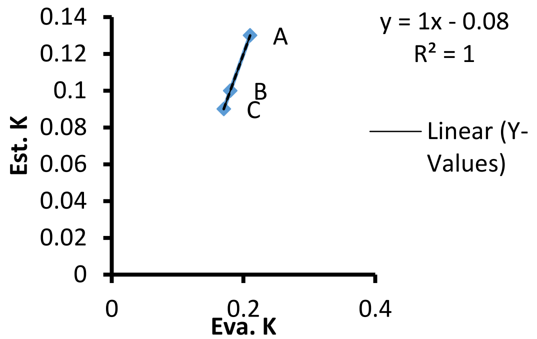

Fig. 3: Stage one

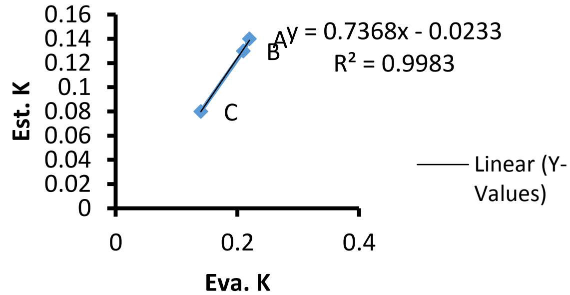

Fig. 4: Stage two

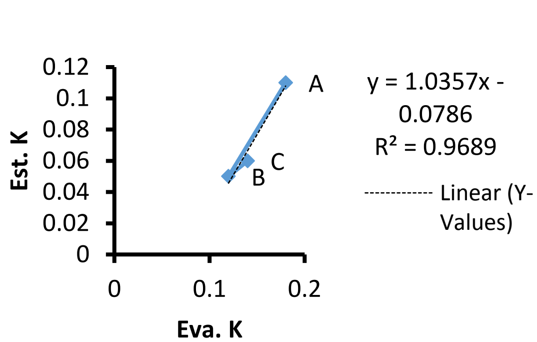

Fig. 5: Stage three

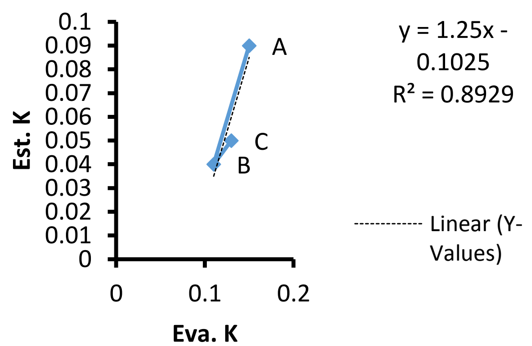

Fig. 6: Stage four

DISCUSSION

Table 1 shows a decrease in soil erodibility, the effect of management practice on soil erodibility factor (K), from beginning of rainy season to the end. The tractor drawn operation has the highest erodibility status followed by the manual operation and lastly animal drawn operation with an average evaluated K-value of 0.1175, 0.08 and 0.07 using regression equation while estimated K-value is 0.19, 0.155 and 0.145 using nomograph. This has to do with high disturbance of the soil during tillage operation. The erodibility values as estimated from the erodibility nomograph are linearly close as the ones evaluated using the Regression equation, and compare variably well only that manual operation (plot c) show the least erodibility value towards the end of the rainy season when estimated as compared to other soil tillage operations which is also the least value as evaluated using the regression equation. These values still show that these soils are almost equally likely to be eroded, so, they must be given almost equal attention in terms of erosion conservative measures.

CONCLUSION

The study under different tillage operations reveals that lower values of erodibility status were obtained under animal operation in the first two stages and manual operation in the last two stages while the highest were recorded under tractor operation which insinuate that much of the top soil was being disturbed due to high level of pulverization which result to exposing the top soil to the action of erosion. Manual operation being the second in record in terms of erodibility status, indicate less soil loss and disturbance. This shows that tractor operations need expert and carefulness when operating in other to avoid unwanted result at the end of every operation(s).

There are two possible approaches to improving soil resistance in order to control erosion. The first is to choose the most resistant soils in the area for those crops that provide the least cover, leaving the most fragile soils permanently under plant cover. The second solution is to maintain the organic matter in the soil i.e. the organic matter must be in required quantity in the soil surface; Based on the results obtained, the management practice to be considered is strip cropping or terracing; Since there are seasonal variations due to physical, chemical and biological changes over the seasons, Erodibility status is not constant (i.e. it may change over time). Erodibility status should be evaluated for these soils from time to time (say after 3 -5 cropping seasons).

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EFFECT OF ORGANIC AND INORGANIC FERTILIZER ON THE GROWTH AND YIELD OF AMARANTHUS *CURENTUS* IN AKURE, ONDO STATE, NIGERIA

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ABSTRACT

The behavioural effect of different types of fertilizer application on Amanthus curentus was examined. One organic and inorganic fertilizer each was considered for this study. Standard rates of cow dung (16 t ha^{-1}); NPK (0.25 t ha^{-1}) and control (no fertilizer) were administered to a 5 X 5m^2 plot using randomized complete block design (RCBD) with three treatments and three replicates. Parameters measured were plant height, leaves number, biomass and edible yield and were subjected to statistical analysis using SPSS 16.1 version at 95% level of significance. Final biomass yield of the vegetable for cow dung, N.P.K and control were 30,667±5.22 kg ha^{-1}, 60,408± 2.45 kg ha^{-1} and 46,825± 10.22kg ha^{-1} respectively while edible yield were 11,125 ±5.54 kg ha^{-1}, 20,925±6.43 kg ha^{-1} and 11,092±3.33 kg ha^{-1}. Agronomic responses to the three treatments 7 weeks after planting (WAP), 18.83±2.30 cm for cow dung, 23±2.75 cm for the NPK and 17.75±2.40 cm for the control respectively. Plant height responses to the treatment were 70.08±5.45 cm for cow dung, 108.42±5.89 cm for NPK and 89±1.32 cm for control respectively in the same WAP. NPK was outstanding in all treatments during the experiment going by the responses. Usage of raw cow dung was not encouraged due to the possibility of Escherichia coli and NPK has proved to be the most suitable fertilizer.

Keywords*: amaranthus; cow dung; NPK; vegetable; Akure*

INTRODUCTION

Amaranthus cruentus is one of the most important annual leaf vegetables in the tropics. It has a growing period of 5 to 6 weeks thus making it an advantage for the rural and peri-urban farmers to keep cultivating it two or more times on the same piece of land in a year (Adewole and Igberaese, 2011). Amaranthus thrives well on soils with high organic matter. Although the crop responds to organic manure, studies on effect of organic wastes, crop residues and integrated application of organic and inorganic fertilizers on performance of *amaranthus* are scarce.

Grain amaranth also called *Amaranthus cruentus* is a nutritious vegetable and contains relatively high amounts of minerals and vitamins, which are needed for healthy body growth, sustenance and alleviation of problems of hunger and malnutrition mostly experienced amongst children in developing countries (Aphane *et. al.,* 2003). Amaranth is one of such important vegetables that could be domesticated and cultivated, but information on its fertility requirements is scanty due to resource-poor conditions encountered in most rural settings of the most African countries especially, Southern Nigeria, northern Guinea and Sudan Savannas where amaranth farmers encounter such problems as decreasing soil fertility and quantity of organic manure required as the source of crop nutrients for optimum crop production (Lucas and Ojeifo, 2000; Adeyemi *et. al.,* 1999). Moreover, chemical fertilizers are in short supply and when they are available, their cost is prohibitive for the resource-poor farmers who often utilize *Amaranthus* in their diet (Olufolaji *et .al.,* 1991).

Schippers (2000) reported that Amaranthus accessions gave good yields when high levels of nitrogen were applied and it responded well to organic matter. Amaranths cultivation has emerged as an important field not only for enhancing nutritional levels especially of Indian diets, but also as a diversified profession for higher earnings. In order to make it competitive and profitable, it is important and necessary to introduce modern production technology. Timeliness of operations and judicious, efficient use of critical inputs is the key to achieve higher levels of quality and productivity. Vegetable seedlings are one of the most important and costly input in the modern vegetable crops production. Precision in the application of this input is vital in realizing the crop potential and returns. The exclusive use of inorganic nitrogenous fertilizer to improve crop production most of the time has a negative effect on semi-arid tropical soils as this increases soil acidity, which has been well reported by several researchers (Makinde *et. al.,* 2010: Modisane *et. al.,* 2009; Akparobi, 2009).

There is the need therefore, to investigate alternative sources of fertilizers for amaranth production in order to increase the availability of high quality *Amaranthus* throughout the wet cropping season and at affordable price.

MATERIALS AND METHODS

Description of the Study Area

Field Experiments were conducted during the rainy seasons of 2013 (April-July) at the Teaching and Research Farm of the department of Agricultural and Environmental Engineering, Federal University of Technology, Akure, Nigeria. Akure, capital city of Ondo State of Nigeria is located between latitude 9°17¹N and longitude 5°18¹E, it has a tropical humid climate with two distinct seasons, a relatively dry season from November to March and a wet/rainy season from April to October. The average annual rainfall ranged between 1405 mm and 2400 mm of which the rainy season accounts for 90% while the month of April marks the beginning of rainfall (Akinbile 2006).

Land Preparation and Experimental Design

The land was prepared using conventional method, slashed, ploughed, pulverized, and made into ridges in readiness for cultivation. One organic and inorganic fertilizer each was considered for this study. Standard rates (16 tha^{-1}) of cow dung manure, NPK (0.25 tha^{-1}) and a control using convectional practices were administered to a 5 x 5m^2 plot using a randomized complete block design (RCBD). Amaranth seeds were planted on each plot using broadcast method after which two of the plots were treated with cow dung manure and NPK 15:15:15 respectively. Agronomic parameters such as number of leaves, plant height, and root depth were monitored on all the experimental plots for seven weeks after planting (WAP) after which the plants were harvested. Post-harvest measurements include biomass and edible yield using an electronic weighing balance of 0.01g accuracy. Water was supplied to the vegetables using sprinkler irrigation system.

Nutrient analysis of Soil

150±0.1g of soil samples were air-dried, crushed and made to pass through a 2mm and 0.5mm sieve and taken to the FUTA University Central Laboratory for physiochemical analysis in order to determine its nutrient level. Parameters analysed included the pH, using a pH meter, total nitrogen using the micro-kjeldahl method (Bremner et al., 1996) and exchangeable cations (K, Ca, Mg and Na) using APHA (2005) standard procedures. Available phosphorus was determined by colorimeter using the method of Bray and Kurtz (1998) and organic carbon.

Data analysis

Data obtained were subjected to descriptive analysis and SPSS (version16) environment and results were presented in tables and figures.

RESULT AND DISCUSSION

Soil analysis

The results of soil analysis carried out before and after planting in all the three treatments were as presented in Table 1. From the table, the soil was very low in OC, K, N, Mg and available P and was acidic and less suitable for *Amaranthus* and agreed with the findings of Akinbile and Yusoff (2011) under similar circumstance. The soil was also low in Ca and Mg hence its acidic nature which may require addition of soil amendments for optimum crop production. When comparisons were made among the three treatments viz; cow dung manure, NPK fertilizer and the control, NPK fertilizer showed highest responses in plant height, number of leaves, biomass and edible yield. Growth and yield components of *Amaranthus* also increased as the day after sowing (DAS) increased in plots treated with NPK fertilizer when compared with cow dung and control. This could be due to enhancement of decomposition of the organic materials and mineralization of nutrients especially Nitrogen and Potassium by addition of NPK. Ayeni *et al.,* (2008) observed similar increase in N and P with the application of NPK fertilizer. The lower performance of cow dung manure might be as result of the insufficient availability of plant nutrient and immobilization of N and P by microbial activities. The substantial growth rate obtained by *Amaranthus* confirmed the report of Ipinmoroti *et al.,* (2002) that quick mineralization of organic component and slow nutrient release of inorganic constituents must have sustained the continuous better performance of *Amaranthus cruentus* than separate applications.

Table 1: Result of soil analysis of soil samples taking before and after planting

Treatments		pH	OC	OM	N	P	K	Na	Ca	Mg	CEC
A	BP	5.86	1.92	3.30	0.17	3.97	0.20	0.17	2.40	1.00	14.26
	AP	6.28	3.14	5.42	2.54	3.80	0.15	0.14	1.23	0.32	14.30
B	BP	6.01	2.05	3.53	0.18	4.20	0.20	0.22	2.40	1.00	18.46
	AP	6.55	1.10	2.18	2.21	3.25	0.36	0.12	1`.05	0.31	14.30
C	BP	5.62	1.63	2.81	0.14	2.80	0.18	0.17	2.60	1.20	14.16
	AP	5.25	0.08	1.50	0.56	0.83	0.12	0.14	1.25	0.20	10.18

Except otherwise stated, all dimensions are in mg/L

Legend
A = Plot treated with cow dung manure
B = Plot treated with NPK fertilizer
C = Control plot
BP = before planting
AP = after planting

Agronomic parameters

Number of Leaves

Table 2: Result of numbers of leaves in all the three treatments with respect to weeks after planting (WAP)

Week after Planting	Replicates	Plot A COW DUNG	Plot B NPK 15:15:15	Plot C Control
2	1	2.25±0.50	5.50±1.29	3.00±0.82
	2	2.00±0.82	4.75±0.96	3.00±0.82
	3	4.25±1.26	5.75±0.96	2.57±0.96
	Average	2.83 ± 0.86	5.33 ± 1.07	2.86 ± 0.8
3	1	5.00±0.82	8.75±0.96	5.50±0.58
	2	6.50±1.29	9.75±0.50	5.50±0.57
	3	6.75±0.96	9.00±0.82	5.50±0.50
	Average	6.08 ± 1.02	9.17 ± 0.76	5.5 ± 0.55
4	1	9.00±0.82	11.75±0.50	8.75±0.50
	2	9.50±1.58	10.75±0.75	8.50±0.58
	3	10.00±0.00	11.62±0.82	9.75±0.50
	Average	9.5 ± 0.8	11.37 ± 0.69	9.0 ± 0.53
5	1	10.25±0.50	13.50±0.58	12.75±0.96
	2	10.00±0.00	14.50±0.58	11.00±0.82
	3	10.50±0.58	15.75±0.50	11.00±0.00
	Average	10.25±0.36	14.58±0.55	11.58±0.59
6	1	11.75±0.50	21.25±0.50	18.25±0.96
	2	14.75±0.51	17.25±1.26	14.50±1.29
	3	12.75±0.50	18.75±1.26	14.45±1.37
	Average	13.08±0.50	19.08±1.01	15.75±1.21
7	1	18.75±2.99	22.50±2.52	19.25±1.83
	2	18.75±0.50	21.50±1.16	15.75±1.26
	3	19.00±1.16	25.00±1.83	18.25±1.71
	Average	18.83±1.55	23.0 ±1.84	17.75±1.60

**Values are means of Quadruplicates reading and standard deviation. Dimension (cm)*

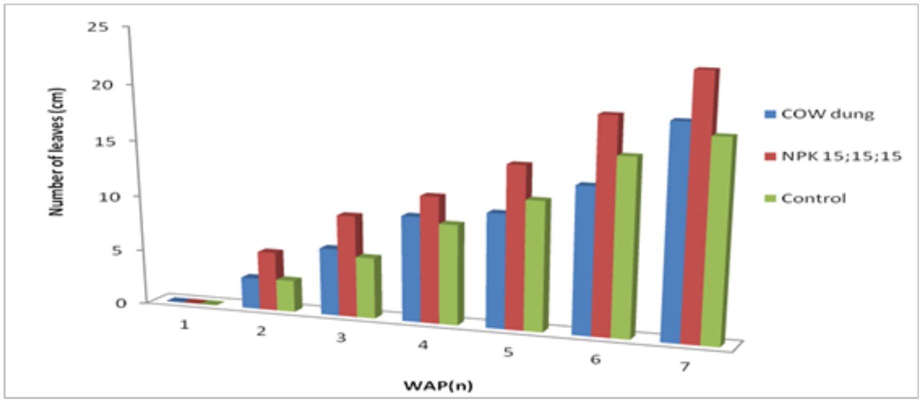

Figure 1: Number of leaves of each treatment for each week after planting (WAP)

The effects of different manures applied showed remarkable different in altitude on the average number of leaves of *A. cruentus* produced measured at weekly intervals as presented in Figure 1. It was observed that the number of leaves produced on the plot treated with NPK fertilizer had the highest value of 5.33±1.07 when compared with the control (2.86±0.8) and CDM (2.83±0.86) at 2WAP. As the WAP increases, the number of leaves also increased but the pronounced increase was obtained in the plots with NPK fertilizer. Application of NPK fertilizer gave significant highest values in number of leaves produce while the application of cow dung showed least significance and this compared with the findings of Adeyemi et al., (1999).

It was obvious from this study that, nitrogen content of the applied fertilizer was higher than the cow dung that promoted vegetative growth in amaranth (Table 2). *Amaranths curentus* performed significantly better in plots where NPK was applied till maturity than those plots where cow dung was applied. The performance of both cow dung and NPK were clearly seen at vegetative and mid-season stages and significantly differed at maturity where NPK performed better yield in number of leaves. Thus, NPK fertilizer which appeared to supply the required nutrients up till maturity in all the growth parameters would be the best fertilizer in *Amaranthus cruentus* production.

Table 3: Result of plant height in all the three treatments with respect to weeks after planting (WAP)

Weeks after Planting(WAP)	Replicates	Plot A COW DUNG	Plot B NPK 15:15:15	Plot C Control
2	1	2.38±0.48	11.75±1.26	4.00±0.87
	2	2.18±0.58	10.88±1.03	3.93±0.83
	3	2.68±0.47	11.50±1.29	3.75±0.96
	Average	2.41 ± 0.51	11.37 ± 1.19	3.89± 0.89
3	1	7.50±0.58	19.25±0.96	6.00±0.82
	2	7.30±0.57	19.26±0.56	6.25±0.50
	3	7.75±0.50	19.00±0.82	6.75±0.50
	Average	7.52 ± 0.55	19.17± 0.78	6.33± 0.61
4	1	10.00±0.82	24.28±0.66	14.36±3.75
	2	7.30±0.63	29.25±0.96	13.50±1.29
	3	7.75±0.50	24.75±3.96	9.25±1.71
	Average	8.35± 0.65	26.09± 1.86	12.37±2.25
5	1	36.50±1.29	50.75±0.96	44.00±0.82
	2	43.00±0.82	59.75±0.98	43.00±1.41
	3	32.25±0.50	60.75±0.96	44.75±0.96
	Average	37.25±0.87	57.08±0.97	43.92±1. 06
6	1	44.50±1.29	80.00±0.82	64.00±1.41
	2	53.25±0.50	67.00±0.83	57.75±2.87
	3	52.00±0.82	73.25±0.50	52.25±5.75
	Average	49.92±0.87	73.42±0.72	58.01±3.25

7	1	68.75±3.78	111.75±6.19	89.25±4.27
	2	74.25±4.57	110.25±0.96	89.50±12.00
	3	67.25±5.74	103.25±4.27	88.25±3.50
	Average	70.08±4.70	108.42±3.81	89.0±6.59

**Values are means of Quadruplicates reading and standard deviation. Dimension (cm)*

Plant height

The effects of different fertilizers applied showed remarkable different on the mean number of plant height of *Amaranthus cruentus* produced measured at weekly intervals as represented in Table 3 and Figure 2 showed significant differences in the height. It was observed at 7 WAP that the plants grew to the mean height of 108.42±3.81cm on the treatment with NPK while that of the cow dung grew to mean height of 70.08±4.70cm and the control to 89.0±6.59cm (Table 3). This is another clear evidence of NPK's performance which agreed with the findings of Akinbile and Yusoff (2011) and Okokoh and Bisong (2011). Similarly, Makinde *et al.* (2010a) obtained similar increase in plant height of *Amaranthus cruentus,* though with increased organ mineral fertilizer applications.

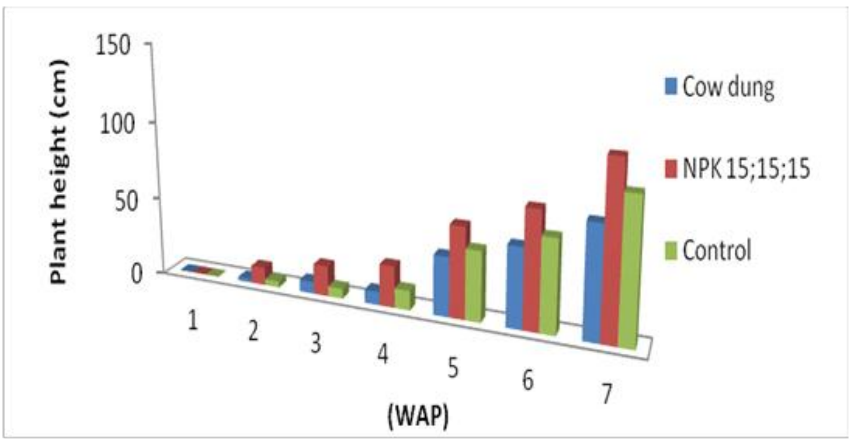

Figure 2: Plant height of each treatment for each week after planting (WAP)

Biomass and Edible yields

Table 4 Result of the Biomass yield expressed per treatment and per hectare in each of the three plots

	Plot A cow dung	Plot B NPK 15:15:15	Plot C Control
Min	24500	59875.00	38600.00
Max	34125	60875.00	53125.00
Average	30667	60408	46825
STDEV	5.22	2.45	10.22
Aveg±STDEV	30,667±5.22	60,408± 2.45	46,825± 10.22

Values are quadruplicates reading from each treatment. Dimension (kg ha^{-1})

Table 5: Result of the Edible yield expressed per treatment and per hectare in each of the three plots

	Plot A cow dung	Plot B NPK 15:15:15	Plot C Control
Min	9125.00	14825.00	9350.00
Max	14150.00	25350.00	12425.00
Average	11125	20925	11092
STDEV	5.54	6.43	3.33
Aveg±STDEV	11,125 ±5.54	20,925±6.43	11,092±3.33

*Values are quadruplicates reading from each treatment. Dimension (*kg ha^{-1})

The study showed that cow dung manure and NPK had significant influence on growth, biomass yield and edible yield of *Amaranthus cruentus* but the significance of NPK was highly pronounced. This agreed with the findings of Walters *et al.* (1993) and Webber *et al.* (1993).
The mean biomass yield of 60,408± 2.45 kg ha^{-1} and 20,925±6.43 kg ha^{-1} edible yield were obtained for plot treated with NPK fertilizer while for biomass yield 30,667±5.22 kg ha^{-1} and 11,125±5.54 kgha^{-1} edible yield were obtained for plot treated with cow dung and that of control was 46,825± 10.22 kgha^{-1} for biomass yield and 11,092±3.33 kgha^{-1} for edible yield (Tables 4 & 5). The values obtained for both edible and biomass yields of plot treated with NPK were above that of the cow dung and of the control which gave the least mean yield. Oworu *et al.* (2010) and Okokoh and Bisong (2011) gave similar results of increased leafy productivity, edible yield and biomass yield of grain *amaranth* when the combination of poultry manure and urea-N fertilization was compared with NPK fertilizer. The results of the soil analysis showed that the soil treated with NPK fertilizer was rich in NPK, Ca and Mg (Table 2) this could have led to the significant positive response observed on the yield performance of *Amaranthus cruentus.* Comparable results, though at low magnitude were obtained by Adewole and Adeoye (2008).
The effects of fertilizers on *Amaranthus cruentus* performance on growth and yield components to show that NPK fertilizer was better than control and cow manure. The substantial growth rate obtained by *Amaranthus cruentus* confirmed the report of Makinde *et al.,* (2010b) that quick mineralization of inorganic component and the slow nutrient release of the organic constituents must have sustained the continuous better performance of *Amaranthus cruentus* than their separate applications. The field used for the experiment has already been cultivated and used for research work and has been confirmed suitable for plant growth and root development according to Ipinmoroti *et al.,* (2002).

CONCLUSION
The effects of organic and inorganic fertilizer on the growth and yield of *Amaranthus curentus* in Akure Nigeria was determined. From the study, NPK fertilizer had positive significant influence on growth, biomass yield and edible yield of *Amaranthus cruentus* when compared other fertilizers such as FYM and in this case, cow dung. The study further underscored the importance of inorganic fertilizer such as NPK within the context of increasing vegetable production for a healthy living which further confirmed the findings of Akinbile and Yusoff (2011) and Makinde *et al.,* (2010a & b) in line with this assertion in their separate studies.

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ASSESSING THE IMPACTS OF IRRIGATION SYSTEMS ON FOOD SECURITY IN SOUTHWESTERN NIGERIA

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ABSTRACT

Irrigation is considered an essential factor for agriculture and food security and therefore this study focused on the assessment of major systems and challenges of irrigation practices in Ondo and Ogun States, Nigeria. Structured questionnaire were administered to farmers in generating information used. Demography of the farmers showed that majority of them were males (84%) while only (11%) female were from Ogun state. Most respondents (89%) were aged 45 years and above while the least-represented age group was less than 35 years. Educationally, over 63 % had formal education out of which only 5 % of respondents had primary education. The response showed that majority of the respondents in the study area practiced surface irrigation which accounted for 57% of the types of irrigation considered. Sprinkler(26%) and drip (13%) irrigation respectively were practiced by the farmers. However, lack of technical knowhow, inadequate knowledge of crop water requirements and irrigation scheduling strategies were the greatest challenges to sustainable small-scale irrigation in the study areas.

Keywords: *Irrigation systems; Water resources; Agriculture; Impacts; Food security.*

INTRODUCTION

Irrigated agriculture is the dominant use of water, accounting for about 80 % of global and 86% of developing countries water consumption as at 1995 (Akinbile *et al.,* 2011). Irrigation was responsible for about 75% of the world's total rice production. In Nigeria, Irrigation has the capability to play a crucial role in helping to achieve its goal of food security through increased food production and poverty reduction but has largely been ineffective due to myriads of problems confronting its operations (Adeoti, 2006). Inappropriate management of irrigation has contributed, not only to food insecurity but also to environmental problems including excessive water depletion, water quality reduction, water logging and salinization (Akinbile *et al*., 2011). Therefore, the water crisis being experienced is not about having too little water to satisfy our needs especially in agriculture but a crisis of proper management. Nigeria has relatively rich water resources, and its irrigation potential can be as high as 3 million hectares (ha) (You *et al.,* 2011), which is only 10 percent of the country's cultivated area of 30 million ha. However, it is estimated that only about 0.9 million ha use water management techniques, of which approximately 0.2 million ha are irrigated with equipment such as pumps and tube wells (Takeshima *et al.,* 2010). Of the cultivated area that benefits from water management, more than 95 percent uses farmer-managed, small-scale irrigation schemes. However, due to the dominance of privately managed irrigation schemes, irrigation use in Nigeria may was highly affected by the socioeconomic characteristics of farmers and the agro ecological factors of the areas in which those farmers reside (Baba and Adedibu, 1998).

Irrigation activities in Nigeria have been effectively practiced on small- scale irrigation schemes. This was because various government efforts to exploit the country's large irrigation potentials through investment in large public irrigation schemes which have not been successful (FGN, 2006). The failure arises partly from the high cost of the projects and because most of them were conceived, designed, constructed without the input or knowledge of the intending users (farmers inclusive). Very often such schemes do not meet the desire or need of the people or users. In fact, it is generally believed that small-scale private irrigation schemes have so far performed better than the large-scale schemes (Venot *et al.,* 2010). Irrigation is considered an essential factor for agriculture and food security since overreliance on rainfall represents a major constraint on agricultural productivity and rural poverty reduction especially in Ondo and Ogun States. Fadama (small-Scale) farmers are reported to be self-sustaining, cost-effective, and require little assistance from government or aid agencies however, that their success may be short-lived as a result of growing signs of over exploitation of the shallow aquifers and their attendant grievous environmental consequences (Baba and Alassane, 1997). The issue of sustainability challenges posed by continuous Fadama land irrigation with ground water which have to do with sustainability of soil fertility, environmental degradation, sustainability of the ground water itself and sustainability of the technologies used in small-scale Fadama irrigation (Baba, 1993). It is evident therefore, that there are serious challenges with both small and large-scale irrigation. Therefore, this study was aimed at evaluating types of challenges associated with the irrigation systems and the implications of its potentials especially in Ondo and Ogun States of southwestern Nigeria.

MATERIALS AND METHODS

Description of Study Areas

The study was conducted in both Ondo and Ogun States, south western Nigeria (Figure 1a). The two states were created in 1976 from the old western region and while Ondo state has a land area of 14,769 Km^2 Ogun state covered a total of 1,640,076 Km^2. Going by 2006 census, the Ondo state has a population of 3.44 million and is geographically located in south west of Nigeria between Longitude 4.30^0 E and 6.00^0 E of the Greenwich and Latitude $5^0 45^1$ and $8^0\ 15^1$ of the equator. Kogi and Ekiti states bounded the State to the North; Edo and Delta States in the East; Ogun and Osun States in the west and Atlantic Ocean in the south (Figure 1b). With respect to the climate, it is tropical with two distinct seasons of wet and dry in the state. The wet season occurred between April and October, while the dry season begins in November and last till April. Although in recent times, minor alterations were noticed in rainfall regimes due to global climate change. The state is blessed with a moderate year temperature of around 25^0 C. Annual rainfall varied from 2000 mm in the southern part to 1,150 mm in the Northern extremes. The occupation of the inhabitants of the State is predominantly farming. Ondo State is the highest cocoa producing State in Nigeria (Ojo, 2003).

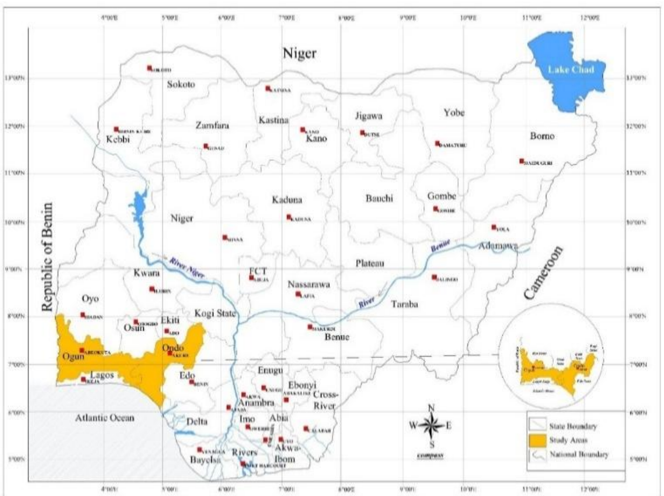

Figure 1a: Map of the Nigeria indicating the Study Areas

Ogun State is located in the South Western part of Nigeria and lies between latitudes $2^0 6'$ and $3^0 6'$ E of the Greenwich Meridian. The state is bounded on the west by the Republic of Benin and on the East by Ondo State. To the North is Oyo State while Lagos State and the Atlantic Ocean are to the South (Figure 1b). The geographical location of the state makes it accessible to the economically developed regions in Nigeria. The state is blessed with over 60 percent cultivable arable land, with an estimated population of about 3.391 million people. Ogun State people are predominantly farmers, dealing in food crops such as maize, cassava, yam, cocoyam, soybean, etc. Tree crops such as cocoa, oil palm, citrus, kola nuts, rubber, etc. are produced in the State. The physical environment (soil characteristic and climatic effects), the vegetation type and the availability of markets are all contributory factors that have facilitated the development of the agricultural sector in the State. The vegetation in the State covers the rain forest features in the coastal towns to derived savanna features in the northern part of the State. The rainfall pattern is bimodal in nature with peaks at July and September. Generally, the rain period occurs between March and October. Ogun State has good water supply with a vast network of water bodies (rivers and streams) that provides a huge potential for fishing activities, crop production, and Fadama agriculture.

Figure 1b: Map of Ondo and Ogun States

Data Collection

The study employed stratified random sampling technique for the selection of its respondents. The sampling entails both literate and illiterate farmers. One hundred (100) farmers were selected in each state making a total of two hundred (200) farmers that were used for this study. Data collection was performed with the aid of structured questionnaire designed to elicit information on their demographical/socioeconomic characteristics namely age, family size, education and years of farming experience; irrigation variables such as access to water, frequency of irrigation, irrigation systems practiced, crop planted, knowledge on irrigation scheduling and factors to consider before irrigating the land; evaluation of the overall performance of the system of irrigation practiced. The questionnaires were subjected to test pretest method of validation and content adjustment using the method of Reynolds and Diamantopoulos, (1998). The study was conducted from the year September 2013 through January 2014 and was repeated in the same duration in 2014 during the core dry season when farmers' activities were low due to water scarcity. General crop management practices such as weeding, fertilizer application, pest and disease control were carried out by the farmers in order to have optimum yield.

Data Analysis

Descriptive and inferential statistics were employed in the analysis of the generated data. Descriptive statistics involved the use of means, frequency distributions and percentages were employed in analyzing the information collected from the farmers. Statistical Package for Social Sciences (SPSS) version 17 was the software used in analyzing the results.

RESULTS AND DISCUSSION

Demography of the Farmers

From Table 1, majority of the farmers were males (84%) while 11% were females all from Ogun state. This is consistent with Adeoti (2006) who reported that more men were in farming than women in this part of Nigeria. The same cannot be said of other parts such as the northern and southern Nigeria where the female population in farming outnumbered the males. Most farmers (89%) were within the age group of 45 years and above whereas the least-represented age group was < 35 years. As for education status, over 63% have formal education which will directly affect the farmer's ability to adapt to change and to accept new ideas. 5% of the respondents had primary education and were mostly involved in peasant farming. Majority of those involved in large scale farming were mostly educated people and this was obvious that educational levels of the respondents were generally high as the majority of the respondents have tertiary and post graduate certifications. Therefore, this high educational status would encourage acceptance of innovation which would raise farm productivity and income. The total size of respondents' farmland varied from 1 to 100 ha with the majority (47%) having a farm size of between 1 and 10 ha. 42% of the respondents had farm sizes ranging between 10 ha – 50 hectares. There was no farmland that was above 100 ha in size and no variation in the ownership of land used for farming by the respondents. The highest proportion (53%) claimed that the farmland belonged to the family and such farmlands are usually very small in size as such parcel of land most often normally shared among many children. Only a few (5%) indicated that the land belonged to the community. The study also showed that 79% of the farmers practiced irrigation while 16% confirmed that they do not. The remaining 5% neither did indicate whether or not they practice irrigation farming.

Figure 2 showed different crops the farmers planted and on which crops irrigation was used for its growth. It is observed that the major crops planted by the farmers were cereals and cash crops (25% and 28%) respectively. This was followed by tuber crops (22%) and legumes (17%) while the least grown crop were tree crops (5%) on which the respodents confirmed that irrigation was practised. Furthermore from the same figure, information on crops irrigated were supplied which were cereals and cash crops (30%) , legumes (11%), tuber (18%) and tree crops (7%) . This supported the findings of Musa (1999) in a similar research.

Table 1: Gender, age, educational levels, size of farm, and type of ownership of farmers in south west Nigeria

VARIABLES	LOCATIONS		
	Ogun	Ondo	Total
Gender			
Male	70(37%)	90(47%)	160(84%)*
Female	20(11%)	0(0%)	20(11%)
Not answered	0(0%)	10(5%)	10(5%)
Age of respondents			
Below 25	0(0%)	0(0%)	0(0%)
25-35	0(0%)	0(0%)	0(0%)
35-45	10(5%)	0(0%)	10(5%)
Above 45	80(42%)	90(47%)	170(89%)*
Not ticked	0(0%)	10(5%)	10(5%)
Educational background			
Primary	10(5%)	0(0%)	10(5%)
Secondary	0(0%)	20(11%)	20(11%)
Tertiary	40(21%)	50(26%)	90(47%)
Post tertiary	40(26%)	30(37%)	70(63%)
Not ticked	0(0%)	10(5%)	10(5%)
Size of farm			
1-10 ha	50(26%)	40(21%)	90(47%)
10 -50 ha	30(16%)	50(26%)	80(42%)
50-100 ha	10(5%)	0(0%)	10(5%)
Above 100 ha	0(0%)	0(0%)	0(0%)
Not ticked	0(0%)	10(5%)	10(5%)
Type of ownership			
Individual /personal	50(26%)	20(11%)	70(37%)
Family	40(21%)	60(32%)	10(53%)
Group	0(0%)	0(0%)	0(0%)
Community	0(0%)	10(5%)	10(5%)*
Not ticked	0(0%)	10(5%)	10(5%)

Types of Crops Grown and Irrigated by the Farmers

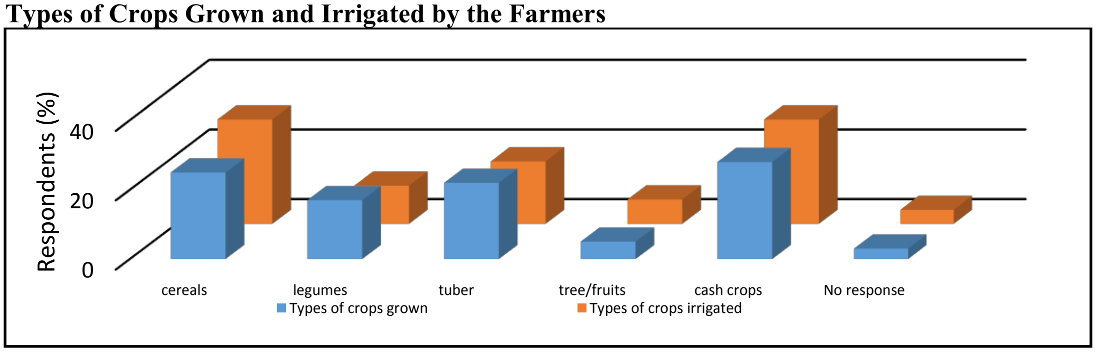

Figure 2: Crop types grown and irrigated by respondents

Table 2: Type of irrigation system practiced

Irrigation type	Drip	Sprinkler	Surface	No response
Respondents (%)	13	26	57	4

The response showed that majority of the farmers in the study area practiced surface system of irrigation which accounted for 57% of the types of irrigation. Sprinker (26%) and drip (13%) irrigation respectively were practiced by the farmers. This agreed with the findings of Akinbile and Sangodoyin (2011a) and Yidirim (2010) in a similar research conducted. Table 3 provided information on the type, reason for and benefits of using drip irrigation system. This could be attributed to the fact that most of the farmers were familiar with surface irrigation and also because that it saves water and experienced little run off or percolation loss during irrigation.

Table 3: Type, reasons and benfits of using the Drip Irrigation System

Parameter	Respondents (%)
Type of drip irrigation practiced	
Porous soaker hose	5
Emitter drip	11
Watermatic drip	6
No response	78*
Reason for using drip irrigation	
Saves water and time	21
Improves growth and discourages weed	17
Helps control fungal diseases	0
Adaptable	8
No response	54*
Benefits of drip irrigation	
Saves water because little is lost to run off or evaporation	21
This watering method also promotes healthy plant growth	14
Controls weed growth	11
Reduces pest problems	7
No response	47*

**show high percentage.*

Considerable number of the farmers knew little about drip irrigation hence their inability to respond appropriately the rationale behind their choices of the type of irrigation. This scenario accounted for 78%, 54% and 47% of the respondents respectively.

Sprinkler System

Table 4: Type, reason for and benfeits of using the Sprinkler irrigation system

Parameter	Respondents
Type of sprinkler irrigation	
Rotating head or revolving sprinkler system	26%
Perforated pipe	0%
Portable sprinkler	11%
Centre pivot	0%
No response	63*%
Reason for using sprinkler irrigation	
Adaptable to any formable slope	12%
It is less expensive	16%
Expansive land leveling is not required	8%
High efficiency due to uniform water distribution	12%
No response	52*%
Benefits of sprinkler irrigation	
Suitable to all types of soil except to heavy clay	16%
Water saving	16%
Increase in yield	20%
Saves land as no bounds etc are required	0%

No response	48*%

*Note: * Indicate High Percentage*

From Table 4, 26% of the farmers who identified with the use of sprinkler irrigation use the rotating head or revolving sprinkler system. 12% of the respondents remarked that the reason for using sprinkler irrigation was because it is less expensive while 20% of the farmers in the study area said yield increase was more in sprinkler system than any other system. 63% did not because, respondents do not know about the sprinkler irrigation system.

Table 5: Type, reason for and benfits of using the Surface irrigation system

Parameter	Respondent (%)
Type of surface irrigation	
Basin irrigation	48
Border strip	5
Furrow irrigation	26
No response	21
Reason for using surface irrigation	
The water spread quickly over the field	22
It reduces labor requirements	25
It is less expensive	24
Saves time and water	22
No response	7
Benefits of surface irrigation	
Adaptable	32
Improves growth	41
It promotes healthy plant growth	16
No response	11

From Table 5, it was evident that the farmers used more of surface irrigation system than drip and sprinkler systems. Majority (48%)of the respondents use the basin irrigation while only 5% use the border strip type. Furrow type of surface irragation accounted for 26% while 21% did not give any response. Akinbile and Ogedengbe (2006) remarked that furrow irrigation is best practised in this study area due to the severity of rainfall experienced especially during wet season. This expalined a reasonably high number of farmers using this type of irrigation for their cultivation. The responses for using surface irrigation was almost identical based on the percentage spread of the respondent choices while 7% did not give any reason for their actions. Also, from the responses of the respondents with respect to benefits in their choices of surface irrigation, 41% opined that it improve growth, 32% said it was easily adaptable while 16% said it promotes healthy plant growth. 11% of the respondents had no response to the benefits. The reasons given for their choices were in agreement with the submission of Alarcon *et al.,* (2014)

Problems/ Challenges Associated with Irrigation Systems

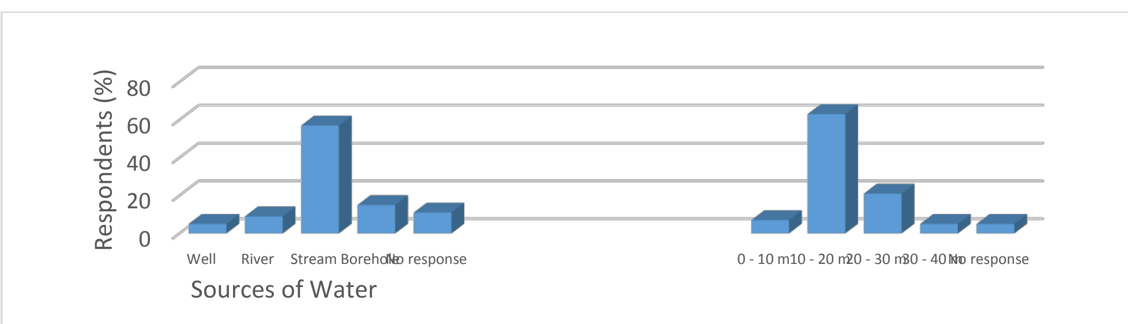

Figure 3: Source of water and proximity to source of water

Figure 3 gave information on water source and associated challenges during irrigation. More than half (57%) of the respondents declared that stream is the major water source while a greater proportion (63%) said it is close to their farms, within 10-20m distance. 21% of the respondents said the disatnce of the source of water to their irrigsted farms is 20 – 30m away which would seriously affect the effectiveness of irrigation since proximity to water use would be advantageous to the farmers. Any distance beyond 50m from the the farm will likely be stressfull and unproductive for farmers

Sources of Energy and Factors Considered for Irrigation System

Figure 4 showed the type of energy used by the farmers in transporting the water to the field. 56% used generators to power their pumping machines while 32% depended on the public electricity. None of the farmers used the solar energy mechanism for power generation used for the irrigation perhaps due to the unpopular nature of the enegry source however, 4% utilize the wind power while about 8% did not respond. The factor that the respondents considered before their choice of the type of irrigation system was majorly facilitated by the availability of land and its value (27%). The availability of energy, reliability acounted for 17% while flood hazard considered had only 4%. Davis and Dukes (2015) remarked that in order to successfully implement smart irrigation controllers, the issue of uninterupted power supply is non negotiable. This had been reinforced by Rowshon *et al*.,(2014) during his studies in Malaysia. 2% of the farmers did not respond at all and when the farmers were asked if they estimated the quantity of water applied during irrigation, 32% was affirmative while 26% said they do not. However, 42% of the respondents did not attempt to answer the question. For those who said they estimated the amount of water they applied during the irrigation, they were asked the methods used and their responses were as shown in Figure 5. From the Figure, 46% of the respondents remarked that they used number of hours scheduled for irrigation while none of the farmers used any of the evapotranspiration (ET)'s equations to determine the quantity of water adminstered. Several researchers (Tindula *et al.,* 2013; Bautista *et al*., 2012; Akinbile and Sangodoyin 2011b) had emphasized the use of ET in estimating water use as the best method under different scenarios and using different types of crops. 29% used the net amount of water they want to supply. However, some of them irrigate until soil was saturated (11%) while 14% did not respond.

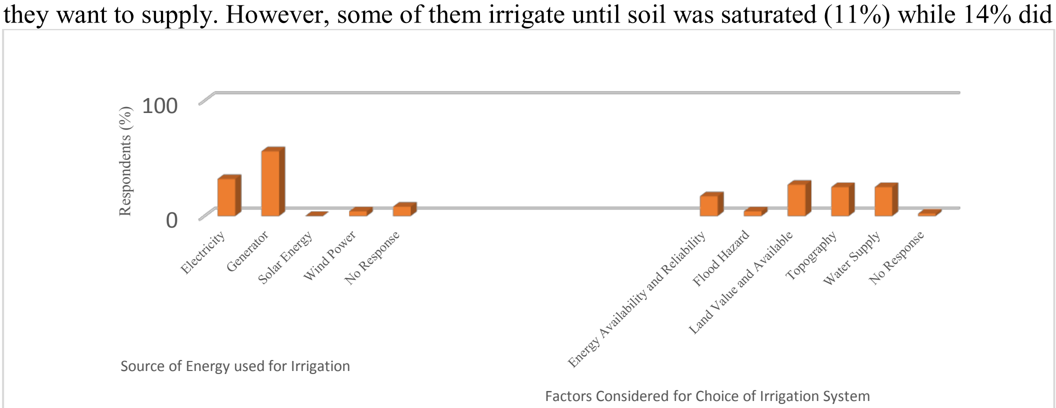

Figure 4: sources of energy for irrigation and factors considered for choice of irrigation system

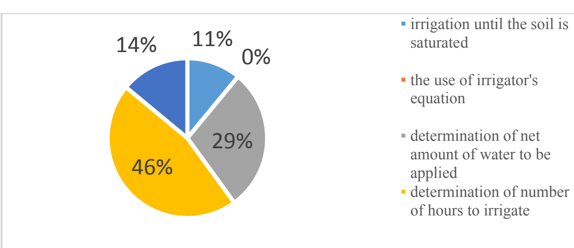

Figure 5: method used to determine the quantity of water applied during irrigation

Knowledge of the Farmers about Irrigation Water Requirements

The probability of over-irigation was evident from the questionniare based on their little knoweledge on irrigation water requirements. Intrestingly, a few of the respondents understood the over-irrigation implications as reflected by the information gathered and presented in Table 6. 32% choose flooding and leaching respectively while 34% ticked poor yield (34%) and 2% did not respond. Information on irrigation scheduling and the choices for the intervals as well as active years of practising irrigation were also contained in Table 6

Table 6: Over- irrigation, scheduling, reason for scheduling and years of practicing irrigation

Parameter	Respondents (%)
Aftermath effect of over application of water	
Flooding	32
Leaching	32
Poor yield	34
No response	2
Irrigation interval practiced	
1 day	0
2 days	11
3 days	21
4 days	26
5 days	16
No response	26
Reason for intervals	
Professional advice	42
Experience	47
Personal intuition	0
No response	11
Years of practicing irrigation	
0-5yrs	21
5-10 yrs	48
10-15 yrs	26
15 yrs and above	0
No response	5

The highest number of irrigation schedule was observed to be 4 days. This phenomenon may be attributed to the fact that most of the farmers were experienced enough to accuratetly predict the schedule interval for maximum yield. Table 6 showed that both experience (47%) of the farmers and professional advice they receive from extension workers played a vital role in the practice of irrigation of the farmers. Most of them have been in the pactice of irrigation for an average of of 10 – 15 years. Most (95%) of these farmers have made more profit as a result of practicing irrigation while just 5% was disadvantaged for unknown reasons.

Table 7: Experience, Irrigation Scheduling, Determination of Crop Water Requirement

Parameter	Response (%)
Experiences with irrigation	
The servicing of the equipment is problematic	15
The cost is high compared to the benefits	4
The purchase of equipment requires high capital	12
It has led to improvement in yield and generally fruitful	65
No response	4
Period irrigation is practiced	
Raining season	0
Dry season	48
Round the year	47
No response	5
Practicing irrigation scheduling	

Based on potential evapotranspiration demand	32
Crop water requirement estimation method	5
Water stress indicators	10
The use of remote sensing techniques	0
No response	53
How to determine crop water requirement	
Through ETo	48
Through Etc	5
Through Kc	26
Through Kc x ETo	5
No response	16

Note: ETo: reference evapotranspiration; ET – Evapotranspiration; Kc – Crop coeficient

Table 7 showed how the farmers determine crop water requirement in their proportions, Table 8 contained information on irrigation scheduling, crop water requirement while Table 9 captured the responses of the farmers to how oftern they conduct physicochemical test on their farmlands to ascertain depletion and when to administer fertilizer.

Table 8: various questions analyzed during the research

Questions	Response		
	Yes	No	Not ticked
Do you understand the term irrigation scheduling	100(53%)	0(0%)	90(47%)
Do you understand the term crop water requirement	90(47%)	20(11%)	80(42%)
Did you consult professional before setting up irrigation system	160(84%)	20(11%)	10(5%)
Do you do physiochemical test	50(26%)	50(26%)	90(47%)

Table 9: How often do you practice physiochemical test?

Parameter	**Response**
Yearly	0(0%)
before every farming season	50(26%)
every five years	0(0%)
Not Ticked	140(74%)

CONCLUSION

Irrigated Agriculture no doubt is a profitable and sustainable venture for farmers especially during the dry season. The study showed that climate change, educational background and government policies were major issues hindering irrigation development in Ondo and Ogun states. This was more likely so because the states are located in an area with well-defined wet and dry seasons and seasonal river flow. The sustainability of irrigation and rainfed farming systems was largely dependent on climate variability and their future viability may be threatened with this phenomenon. Irrigation is seen as promising avenue of public investment for solving problems of rural and urban unemployment, hunger, malnutrition and poverty. Findings from this study further showed that increasing public investment to provide irrigation tools to the farming community together with more favourable economic incentives such as soft loan and farm input provision might bring about the intended results of poverty reduction as well as increase food production in the study areas.

ACKNOWLEDGMENTS

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SPATIAL ASSESSMENT OF HEAVY METALS IN THE IRRIGATED AREA OF DALILI SECTOR OF KANO RIVER IRRIGATION PROJECT (KRIP)

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ABSTRACT

This study was conducted to assess the distribution of heavy metal in the Dalili sector of Kano River Irrigation Project (KRIP), which may be a potential threat to human health by the heavy metals (Cd, Co, Cr, Cu, Ni, Pb,) through the intake of locally grown food crops. Food consumption is an important route of food chain transfer of heavy metals from plants to animals and finally to human beings. Samples were collected from different parts of the sector and were subjected to standard tests, using Atomic Absorption Spectroscopy (AAS). Results of average concentration of heavy metals in this area were Cd = 0.38 mg/kg, Co= 2.28 mg/kg, Cr =1.16 mg/kg,Cu = 9.09 mg/kg, Ni = 0.14 mg/kg, Pb = 0.68 mg/kg. The levels of these heavy metals are below the FAO standards, therefore they do not place the consumers of crops grown within the study area at health risk, but such studies need to be conducted regularly in the future in order to close mark the accumulation of such dangerous chemicals in the irrigated area of Dalili sector of KRIP.

Keywords: *Heavy Metals, Spatial, Irrigation, Soil.*

INTRODUCTION

Long-term and excessive application of chemical fertilizers on the farm showed higher metal accumulation in the soils of different farming systems (Chen *et al* 2014). Long-term use of excessive chemical fertilizers in the bare vegetable fields and the greenhouse vegetable fields contributed to the accumulation of heavy metals in the soils (Huang and Jin 2008). The presence of cadmium in some fertilizers at high concentrations is of most concern due to the toxicity of this metal and its ability to accumulate in soils as well as its bioaccumulation in plants (Singh *et al* 2010; Brigden *et al* 2002).

Lime and superphosphate fertilizers contain not only major elements necessary for plant nutrition and growth but also trace metal impurities such as Cd, Cr and Pb. These metals can accumulate in the soil, be taken up by plants, and passed on in the food chain to animals and humans (Taylor and Percival 2001). Fertilizer applications may be able to influence Cd related problems, which also affects the Cd movement to plant roots as well as Cd uptake. High fertilizer applications and acid atmospheric depositions, combined with insufficient liming, may also cause a decrease in pH and thus increase heavy metal availability, aggravating the problems of deteriorating food quality, metal leaching, and impacts on soil organisms (Girmaye 2014).

Based on interviews with farmers and the information available at agricultural agencies across the country, the fertilizers application procedures indicates over applications. This leads to more than land requirements, which can result in high concentration of heavy metals in the soil(Liang, Chen, and Song 2011). The soil pollution by heavy metals resulting from phosphate fertilizer application has been a cause of concern in many places. Heavy metal built up in the system as a result of nitrogen fertilizers may increase Cd concentrations in plants, even if the fertilizers do not contain significant levels of Cd. Furthermore, Alloway (1995) concluded that phosphate fertilizer applications in agricultural lands can cause increased levels of Cd, As, Cr, and Pb in soil and dramatically decreased soil pH that cause desorption of heavy metals from the soil matrix.

Heavy metals can be very harmful to the human body even in low concentrations as there is no effective excretion mechanism (Ghosh *et al*, 2012). Lead (Pb) gives rise to adverse effects in several organs and systems in all known animal species, such as the blood, central nervous system, kidneys, reproductive and immune systems. Cadmium is persistent and accumulates mainly in the kidney and liver of vertebrates, producing severe diseases in these organs (UNEP, 2006). Chromium can cause skin ulcers and nasal septum perforations (USEPA, 1980). While both Cr (III) and Cr (VI) can be toxic to plants and animals. Cr (III) toxicity occurs in higher concentrations, and this form is actually an essential nutrient to humans and other animal. Cr (VI), on the other hand, is toxic in much lower concentrations and also tends to be more mobile and bioavailable than Cr (III) in surface and subsurface environments (Adriano, 2001). The focus of the paper is to evaluate the spatial distribution of soil heavy metal contents of Dalili sector of KRIP using geospatial systems and field investigations.

MATERIALS AND METHODS

Location

The project area lies about 30 km southeast of Kano City, on either side of the Kano-Zaria Expressway. Presently, the total area of irrigated land amounts to about 13 300 ha, and the feasibility study for the extension of Phase I to 20 300 ha of irrigated land has recently been completed (Simon, 1997). Proposal 66000ha: Phase1 22000ha: 15000ha achieved by 1970s – 80s. 2003-2004 1920ha added. Located in Kano state. Divided into KRIP West at Kura and KRIP East at Bunkure (Figure 1).

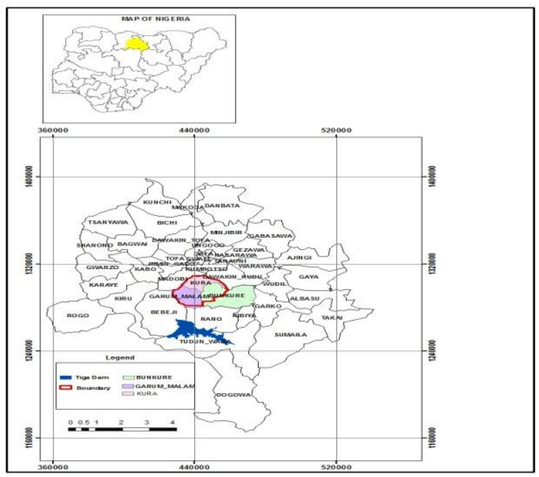

Fig. 1 Map of the study area

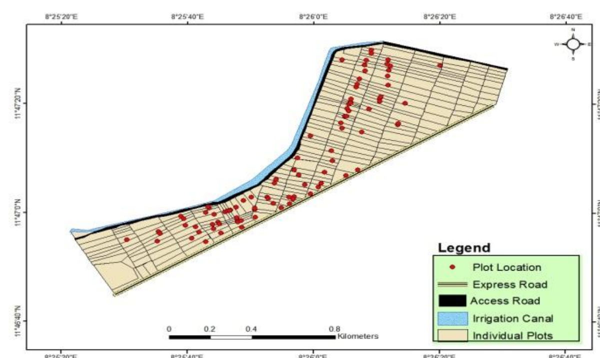

Fig. 2 Dalili sector of the KRIP

The features in the image were classified using a supervised classification method in ERDAS IMAGINE. The method of classification employed was supervised because the analysts are conversant with the area of study. The features were classified using the elements of visual interpretation to identify homogeneous groups of pixels representing various features or land cover classes of interest. These classifications were done on both the active and the inactive sectors of KRIP. The numerical information in all spectral bands for the pixels comprising these areas is used to "train" the computer to recognize spectrally similar areas for each class.

Geostatistical Analysis of Soil Data

The soils of the sector were analysed for texture and heavy metals. The soil textural classes were predominantly loamy sand and sandy loams (table 1). The results are presented using spatial interpolation techniques. The kriging technique of geostatistical analysis that shows continuous raster surfaces created from known sample points was employed. The values at measured points were used as a basis for predicting values at other points in the area under consideration. The analysis was done with ArcGIS 10.2 to show the spatial distribution of the heavy metals in the study area.

RESULTS AND DISCUSSION

The soil samples were tasted for the presence of Cd, Co, Cr, Cu and Pb. The results of the interpolation done using ArcGIS 10.2 are presented below.

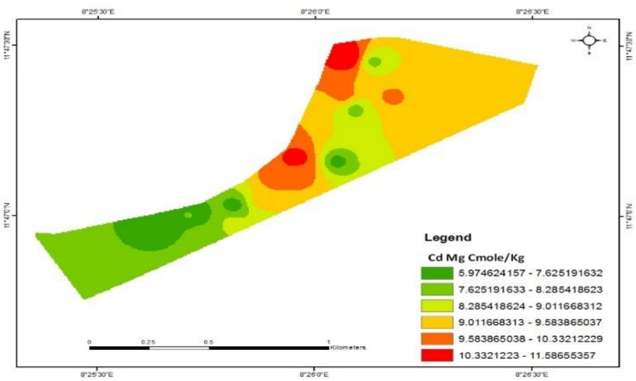

Fig. 3: Distribution of Cd mg/Kg

Figure 3 presents the spread of Cd mg/Kg in Dalili sector which indicates its high concentration dotted with spots of lower concentration in the northern parts and lower concentrations in the southern parts of the study area.

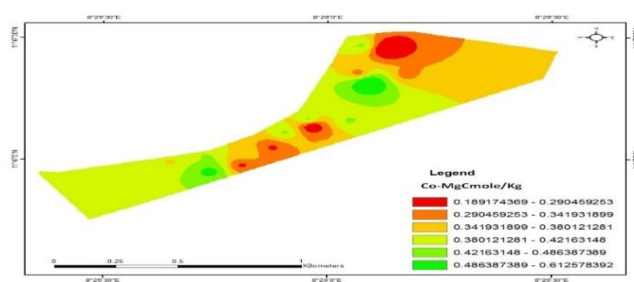

Fig. 4: Distribution of Co mg/Kg

Figure 4 is the spatial extent of Co mg/Kg in the study area. It indicates areas with high and low concentrations. It also indicates the decreasing spread from areas of high concentration to low concentration and vice versa.

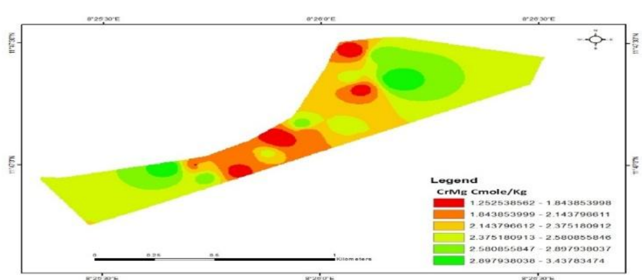

Fig. 5: Distribution of Cr mg/Kg

The result of Cr mg/Kg analysis is presented in Figure 5. It shows higher concentration in the northern and southern parts of the study area with an interruption of lower values in the middle portion of the Dalili sector. It avails the opportunity for plants to be located in favourable areas.

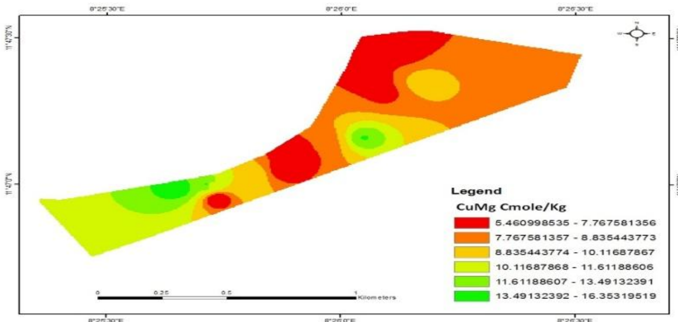

Fig. 6: Distribution of Cu mg/Kg

Figure 6 presents the outcome of Cu mg/Kg analysis which shows high concentration in the northern parts, while the southern parts of the study area indicates relatively lower values. High values are also dotted at widely spread points in the sector.

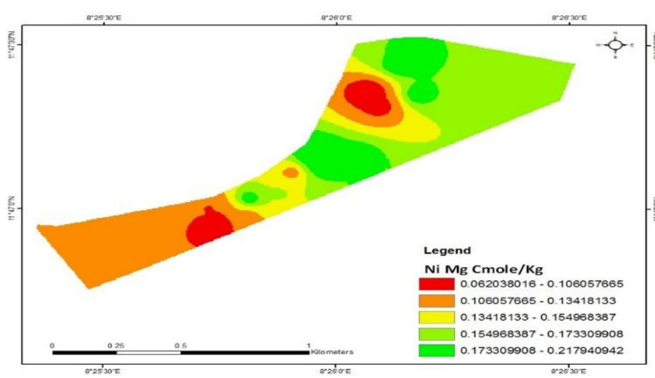

Fig. 7: Distribution of Ni mg/Kg

In Figure 7, Ni concentrations are indicated with higher values in the northern parts and lower values dominating the southern part of the study area. An area of higher and medium concentration occurs in the northern parts decreasing outwards.

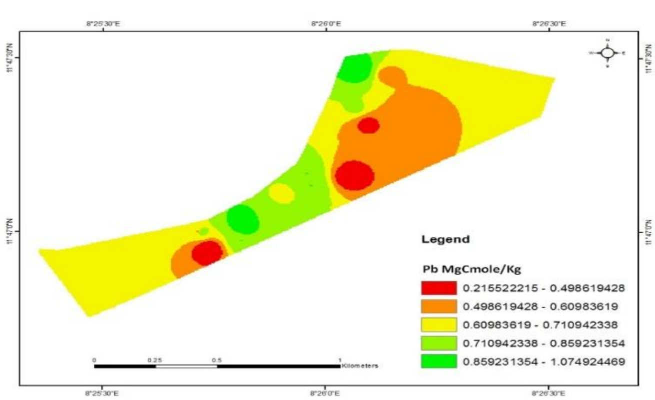

Fig. 8: Distribution of Pb mg/Kg

Lead concentration is displayed in (Figure 8). Its shows presence is more profound in the middle portions of the sector tending towards the northern parts. Areas of medium and low concentration are found in the most northern and most southern parts.

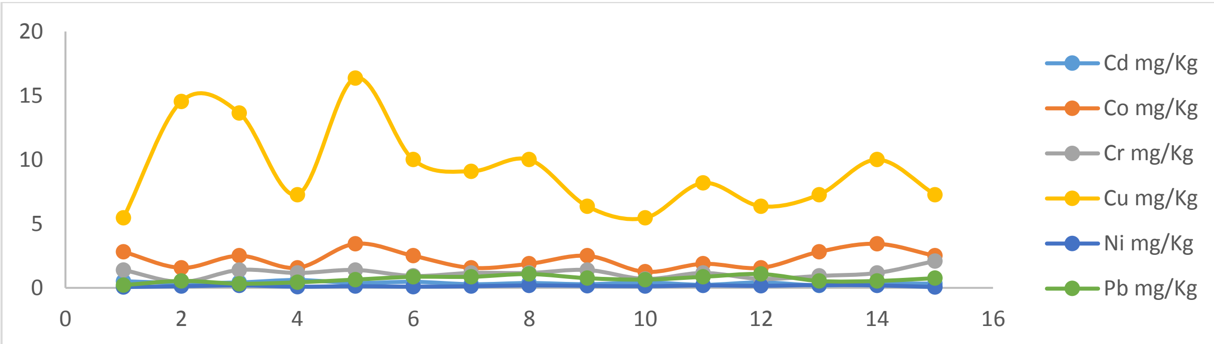

Fig. 9 Heavy Metal distributions in Dalili sector of KRIP

Table: Values of heavy metals and FAO standard

Sample	Cd mg/Kg	Co mg/Kg	Cr mg/Kg	Cu mg/Kg	Ni mg/Kg	Pb mg/Kg
1	0.519	2.813	1.395	5.455	0.062	0.215
2	0.377	1.563	0.465	14.545	0.125	0.538
3	0.425	2.5	1.395	13.636	0.187	0.323
4	0.613	1.563	1.163	7.273	0.093	0.43
5	0.377	3.438	1.395	16.364	0.125	0.645
6	0.472	2.5	0.93	10	0.093	0.86
7	0.283	1.563	1.163	9.091	0.125	0.86
8	0.377	1.875	1.163	10	0.187	1.075
9	0.283	2.5	1.395	6.364	0.156	0.753
10	0.425	1.25	0.698	5.455	0.125	0.645
11	0.236	1.875	1.163	8.182	0.187	0.86
12	0.425	1.563	0.698	6.364	0.156	1.075
13	0.189	2.813	0.93	7.273	0.218	0.538
14	0.33	3.438	1.163	10	0.187	0.538
15	0.33	2.5	2.093	7.273	0.062	0.753
16	0.425	2.813	1.395	8.182	0.218	0.86
Average	0.380	2.285	1.162	9.091	0.144	0.685
FAO Standard	0.3	50	200	50	50	300
Remarks						

Sample	Cd mg/Kg	Co mg/Kg	Cr mg/Kg	Cu mg/Kg	Fe mg/Kg	Mn mg/Kg	Ni mg/Kg	Pb mg/Kg	Zn mg/Kg
1	0.519	2.813	1.395	5.455	5.833	0.645	0.062	0.215	3.333
2	0.377	1.563	0.465	14.545	9.167	1.29	0.125	0.538	1.905
3	0.425	2.5	1.395	13.636	7.5	1.935	0.187	0.323	2.381
4	0.613	1.563	1.163	7.273	8.333	0.968	0.093	0.43	1.905
5	0.377	3.438	1.395	16.364	3.333	1.29	0.125	0.645	2.857
6	0.472	2.5	0.93	10	6.667	0.968	0.093	0.86	2.381
7	0.283	1.563	1.163	9.091	6.667	1.29	0.125	0.86	1.429
8	0.377	1.875	1.163	10	7.5	1.935	0.187	1.075	2.381
9	0.283	2.5	1.395	6.364	3.333	1.613	0.156	0.753	1.905
10	0.425	1.25	0.698	5.455	10.833	1.29	0.125	0.645	2.857
11	0.236	1.875	1.163	8.182	9.167	1.935	0.187	0.86	2.857
12	0.425	1.563	0.698	6.364	6.667	1.613	0.156	1.075	2.857
13	0.189	2.813	0.93	7.273	8.333	2.258	0.218	0.538	2.381
14	0.33	3.438	1.163	10	10	1.935	0.187	0.538	2.857
15	0.33	2.5	2.093	7.273	12.5	0.645	0.062	0.753	3.333
16	0.425	2.813	1.395	8.182	14.167	2.258	0.218	0.86	1.905
17	0.4245	2.1875	0.93	6.364	8.333	1.613	0.156	0.108	4.762
18	0.4717	1.25	0.698	8.182	11.667	1.935	0.187	0.323	2.381
19	0.3774	1.875	1.163	11.818	9.167	2.258	0.218	0.43	2.857
20	0.5189	0.9375	0.93	10.909	12.5	2.258	0.218	0.323	3.333
21	0.6132	3.125	1.163	9.091	5.833	2.581	0.249	0.538	4.286
22	0.3302	2.1875	0.698	12.727	9.167	1.613	0.156	0.753	3.81
23	0.4245	1.875	0.465	8.182	8.333	1.935	0.187	0.645	3.333
Average	0.402017	2.174109	1.071783	9.24913	8.478261	1.654826	0.15987	0.612522	2.795043
F.A.O. Limits	0.3	50	200	50	50	300			

CONCLUSIONS

The assessment of the heavy metals have been analysed and the results showed that all the heavy metals value in the soils were within the safe zone of the FAO standard for soils. However, variations do exist within the area under consideration which has little impact on the productivity of the soil, with the exception of few places which contain Cadmium of higher level than the FAO Standards.

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PRELIMINARY ASSESSMENT OF EXPERIMENTAL PLOTS FOR DRIP IRRIGATION SET UP

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ABSTRACT

With a view to knowing the suitability of selected experimental plots in Makurdi for drip irrigation set up, physicochemical and hydraulic parameters of the soil from the plot were determined. Samples were collected at depths 0-15cm and 16 – 30 cm from five randomly chosen points on three plots each of 7m by 7m. The collected samples were subjected to laboratory analysis. Parameters determined were particle size, pH, organic carbon, organic matter, nitrogen,phosphorus, SAR, hydraulic conductivity, moisture content and total porosity. Results showed that the hydraulic parameters of the soil from the plots make them suitable for drip irrigation though plot two has better hydraulic properties and is expected to have more efficiency under drip irrigation. Inter- elemental correlation revealed some negative and positive correlation among the parameters. For instance, hydraulic conductivity has strong negative correlation with organic matter and bulk density. These are attributed to high clay content of organic matter which tends to block soil pores and reduce the porosity and also closeness of the particle which may inform high bulk density and therefore low porosity. It is recommended that salinity and sodicity of the plots be taken into consideration if repeated drip irrigation will be carried out on the plots.

Keywords: *drip irrigation, hydraulic parameters, coefficient of uniformity, wetting front*

INTRODUCTION

Soil quality has been of increasing concern in recent years. It is usually considered to have three main components: physical quality, chemical quality, and biological quality. Of course, these are not independent because, for example, the biological status of soil depends very strongly on the prevailing physical and chemical conditions (Dexter 2004). However, there is little doubt that an improved measure of soil physical quality could contribute greatly to the overall assessment of soil quality. Soil property is usually considered to have three main aspects: physical, chemical, and biological. All are considered to be important for the assessment of the extent of land degradation or amelioration, and for identifying management practices and to choose the best type of irrigation. Physical properties are however important because they have big effects on chemical and biological process in the soil, and, therefore, it play a central role in studies of soil response to irrigation types. Soil physical quality manifests in various ways, poor physical quality poor water infiltration, run-off of water from the surface, hard-setting, poor aeration, poor rootability, and poor workability (Hu et al., 2009). Soil physical parameter can be considered as an index of soil which control soil compaction, soil organic matter content, which in turn control soil water infiltrability and wetting.

Soil organic matter is considered to be important while describing irrigation methods because it sustains many key soil functions by providing the energy, substrates, and biological diversity to support biological activity, facilitating water infiltration, providing adequate habitat space for soil organisms ensures adequate oxygen supply to roots and soil organisms; and thus preventing soil erosion (Franzluebbers, 2002). Infiltration is an important soil feature that controls leaching, runoff,and crop water availability. Soil hydraulic conductivity (K) and the pore size distribution parameterare important parameters for understanding some aspects of unsaturated soil water flow (Lado and Hur, 2009). They influence infiltration and runoff and the transport of nutrients in soils.

Arid and semiarid regions are characterized by evapo-transpiration that exceeds precipitation during most of the year (Abah, 2012). Therefore, agriculture in these regions relies on supplementary irrigation to enable productive crop growth. At the same time, one of the main environmental problems in these regions is a shortage of freshwater, which is expected to become more severe in the future because of the growing pressure on water resources, as well as climate change (Allaire-Leung, 2001). Therefore, in these regions, one of the challenges facing agriculture, which commonly uses large amounts of water, is to find new sources of water for irrigation.

Drip irrigation has become quite common due to its great potential to use lesswater and to localize chemical applications, thereby enhancing the efficiency of irrigation and fertilization and reducing the risk of pollution. However, these objectives can only be achieved if the emitter spacing, tape lateral spacing, diameter and length of the lateral system are well managed for any given set of soil, crop and climatic conditions. In contrast to surface or sprinkler systems, the frequency of thewater application under drip irrigation is high. This means the infiltration period is a very important stage of the irrigation cycle. A good knowledge of the soil hydraulic and other propertiesis therefore needed to achieve high drip irrigation efficiency. Water extending laterally and vertically away from an emitter is an important criterion for the design of drip systems to ensure efficient irrigation and to avoid the movement of water beyond the root zone (Mubarak et al.,2009).

Having the knowledge of soil hydraulic properties and understanding their temporal variability during the irrigated cropping season are also required to mitigate agro-environmental risks. Soil hydraulic properties are affected by soil texture, bulk density, soil structure, and organic carbon content, many of which are strongly influenced by land use and management. All these have remarkable effect on achieving high drip irrigation efficiency, it is therefore important to determine these properties before setting up drip irrigation project on any farm. The objective of this paper is thus to determine some physical, chemical and hydraulic properties of an experimental plot earmarked for drip irrigation set up.

MATERIALSAND METHODS

This study was carried out in University of Agriculture, Makurdi, Nigeria. The location lies between latitudes 7° 45' and 7°52' N of the equator and longitude 8° 35' and 8° 41' E of Greenwich Meridian. The primary occupation of the people is Agriculture hence the slogan "food basket of the nation" some of the crops grown are potatoes, cassava, soyabeans, guinea corn, groundnut and yam. Makurdi town has a tropical sub humid climate wet and dry type, with double maxima (Ayoade, 1983). The raining season lasts from April to October, with five months of dry season (November to March). Annual ranfall in Makurdi town is consistently high, with an average annual total of approximately 1173mm (Abah, 2012). Temperature in Makurdi is generally high throughout the year, with February and March as the hottest months, it varies from 22.5°C to a maximum of 40°C daily. Geology of Makurdi is basically composed of sedimentary rocks, and sandstones the dominant rock type. The soils in the area reflect the geology. However, it is important to mention that human activities like farming, construction and reclamation have affected the nature of the soils.

Sample Collection and Analysis

Three experimental plots each of 7m by 7m were marked out for drip irrigation set up and therefore five samples were randomly collected from each of the plots using an essential tool for gardeners called stainless steel blade of model 9APH2.The samples were collected in the three different soil types at 0-15cm and 16 – 30 cm depth at five different locations on the same plot.The samples were air dried and sieved through a 2mm diameter sieve and is put in polythene bags, then labelled to be taken for laboratory analysis.Theanalyses were carried out at the Nasarawa State University Agronomy research laboratory. Some standard laboratory procedures used and the parameters that were analysed are as shown in Table 1.

Table 1: Methods of Soil Samples Analysis

S/N	PARAMETER	STANDARD METHODS
1	Bulk density	Core (FAO 2002a).
2	Porosity	Core (FAO, 2002a).
3	Organic matter	FAO (2002b).
4	Field capacity	Egharevba, (2009)
5	Hydraulic conductivity	Falling head permeability
6	Moisture content	Oven dry method
7	SAR	Spectrophotometer and flame photometer
8	Phosphate	Calorimetrically with metrospectrometer.
9	P^H	Glass electrode
10	Particle size distribution	Bouyoucos hydrometer
11	EC	Jenway digital conductivity meter model 4520

AOAC 2005 method was used to determine the chemical properties of soil samples after adopting standard digestion method.

RESULTS AND DISCUSSIONS

The results of particle size distribution of the soil samples and other parameters analysed are as shown in tables 2 and 3.

Table 2: Particles Size Distribution of the Soil Samples.

Site	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	0 - 15	60.8	5.4	33.4	Clay Loam
	16 - 30	60.6	3.4	34.0	
2	0 - 15	77.3	3.4	19.4	Sandy loam
	16 - 30	77.0	3.6	19.4	
3	0 - 15	74.2	5.4	20.4	Sandy clay loam
	16 - 30	74.2	5.4	20.4	

The three plots are considered to be suitable for Drip irrigation, considering their sand and silt components in Table 2. Sand and silt composition of all the plots exceeded 60% and 2.5% respectively. Mubarak *et al,* (2009) suggested that soil plot having these compositions can be subjected to drip irrigation since it will give good wetting front. From table 2, there are slight differences between values got at the two depths considered. For instance, pH, organic carbon, organic matter, Sodium Absorption Ratio (SAR) and field capacity have no significant difference in their properties both for the five locations and between the two depths considered. This may point to the fact that if sample plot A is suitable for any particular irrigation type with respect to any of these properties, other two sample plots will also be suitable for such irrigation techniques. However, parameters like phosphorus, nitrogen, electrical conductivity, hydraulic conductivity (HC) and moisture content exhibited some significant difference both for depths and for sample plots. Though SAR and HC are considered to be important while studying suitability of any soil for irrigation (Hu *et al.,* 2009), the change and variation in this particular scenario do not make the plots unsuitable.
Figures 1 and 2 presents variations of some of the parameters, Hydraulic Conductivity (HC) is higher for site 2 than for other sites and this shows that plot two will exhibit more wetting front when water is released from emitters during drip irrigation. Other parameter considered important in this project is total porosity which in turn will determine the effective porosity of the soil (Lado and Hur 2009). Sample from plot 2 also have higher porosity and FC and therefore will be able to withstand the release of more water either by higher irrigation frequency or bigger emitter size when the conceived drip irrigation is set up.

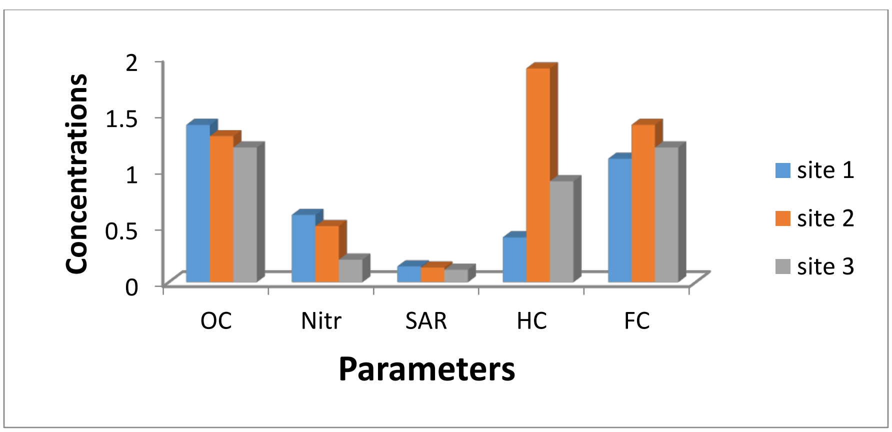

Figure 1: Variations in soil physicochemical and hydraulic parameters.

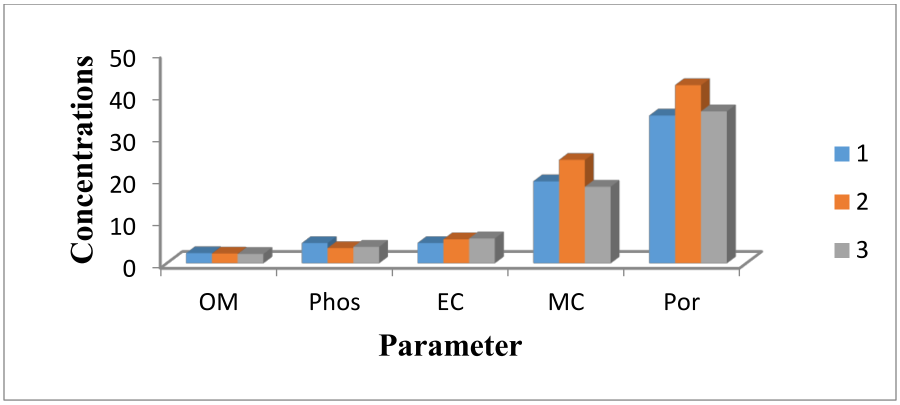

Figure 2: Variations in Soil Physicochemical and Hydraulic Parameters.

Table 2: Physicochemical and Hydraulic properties of the soil samples

Site	Depth (cm)	pH	OC (%)	OM (%)	N (mg/g)	P (mg/g)	EC (µs/cm	SAR (Meq/100g)	FC (%)	HC (m/day)	MC (%)	Total Porosity ((%)
1	0 - 15	$6.3^{a} \pm 0.4$	$1.4^{c} \pm 0.5$	$2.4^{b} \pm 0.1$	$0.6^{e} \pm 0.0$	$4.8^{g} \pm 1.0$	$4.8^{h} \pm 0.7$	$0.14^{r} \pm 0.3$	$1.1^{t} \pm 0.2$	$0.35^{v} \pm 0.1$	$19.5^{u} \pm 1.2$	35.1 ± 2.4
	16 -30	$5.9^{a} \pm 0.4$	$1.4^{c} \pm 0.6$	$2.4^{b} \pm 0.4$	$0.3^{d} \pm 0.1$	$4.4^{g} \pm 1.1$	$4.5^{m} \pm 0.3$	$0.18^{r} \pm 0.0$	$0.9^{t} \pm 0.3$	$0.33^{v} \pm 0.1$	$20.1^{u} \pm 1.4$	34.9 ± 2.1
2	0 - 15	$6.4^{a} \pm 0.4$	$1.3^{c} \pm 0.5$	$2.2^{b} \pm 0.0$	$0.5^{e} \pm 0.2$	$4.8^{g} \pm 0.3$	$5.7^{m} \pm 0.4$	$0.13^{r} \pm 0.0$	$1.4^{t} \pm 0.2$	$1.86^{x} \pm 0.4$	$24.6^{u} \pm 3.0$	42.3 ± 3.0
	16 -30	$6.5^{a} \pm 0.6$	$1.3^{c} \pm 0.2$	$2.3^{b} \pm 0.5$	$0.5^{e} \pm 0.2$	$3.6^{f} \pm 0.1$	$4.7^{n} \pm 0.2$	$0.07^{r} \pm 0.0$	$1.2^{t} \pm 0.3$	$1.98^{x} \pm 0.3$	$22.3^{u} \pm 0.4$	41.6 ± 0.8
3	0 - 15	$6.5^{a} \pm 0.3$	$1.3^{c} \pm 0.2$	$2.2^{b} \pm 0.1$	$0.3^{d} \pm 0.0$	$3.9^{f} \pm 0.2$	$5.9^{n} \pm 0.3$	$0.07^{r} \pm 0.0$	$1.2^{t} \pm 0.0$	$0.78^{v} \pm 0.2$	$19.0^{v} \pm 0.9$	37.0 ± 2.1
	16 -30	$6.4^{a} \pm 0.2$	$1.2^{c} \pm 0.2$	$2.1^{b} \pm 0.2$	$0.2^{d} \pm 0.0$	$3.6^{f} \pm 0.2$	$5.9^{n} \pm 0.3$	$0.10^{r} \pm 0.0$	$1.1^{t} \pm 0.1$	$0.92^{v} \pm 0.1$	$18.2^{v} \pm 1.8$	36.1 ± 2.2

OC – Organic Carbon, OM – Organic matter, N – Nitrogen, P – Phosphorus, EC – Electrical conductivity, SAR – Sodium Absorption Ratio, FC Field Capacity, HC – Hydraulic Conductivity, MC- Moisture Content. Results are mean of three replicates ± SEM; Mean with similar superscripts along same column are not significant difference (p< 0-.5) while mean with different superscripts along same column have significant difference.

Table 3: Correlation Matrix for Soil Parameters

	pH	*OC*	*OM*	*Nitr*	*Pho*	*Pot*	*Cal*	*Sod*	*Mag*	*EC*	*SAR*	*FC*	*HC*	*MC*	*TP*	*BD*
pH	1															
OC	-0.14	1														
OM	-0.12	**0.99***	1													
Nitr	-0.08	0.06	0.11	1												
Pho	0.19	**0.53***	0.52	0.13	1											
Pot	-0.08	-0.17	-0.16	-0.31	-0.07	1										
Cal	0.30*	-0.60	**-0.57***	-0.01	**-0.49**	0.22	1									
Sod	-0.18	0.30	0.27	-0.27	0.35	0.16	-0.20	1								
Mag	-0.13	-0.41	-0.39	0.57*	-0.21	- 0.28	0.37*	-0.30	1							
EC	0.21	-0.24	-0.22	0.19	0.03	0.05	**0.64***	0.14	**0.46***	1						
SAR	-0.18	0.35	0.33	-0.21	0.37	0.14	-0.29	**0.92***	-0.25	0.10	1					
FC	-0.43	-0.17	-0.18	0.30	-0.18	- 0.34	-0.04	-0.10	**0.64***	0.19	-0.13	1				
HC	-0.17	-0.38	**-0.40***	0.29	-0.06	- 0.26	0.08	0.13	**0.66***	**0.40***	0.08	0.72	1			
MC	0.02	0.08	0.07	0.23	**0.54***	- 0.26	-0.27	0.37	0.29	0.28	0.38*	0.39	0.67*	1		
TP	-0.19	-0.29	-0.30	0.02	0.00	- 0.24	-0.16	0.34	0.28	0.06	0.30	0.43*	0.77*	**0.58***	1	
BD	0.18	0.31	0.32	-0.02	0.02	0.25	0.14	-0.32	-0.30	-0.06	-0.30	**- 0.43***	**- 0.78***	**-0.58***	- 1.00	1

**correlation is significant (p < 0.05) at 2- tailed*

Table 3 presents inter-elemental correlation among the parameters tested. Both negative and positive correlation existed. For instance pH exhibit negative correlation with other parameters except phosphorus, bulk density and moisture content though the correlation are not so significant. Correlation between hydraulic conductivity and percentage organic matter is a strong significant one and this may be interpreted that increased organic matter in a soil sample may lead to reduced HC; reason Franzluebbers (2002) attributed to this was higher clay content of organic matters which can seal up the pores in the soil samples. Similarly, bulk density and HC also exhibited strong significant correlation which may also be as a result of aforementioned points. And also that high bulk density can be as a result of well parked soil particles, reduced soil pores and therefore less HC.

CONCLUSION

From this project, it can be concluded that

(i).The three experimental plots used for this work are suitable for drip irrigation set up having considered values of their physicochemical and hydraulic properties.
(ii) Samples from plot 2 exhibited better hydraulic properties and will therefore conduct water faster, hence, more water can be released and the plot can also be planted with crop with more reference evapo-transpiration (ET_e)
(iii). There is no significant difference between the parameters of samples taken from depth 0-15 cm and from samples taken from depth 16 – 30cm. Therefore crop that can tap water or nutrient up to 30 cm depth can be established on the plot.
It is however recommended that SAR, percentage magnesium and sodium of the plots should be considered if repeated drip irrigation will be carried out on these plots as this may lead to salt build up and sodicity of the experimental plots.

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EVALUATION OF COAGULATION EFFICIENCY OF MORINGA OLEIFERA EXTRACT AND ALUM ON FISH POND WASTEWATER

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ABSTRACT

In this study titled evaluation of coagulation efficiency of Moringa oleifera and Alum in wastewater sample was carried out using fish pond wastewater. A preliminary investigation was carried out on initial parameters of fish pond wastewater such as turbidity, pH, BOD, electrical conductivity and total dissolve solid. Coagulant from Moringa oleifera seeds were extracted and the dosages were 2 ml, 4 ml, 6 ml and 8 ml same dose was applied to alum. Optimum dosage for percentage removal in turbidity using Moringa oleifera extract and Alum was found to be 89% and 96.8% respectively at 6 ml dose. Moringa oleifera has no significant effect on TDS, pH, EC and BOD except on BOD in which it increases the BOD. Alum increased the parameters mentioned above. Therefore, Moringa oleifera can serve as alternative coagulant to chemical coagulant alum in water and wastewater treatment.

***Keywords**: Moringa oleifera, Alum, fish pond wastewater*

INTRODUCTION

Wastewater is produced by community after domestic use. Components of wastewater vary from place to place and type of industry discharges. Domestic wastewater mostly contains waste from home garden, kitchen and bathroom. Other than this wastewater can be generated intentionally or unintentionally from houses. Sanitary wastewater contains commercial, domestic and institutional or similar kind of amenities. However, these wastewaters are usually turbid in nature, contaminated with microorganisms, contain suspended and colloidal particles. Most particulate matter cannot settle by gravity and their sizes are so small that they pass through the pores of most common filtration media (cech, 2005). Conventionally, the enmeshment and removal of the colloids in water could be achieved by coagulation, using certain chemical coagulants like certified alum. Many coagulants are widely used in conventional water treatment processes for tap water production. These coagulants can be classified into inorganic coagulants (e.g.aluminumsulphate, polyaluminum chloride, and ferric chloride), synthetic organic polymers (e.g. polyacrylamide derivatives and polyethylene amine) or naturally occurring coagulants (e.g. Chitosan, plant extracts) (Mataka Henry, Masamba and Sajidu, 2006).
Alum is the most widely used coagulant in water and wastewater treatment all over the world. However, some studies have reported that aluminum that remains in the water after coagulation, may induce Alzheimer's disease (Ordonez, Hermosilla, Moral and Blanco, 2010) besides, many developing countries can hardly afford the costs of imported chemicals for water and wastewater treatment. On the other hand, naturally occurring coagulants such as *Moringa oleifera* are biodegradable and are presumed safe for human health. The use of natural materials of plant origin to clarify turbid raw waters is not a new idea. In recent time there has been more interest in the subject of natural coagulants, especially to reduce the problems of water and wastewater treatment in developing countries and to avoid some health risks (Mataka *et al*., 2006). *Moringa oleifera* is a multipurpose tree native to Northern India that now grows widely throughout the tropics. Studies also revealed that *Moringa oleifera* can be either used in shelled or non-shelled dry form seeds. However, shelled seeds are more effective. Furthermore, sludge produced by *Moringa oleifera* during coagulation is not only innocuous but also four to five times less in volumes than the chemical sludge produced by alum coagulation (kebreab, Gunaratna, Brumer, Dalhammer, 2005). This study seeks to confirm and compare the efficiency of *Moringa oleifera* seed extract and alum in fish pond wastewater sample.

MATERIALS AND METHODS

Samples Collection

Dry seeds of *Moringa oleifera* and the commercially available alum were purchased from Engr. A. A. Kure Ultra-Modern Market Minna, Niger State. Seeds were sorted out and de-shelled by hand to remove the kernels. The kernels were crushed and ground to a medium fine powder by ceramic mortar and pestle and sieved using 250 µm sieve size to obtain a fine powder in order to achieve solubilisation of active ingredients in the seed.

Wastewater Collection

The fish pond wastewater was collected from Adamu Farm Airport City Estate Maikunkele Area of Niger state. The wastewater sample used was collected in 25 litres plastic container and was analysed for some physiochemical properties.

Experimental Procedure

Sample Preparation

Twenty five (25) litres of fish pond wastewater sample was fetched from Adamu Farm, this was further dispensed into nine (9) beakers. The volume of sample in each beaker was 500 ml.

Four different concentrations of the stock solutions for the loading dose were prepared by measuring 2.0 ml, 4.0 ml, 6.0 ml and 8.0 ml of alum and *Moringa oleifera* stock solution separately into a beaker containing 500 ml of raw wastewater. The mixtures in the beakers were stirred using a glass rod to obtain a clear solution. A 500 ml of raw wastewater with no alum neither *Moringa oleifera* stock solution was kept as the control treatment. The stirring was been performed to allow flocculation to take place.

The coagulant dosage can be selected depending on the turbidity of wastewater and can also be calculated (Guibal, et al., 2006). Floc formation was observed throughout this time and was allowed to settle for one hour before obtained for samples analysis. After settling, clear water sample was collected from each of the beaker by decantation and placed in small beaker for further analysis.

RESULTS AND DISCUSSION

Table 1, present the initial experiment carried out to determine the preliminary characteristics of fish pond wastewater. The characteristics of raw fish pond wastewater are as presented below.

Table 1: Preliminary Characteristics of Fish pond Wastewater (control)

Parameter	Wastewater
Turbidity (NTU)	90.6
pH	7.28
conductivity (µS/cm)	156
BOD (mg/L)	10
TDS (mg/L)	104

Effect of Coagulants on Constituent Parameters

The treatment efficiencies of M.O. and alum are presented in Tables 2 and 3. At the varying coagulant dosage, slight change was observed on pH, TDS, EC for sample treated with *Moringa Oleifera*. Alum increased the TDS and EC of the treated water and drastically reduced the pH in response to increasing dosage. The high levels of EC in the treated wastewater were the result of the dissolution of aluminum ions. This is in agreement with the findings of Ordonez *et al*. (2010) and Alo, et al., (2012) which indicated that conductivity increases as more coagulant is added to water. The sulphuric acid that was produced in the process resulted in the drop in pH of the treated wastewater.

Table 2: Characteristics of Treated Wastewater with *Moringa oleifera* Extract

Parameter	Coagulant Dosage			
	2 ml	4 ml	6 ml	8 ml
pH	7.50	7.40	7.31	7.32
Turbidity (NTU)	15.9	12.2	9.93	14.5
TDS (mg/L)	96	100	104	107
Conductivity (µS/cm)	143	149	154	160
BOD (mg/L)	27	82	71	48

Table 3: Characteristics of Treated Wastewater with Alum

Parameter	Coagulant Dosage			
	2 ml	4 ml	6 ml	8 ml
pH	4.47	4.31	4.26	4.23
Turbidity (NTU)	3.45	3.79	2.87	3.18
TDS (mg/L)	176	247	312	370
Conductivity (µS/cm)	263	368	465	552
BOD (mg/L)	0	33	0	0

Effect of Moringa oleifera Extract and Alum on Turbidity Removal Efficency

At optimum dosage of 6mL of *Moringa oleifera* (fig. 1), the turbidity of fish pond wastewater sample reduced from 90.6 to 9.93 NTU compare to alum at optimum dosage of 6ml (fig. 1) that reduce the same 90.6 to 2.87 NTU. The removal efficiency of *Moringa oleifera* and Alum coagulants are 89% and 96.8% respectively. This result agrees with Kayaton, et al.,(2004) that *Moringa oleifera* coagulant is not efficient in treating low turbidity water. The variation in performance could be due to different protein contents of seed and development owing to varying geological locations (Narasiah, et al., 2002). Residual turbidity in the control is 50 NTU. It is therefore concluded that the method of allowing water to settle without coagulation is not efficient.

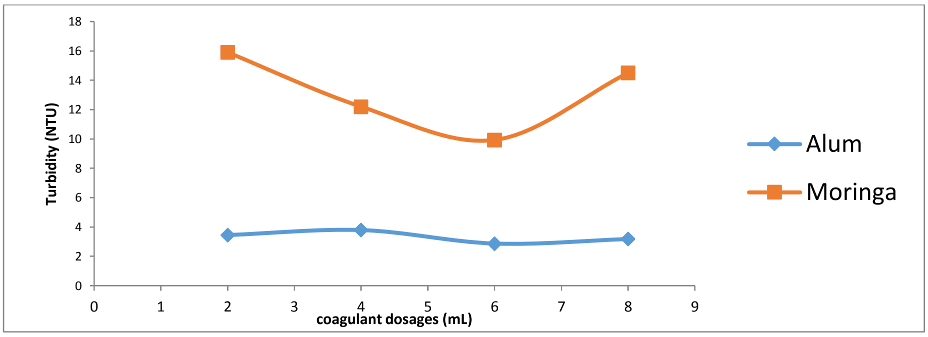

Figure 1: Effect of coagulants on Turbidity

Effect of Moringa oleifera Extract and Alum on pH

From fig. 2, there is slight change in pH after treatment. As *Moringa oleifera* dosage increases from 2 ml, 4 ml, 6 ml, to 8 ml give the yield 7.50, 7.40, 7.31 and 7.32 respectively. Thereafter, as dose of alum increases, the initial pH of wastewater which was 7.26 reduced to 4.47, 4.31, 4.26 and 4.23 respectively. The concentration of alum increases acidity of wastewater.

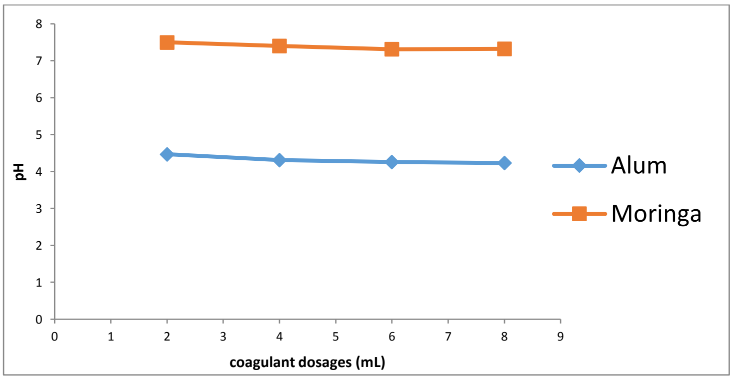

Figure 2: Effect of coagulants on pH

Effect of Moringa oleifera Extract and Alum on Total Dissolve Solid (TDS)

According to fig. 3 the *Moringa oleifera* extract has minimal effect on total dissolve solid. Increase in alum dosage leads to increase in initial TDS of 104 mg/L to 176 mg/L, 247 mg/L, 312 mg/L and 370 mg/L respectively. This show that alum increases the total dissolved solid (TDS) of wastewater.

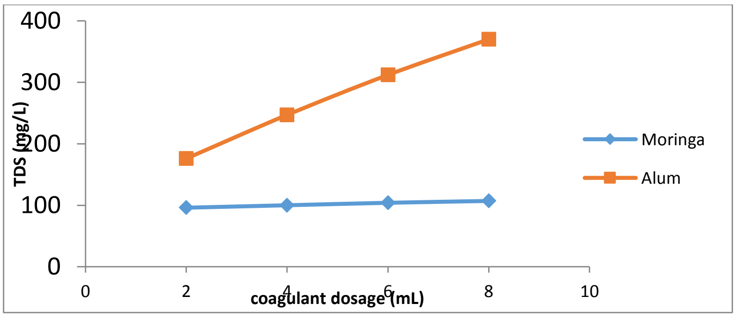

Figure 3: Effect of Coagulants on Total Dissolve solid (TDS)

Effect of Moringa oleifera Extract and Alum on BOD Removal

The initial BOD of the wastewater was 10 mg/L (table 1). Treatment with *Moringa Oleifera* extract (fig. 4) increased BOD in wastewater sample compare to alum (fig. 4) which has 100% BOD removal efficiency after treatment. The result shows that alum is more efficient in BOD removal than *Moringa oleifera* Extract.

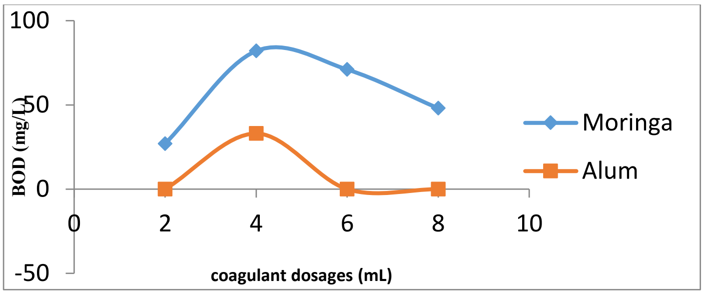

Figure 4: Effect of Coagulants on BOD

Effect of Moringa oleifera Extract and Alum on Conductivity

There was slight change in conductivity of the wastewater after treatment prior to addition of *Moringa oleifera* extract while alum increased conductivity of the wastewater due to dissolution of aluminium ions. Conductivity increases as dose of alum increases (fig 5).

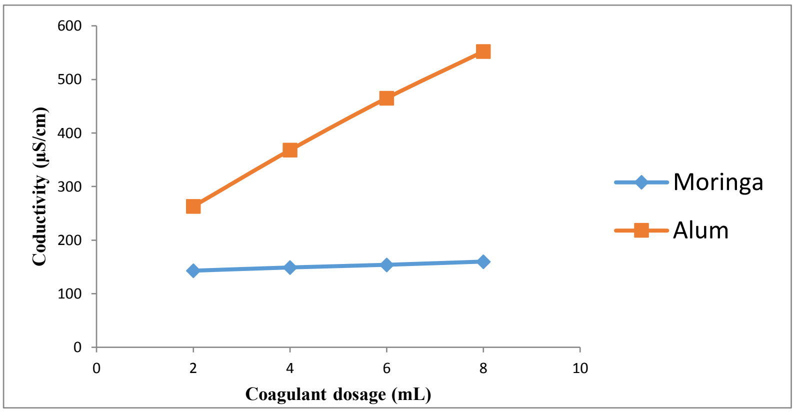

Figure 5: Effect of Coagulants on Conductivity

CONCLUSION

After the treatment of the collected fish pond wastewater using the natural coagulant *Moringa oleifera* (MO), it was observed that the optimum dosage for removal of turbidity was 89% and for Chemical coagulant Alum (Al_2 $(SO4)_3.18H_2O$ was 96.8% both at 6 mL dose. When MO and Alum was used as a coagulant in the removal of TDS, pH, EC and BOD, MO extract was observed to have no significant effect on TDS, pH, EC except on BOD in which it increases the BOD while Alum increased the aforementioned parameters.

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EFFECT OF ATRAZINE ON THE GROWTH AND YIELD OF MAIZE IN JOS NORTH - PLATEAU STATE

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ABSTRACT

A Field study was conducted in 2015 at the teaching and research farm of Federal College of Forestry, Jos, to evaluate the effect of various level of concentration of atrazine on the growth and yield of maize. Four (4) plants were tagged randomly within each plot of the inner rows at 2 WAP (weeks after planting) till eight week when the maize had attained full maturity, for the assessment of height (cm), stem girth (cm) and leaves count. The maize cobs were harvested 90 days after planting, dehusked and further dried to reduce the moisture level of the grains to 14% before yield records were taken. The highest plant height value of 85.2cm was obtained at week 8, when 3kg/ha of Atrazine was applied with 40 liters of water, while the lowest plant height value of 10.1cm was observed at week 2, when 0.3kg/ha of atrazine was applied with 40 liters of water, the highest mean leaf count value of 13.2 was recorded at week 8.The grain yield ranged from 3 - 5.4 t/ha, while the biomass yield ranged from 9.5 - 17.1 t/ha. The results obtained implies that if the concentration level required by the manufacturer is reduced beyond 25%, it will encourage the infestation of weeds, leading to grain and biomass yield reduction that may reduced expected returns by farmers.

Keywords: *Atrazine, Concentration, Maize, Grain and Biomass yield*

INTRODUCTION

Maize (Zea mays L.) is the world's third most important cereal grain after wheat and rice, grown primarily for grain and mostly consumed by humans as food, animal feed, and it also serves as raw material for food industries. According to estimation,75% of the total production of maize is used as food by the farming community and the remaining finds its way to starch manufacturing industry, poultry feed and food grain sales (Peace and Oyibo, 2015).

Maize has been in the diet of Nigerians for centuries, it started as a subsistence crop and has gradually risen to a commercial crop, on which many agro-based industries depend on as raw materials (Iken, 2004). Ogunbode (2001) reported that western Nigeria generally produce about 50% of Nigeria's green maize; there has been a dramatic shift of dry grain production to the savanna, especially in the northern guinea savanna. This trend may have been brought about for several seasons, including availability of streak resistant varieties for northern ecological zones in Nigeria, availability of high – yielding hybrid varieties, increase in maize demand coupled with the Federal Government imposed barn on importation of rice, maize and wheat. Local production had to be increased to meet the demand for human consumption, breweries, pharmaceutical companies, livestock feeds and other industries.

However, despite the growing popularity of maize as food, feed and industrial raw material, average production per hectare in Nigeria is comparatively very low (Onwueme and Sinha, 1997). Some of the factors responsible for low yield of maize include pest, diseases, low soil fertility and weed infestation among others. The weeds that germinated before or at the same period with Maize are more competitive than the ones that germinate after the emergence of maize, which causes higher yield losses (Swanton *et al.,* 1999; Bükün, 2004). Maize is very susceptible to competition from weeds especially in the early stages of growth therefore, efficient control at the pre and early post-emergence stages is essential. Once maize reaches approximately 0.5 m in height, weeds control no longer affects yield (Marshall, 2004).

The detrimental effect of weeds on maize is very dramatic as maize is not known to be able to compete with weeds, resulting in yield reduction of up to 60 percent (Akobundu, 1987). Weeds are one of the most important factors in maize production, causing severe yield losses worldwide, with an average of 12.8% when weed control is applied and 29.2% without weed control (Oerke and Steiner, 1996). Yield loss due to weeds is estimated to be 38% in Africa as a whole and 64–75% in the Guinea savanna zone of Nigeria (NACWC, 1994), varying from 40 to 100% in Nigeria (Fadayomi, 1991; Ford and Pleasant, 1994; Sha A *et al*., 2015). Therefore, weed control is an important management practice for maize production, which must be carried out to ensure optimum grain yield. Success of weeds control methods depends upon several factors like: weed emergence pattern, application timing and stage of crop are important in chemical control (Hoverstad *et al.,* 2004).

Exhausted by cultural methods, farmers are moving towards other alternative methods of weed control, which is a chemical method. Chemical control method is quick, more effective, time and labour saving method than others; Chemicals are increasingly being used in Nigeria and other developing countries for the control of weeds in maize because they offer an effective and relatively inexpensive means for managing cereal weed problems (Ahmed *et al*., 2008).

Different herbicides exist for controlling weeds on maize farms, but their efficacies vary depending on the reaction of the test plant and the nature of the weed to which it is prone. Selective herbicides kill certain targets weeds, while leaving the desire crop relatively unharmed. Some of the herbicides act by interfering with the growth of the weed and are often based on plant hormones, several reports address the importance of herbicides in maize (Swanton *et al*., 1999; Bükün, 2004).

In general, the evaluation of herbicide used in maize should depend not only on its efficiency in controlling the weeds, but also its effects on growth of plants and grain yield (Sha A *et al*., 2015). Several herbicides have been identified for weed control in maize and are applied at various stages of development; hence, they are classified according to their time of application as pre-plant, pre-emergence, or post- emergence (G.G.D.P, 1991).

Atrazine is a prominent herbicide which is currently one of the most widely used herbicides in world agriculture (llhan *et al*., 2010). It is a selective pre-herbicide used for control of many broad leaf weeds and grasses in corn, sorghum, sugarcane, pineapple, turf and orchards (llhan *et al*., 2010).

For many years maize producers in Yugoslavia (Pakistan) have mainly relied on triazine and chloractanilide as standard herbicides for the control of broad leaf and grassy weeds before crop emergence (Gressel and Segel, 1990). If these herbicides are applied at higher rates, they endanger the safety of the environment and the toxicological justification of application, which lead to as limitation of their use. As a consequence, there is a shortage of effective herbicides which can be applied before emergence and at the same time weeds resistant to triazines have developed, further limiting the efficacy of herbicides in maize (Gressel and Segel, 1990). Some farmers on the process of application would tend to destroy the whole plant in the farm, to determine the level of application of this pre-emergence herbicide (atrazine) to improve yield of maize as there are problems of inconsistency in the application of herbicides as reported by Gressel and Segel, (1990).

These call for the use of pre-emergence Herbicide (atrazine) at various levels to check the effectiveness of weed infestation, that helps in achieving a speedy breakthrough for increasing maize production (Devender *et al.,* (1998). Much work has been done on the efficacy of these herbicides on their weed control ability; the knowledge gap is therefore, the need to evaluate the impact of these herbicides at different concentration levels to check its impact on weeds. Hence, this study focuses on effect of various concentration levels of atrazine on the growth and yield of maize, so as to recommend the adoptable dose for farmers within the study area.

MATERIALS AND METHODS

Study Area

The experiment was conducted in Federal College of Forestry Jos, which lies at latitude $9^0$56N, and 8°53E and longitude 9.933°N and 8.833°E in the middle belt within the southern Guinea Savannah ecological zone of Nigeria with a mean annual rainfall of 1260mm (Olowolafe and Dung, 2002).

Soil Analysis

Soil sample at 0-15cm depth from study area was taken to Chemical and physical laboratories, Nigerian institute of mining and geo-sciences, Tudun Wada, Jos for analysis. The analysis showed that the soil is sandy loam, pH of 6.30, 0.035% of Nitrogen (N), 2.09% of organic matter (OM), exchangeable bases include 49 ppm of phosphorus (P) 0.1ppm of Na, 1.5ppm of Ca, 0.45ppm of mg, and 20ppm of K, exchangeable acidity 3.5 mmol/10 of H^+, while the clay, silt and sand were 6.34, 8 and 85.9% respectively.

Meteorological Data of the Study Area

The pan evaporation ranged from 5.0 to 49.5mm per day, while relative humidity was fairly stable from September – October, humidity value of 76.52% was recorded in the month of September as the highest and 56% in November as the lowest observed humidity. The highest rainfall value of 14.70mm was observed in September while the lowest rainfall value of 2.20mm was obtained in November. The highest temperature value of 30.49^{0}C was observed in November, while the lowest temperature value of 23.25^{0}C.

Experimental Design and Treatments

The treatments involved five concentrations replicated three times to give a total of 15 treatments laid in randomized complete block design (RCBD).The treatment description is shown in Table 1.

Table 1: Description of Treatments

Treatment No.	Treatment Description
T_1	3.00kg/ha per 40 litre of H_20 (control)
T_2	2.25kg/ha per 40 litre of H_20
T_3	1.50kg/ha per 40 litre of H_20

T_4	0.75kg/ha per 40 litre of H_20
T_5	0.30kg/ha per 40 litre of H_20

Agronomic Practices
The study was carried out from 3rd September, 2015 to 3rd December, 2015. Maize variety, Pod corn was obtained from ASTC Kassa in Jos South LGA. The field was prepared manually, the prepared plots were watered for four days, pre-emergence herbicides atrazine was applied as recommended by the manufacturer 3kg/ha per 40 liter of H_20, which was taking as the control, the treatment description are as shown in Table 1. Herbicides were applied using a 20L Knapsack sprayer calibrated at 220L/ha delivery rate with a nozzle. The various concentration of Atrazine was applied two days after sowing. Maize seeds were sown at a spacing of 0.75× 0.25 m on 3rd September, 2015 and were harvested on the 3rd of December, 2015. Three seeds were sown per hill and the seedlings thinned to two plants per hill two weeks after emergence. Each plot measured was 4 × 4 m and the four inner rows of each plot were used for data collection. All the treatments were given equal volumes of water and compound fertilizer 15-15-15 (N-P-K) was applied at a rate of 250 kg/ha as side dressing, two weeks after sowing. Top dressing with Sulphate of ammonia, at the rate of 125 kg/ha was applied six weeks after emergence. Four (4) plants were tagged randomly within each plot of the inner rows at 2 WAP (weeks after planting) till eight week when maize had attained full maturity, for the assessment of height (cm), stem girth (cm) and leaves count. The height of the plant (cm) was determined from the above ground level using graduated meter rule. The numbers of leaves per plant were counted to obtain the mean value in each treatment. The harvest was done manually by cutting stems with cutlass respectively. The maize cobs were harvested 90 days after planting, dehusked and further dried until the moisture level of the grains was 14% before yield records were taken. The above ground biomass was harvested to obtain the biomass of each plot using a weighing balance. The Vegetative and yield data were collected and analyzed using Turkey method at 95% confidence with the use of Minitab 16.

RESULTS AND DISCUSSION

Plant Height
Table 2 shows the means of plant height, the highest plant height value of 85.2cm was obtained at week 8, when 3kg/ha of Atrazine was applied with 40 liters of water (T_1), while the lowest plant height value of 10.1cm was observed at week 2, when 0.3kg/ha of atrazine was applied with 40 liters of water (T_5). Using Minitab 16 with Turkey method of 95% confidence level, there was no difference between treatments T_2 and T_3, however, treatment T_1 was significantly different from T_4 and T_5, which could be due to the fact that atrazine herbicide was effective in controlling seedling grasses in earlier stage of growth of the maize plants, when it is applied in the range of 1.5 - 3 kg/ha per 40 liter of H_20 as it reduced weed interference as reported by Ekpo *et al*., (2010). This result is in line with what Shinde *et al*., (2001) and Sinha *et al*., (2001) reported, that variations in plant height and cob length of maize could be attributed to varying effect of weed competition (light, moisture and nutrients) offered by different weed densities in different treatments.

Table 2 Plant Height (cm)

Treatment	Week 2	Week 4	Week 6	Week 8
T_1	12.9a	39.5a	62.8a	85.2a
T_2	12.6ab	36.3a	57.3ab	79.3ab
T_3	12.4ab	32.6ab	52.8ab	77.6ab
T_4	11.9b	30.3b	49.6b	62.5b
T_5	10.1bc	28.0c	46.1bc	51.2c

Leaf Count
Leaf is the basic photosynthetic machinery for plant food, hence its size would directly affect the yield and yield component of crops. There was no significant difference in leaf count per plant among the herbicide treatments when compared with the control, using Turkey method at 95% confidence with the use of Minitab 16. Table 3 shows the weekly leaf count, the highest mean leaf count value of 13.2 was recorded at week 8 from T_1 (control), while the lowest mean leaf count value of 3 was recorded for treatment T_5; these results were contrary to findings made by Akhtar *et al*., (1984) that the lower leaves of maize are suppressed with lesser concentration of herbicide leading to their early senescence, hence fewer leaves and subsequently lower leaf area. Similar results had been reported by James *et al.*, (2000) on weed competition in maize in Ilorin, Nigeria.

Table 3 Weekly Leaf Count

Treatment	Week 2	Week 4	Week 6	Week 8
T_1	4.7a	7.7a	9.5a	13.2a
T_2	4.0a	7.3a	10.0a	11.8a
T_3	3.8a	6.9a	9.5a	13.2a
T_4	3.8a	6.8a	8.5a	12.2a
T_5	3.0a	7.3a	9.8a	12.8a
LSd (0.05)	NS	NS	NS	NS

Stem Girth

Table 4 shows the mean of stem girth, treatment of T_1 had the highest mean value of 9.7 at week 12, while treatment T_5 had the lowest mean value of 4.8 at week 4. The stem girth after week 8 ranged from 8 - 9cm for all the treatments. Analysis using Turkey method at 95% confidence with Minitab 16 showed there was no difference on the stem girth of the maize plant; indicating that stem girth of maize crop was not affected by the varied concentration of Atrazine in the study area.

Table 4 Stem Girth

Treatment	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week10	Week11	Week12
T_1	5.4a	5.6a	6.5a	6.7a	8.0a	8.0a	8.1a	8.5a	9.7a
T_2	5.3a	6.3a	7.2a	7.9a	8.2a	8.2a	8.7a	8.8a	9.5a
T_3	4.7a	5.5a	6.6a	7.3a	7.8a	7.8a	8.7a	8.9	9.4a
T_4	4.8a	6.4a	7.2a	7.7a	8.7a	8.7a	8.7a	8.8a	9.5a
T_5	4.8a	5.6a	6.6a	7.4a	7.8a	7.8a	8.2a	8.4a	8.5a
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

Grain and Biomass Yield

Table 5 shows the grain and biomass yield. The grain yield ranged from 3 - 5.4 t/ha, while the biomass yield ranged from 9.5- 17.1 t/ha. The highest grain yield value of 5.4 t/ha was recorded for the control (T_1), while the lowest grain yield value of 3t/ha was recorded at treatment T_5 where the required concentration was reduced by 10%. Also, the highest biomass yield was recorded from treatment T_1 (control), while the lowest biomass value of 9.5 t/ha was recorded from T_5. When the concentration was reduced by 25, 50, 75 and 90 %, the corresponding impact on grain and biomass yield reduction for treatments T_2, T_3, T_4 and T5 were 29, 42, 64, and 80%, respectively with respect to the control.

Analysis using Turkey method at 95% confidence with the use of Minitab 16 showed significant difference between treatment T_3 and T_5, treatments T_1 and T_2 were not significantly different from each other; implying that if the concentration level required by the manufacturer is reduced beyond 25% it will encourage the infestation of weeds, leading to grain and biomass yield reduction that may reduce expected returns by farmers. Buhler, 2002; Imeokparia and Okusanya (1997) reported that serious weed competition with the maize plants for soil water and nutrients results in reduced plant height and yield of maize.

Table 5 Grain and biomass yield

Treatment	Grain yield (t/ha)	Biomass yield (t/ha)
T_1	5.4a	17.1a
T_2	4.2ab	13.3ab
T_3	3.8b	12b
T_4	3.3bc	10.4bc
T_5	3c	9.5c

According to Mohammed *et al.,* (2009), lower grain yield was recorded for reduced concentration of Atrazine, this could be attributed to maximum weed density which suppressed the growth and development of maize plants by competing for moisture, light and nutrients.The grain and biomass yield obtained in this study were in agreement with the report of Lyocks *et al*., (2013) who found that grain yield ranged from 2.05- 3.98 t/ha within Samaru region. Also, Garba and Namo (2013) reported grain yield of 3.88 and 3.49 t/ha within two savanna agro-ecologies of Saminaka (lowland) and Vom (mountainous) in Nigeria. Differences in grain and biomass yield reported, may be due to the following: crop variety, extent of irrigation deficit, irrigation method, climate and other agronomic practices.

CONCLUSION AND RECOMMENDATIONS

During the field work, the maize farm was invaded twice by cattle within the college premises, which may be the reason why there were no significant differences among some of the yield component parameters. Therefore, further research should be conducted so as to actually ascertain the impact of different concentrations of Atrazine on growth parameters of Maize crop.

Keeping in view the limitations of the use of herbicide, whose application is an efficient way to check weed infestation it is therefore imperative to develop comprehensive information regarding their quantity, safe and effective use on various crops like maize and others. Analysis on the yield of weed per plot should be done so as to examine weed density per plot. Based on the major findings of this research, it is recommended that when Atrazine is to be applied in the study area, it should not be lower than 25% with respect to the manufacturer's recommendation.

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DETERMINATION OF MAXIMUM WETTED BULB RADIUS AND MAXIMUM INFILTRATED DEPTH FOR A SANDY LOAM SOIL

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ABSTRACT

Good water management is necessary in a water scare condition in order to achieve a sustainable food security to sustain world increasing population. Drip irrigation has the propensity to increase water use efficiency only if the system is designed with the knowledge of moisture distribution pattern which is a pre-requisite for the operation of the system, and so this method was used to apply water to sandy loam soil in other to determine the radius of water entry at the surface, the depth of wetting front for the discharge as a function of time. This was done by conduction an experiment at the demonstration plot of Agronomy department of university of Agriculture, Makurdi. A constant flow rate of 1.3 litres /hr was used. At the end of 10 hrs a maximum depth of 35 cm was attained. Mean maximum wetted radius of 10.38 cm was at the surface. The result indicated that the wetted bulb had circular top area, generally the wetting depth increased as the wetting radius decreased. However, vegetable crops can be planted at this wetting characteristic.

Keywords: *Drip irrigation, wetted radius, wetted depth.*

INTRODUCTION

Change in the availability and demand of water under climate change will affect food security and agricultural activities in the 21st century (Bruinsma, 2003). Modified precipitation pattern and water storage cycles will change annual, inter-annual and seasonal availability of water for terrestrial and aquatic agro-ecosystem. In most part of the world regions climate change will increase irrigation demand because of a combination of decreased rainfall and increased evapotranspiration caused by higher temperature, hence climate change could have a big effect on irrigation water requirement (Bruinsma, 2003).

Irrigation improvements in the future will play a very important role, in other wards the water availability both for production of foods and for competing environmental and human needs will need to be assumed (Bates *et al.*, 2008).

Drip or trickle irrigation is one of the latest methods which is becoming increasingly popular in areas with scarcity and salt problems. It is a method of watering plants frequently and with a volume of water approaching the consumptive use of the plants, thereby minimizing such conventional loses as deep percolation (Michael, 1978). He also described drip irrigation as a method meant for adoption at places where there exist acute water scarcity for irrigation and other salt problems. In this method, water is slowly and directly applied to the root zone of the plants, thereby minimizing loses by evaporation and percolation.

During irrigation the water content in the soil changes spatially and temporally. Water distribution in the soil is strongly dependent on the design parameters of the irrigation system, climate conditions, root distribution, soil type, rates of water application and vegetation. For effective design of trickle irrigation systems, the water dynamics in the soil needs to be predicted using all the above mentioned variables, information about temporal evolution of the wetted volume in specific soil can help in establishing the optimal spacing between the emitters and the irrigation duration as a function of the soil volume where crop roots are located (Provenzano, 2007).

FAO, (2002) said that conventional irrigation is associated with one or more of the following problems; salt problems in irrigated land especially in arid and semi- arid regions; extensive use of water which causes water losses and wastages through evaporation and deep percolation; and poor application of chemicals and fertilizer to crops.

Drip irrigation system can be designed to maximize the above stated problems by delivering irrigation water directly near the root system of plants. The system applies water slowly to keep the soil moisture within the desired range. Knowledge of soil wetting pattern and its movement plays a large role in deciding spacing of pipes and emitters, design of irrigation scheduling and improving the efficiency of point source irrigation.

Most recommended and commonly used strategies to avert an impending water crisis is to provide adequate information that will help farmers switch over from the traditional flooding method of irrigating to the highly efficient drip irrigation and more efficiently, the point source drip system. Also most low-cost micro-irrigation systems in use today, such as drum and bucket drip kits apply water in pulses often twice a day.

The general goal of drip irrigation system design is to provide irrigation water efficiently and uniformly to crop, to help meet the evapotranspiration (ET) needs. At the same time, maintaining desired water content at a depth of the root zone, which is increasing the crop yield and quality, is of great importance (Lamm *et al.*, 2007; FAO, 2002). Interest in the wetting patterns associated with drip irrigation and Subsurface irrigation has resulted in a number of studies on topic from both field trials and theoretical investigations. In a sandy loam soil, Earl and Jury

(1977) found that the wetting front from a single surface emitter extended to 0.6 m with a daily irrigation schedule and 1 m under a weekly schedule.

MATERIALS AND METHODS

Study Area

This study was carried out in University of Agriculture, Makurdi, Nigeria. The location lies between latitudes 7° 45' and 7°52' N of equator and longitude 8° 35' and 8° 41' E of Greenwich Meridian. The primary occupation of the people is farming and the major crops grown are yams, cassava, potatoes, soyabeans, guinea corn, and groundnut. Other activities are construction and reclamation have affected the nature of the soils. Makurdi town has a tropical sub humid climate of wet and dry type, with double maxima (Ayoade, 1983). The rainy season lasts from April to October, while dry season of five months lasts from November to March. Annual ranfall in Makurdi town is consistently high, with an average annual total of approximately 1173 mm (Abah, 2012). Temperature in Makurdi is however, generally high throughout the year, with February and March as the hottest months, it varies from 22.5°C to a maximum of 40°C daily. Geology of Makurdi is basically composed of sedimentary rocks, and sandstones the dominant rock type.

Sample Collection and Analysis

Soil sample for the analysis of physical and chemical properties was randomly collected from the designated plot using an essential tool for gardeners called stainless steel blade of model 9APH2.

The soil samples were collected at 0-15cm to 16-30cm depth from five different location on the same plot of about 7m x 7m. The samples were air dried and sieved through a 2mm diameter sieve and it was put into polythene bags that were assigned laboratory numbers. The analyses of soil physical and chemical properties was carried out at the Nasarawa State University Agronomy research laboratory. Standard laboratory procedures were used and the parameters that were analyses are listed in Table 1 below.

Table1: Laboratory Analysis of the soil samples

S/N	PARAMETER	STANDARD METHODS
1	Porosity (%)	Core (Blake, 1965) too old
2	Organic matter (%)	(Walkey and Blake, 1934) too old
3	Hydraulic conductivity (m/day)	Falling head permeability (Singh, 1989)
4	Moisture content (%)	Oven dry method
5	pH	Glass electrode (Van Rweuwijk, 1992)
6	Particle size distribution (%)	Bouyoucos hydrometer (Bouyoucos, 1962, Van Rweuwijk, 1992)
7	EC (ds m^{-1})	Jenway digital conductivity meter model 4520

Site Preparation and Field Layout

The experimental site was cleared of weeds and shrubs and then slightly ploughed to 0.5 m depth and harrowed to about 0.3 m to thoroughly mix the profile and eliminate any compacted layer, this also brought the soil to an ideal planting condition. A drip irrigation system was used to apply water. The components of the system, which is a complete gravitational drip irrigation unit include plastic bucket of about 200 liters placed 1m above the ground level (water source), the mainline connecting the source of water with the submain, the submain was linked to two laterals, and the laterals have factory-fitted emitters or drippers (at 30cm interval) with fitted filaments which will regulate the emission of water directly to the ground surface. The laterals bear emitter fitted and each discharges at a fixed flow rate of 1.3 litres per hour.

Field Investigation

The experiment was carried out to determine the configuration of the wetted radius on the surface, as well as at different depths of 0cm, 5cm, 10cm, 15cm, 20cm, 25cm, 30cm and 35cm intervals from the surface at the same discharge rate.

Water was discharged to the submain from the source through the mainline with a control valve at 1.3 litres per hour. A coordinate system of the wetted soil was established on the profile after 10 hours of irrigation, with the centre of the soil surface directly under the emitter.

At the end of every 1 hour, three points on the lateral line around the emitter that was wetted was excavated to expose the vertical soil profile and the distance of the wetted front was measured horizontal and vertically downward at different depths with the emitter in the centre. These three points served as replicates. This was repeated at the end of every 1 hour for a total of 10 hours

RESULTS AND DISCUSSION

The results of particle size distribution of the soil samples analyzed are as shown in Table 2 while Table 3 shows the physicochemical and hydraulic properties.

Table 2: Particles Size Distribution of the Soil Samples.

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class
0 – 15	77.3	3.4	19.4	
16 – 30	77.0	3.6	19.4	Sandy loam
Mean	77.15	3.5	19.4	

Table 3: Physicochemical and Hydraulic properties of the soil samples

Depth (cm)	pH	OM (%)	EC (µs/cm)	HC (m^3/day)	MC (%)	Total Porosity (%)
0 - 15	$6.5^{a}\pm0.3$	$2.2^{b} \pm 0.1$	$5.9^{n} \pm 0.3$	$0.78^{v} \pm 0.2$	$19.0^{v} \pm 0.9$	37.0 ± 2.1
16 -30	$6.4^{a}\pm0.2$	$2.1^{b}\pm 0.2$	$5.9^{n} \pm 0.3$	$0.92^{v} \pm 0.1$	$18.2^{v} \pm 1.8$	36.1 ± 2.2

OM – Organic matter, EC – Electrical conductivity, HC – Hydraulic Conductivity, MC- Moisture Content. Results are mean of three replicates ± SEM; Mean with similar superscripts along same column are not significant difference (p< 0-.5) while mean with different superscripts along same column have significant difference.

The percentage of sand in the soil sample is very high (Table 2). This gave rise to large pore spaces which permitted faster movement of water. This is evident in the high values of hydraulic conductivity and total porosity as seen in Table 3. Another factor that may led to high hydraulic properties of this soil was low initial moisture content as well as low organic matter content of the soil before irrigation. Table 4 shows wetting pattern of the soil texture at the regulated constant flow rate of 1.3 litres per hour.

Table 4: Wetting characteristics of the sandy loam

Flow Rate (l/h)	Time (hr)	Depth (cm)	Mean wetted radius (cm)
1.3	1	0	10.38
1.3	2	5	8.77
1.3	3	6.5	4.67
1.3	4	10	1
1.3	5	20	0
1.3	6	25	0
1.3	7	30	0
1.3	8	35	0

The wetted depth increased as the wetted radius reduced with time at constant flow rate (Table 4). As the irrigation continued the wetted radius decreased to a point that cannot be easily measured and eventually to 0. The maximum wetted depth of 35 cm was achieved in 8 hrs while the maximum wetted mean radius of 10.38 cm was at the surface and was achieved in 1 hr. This has shown that with good water management a good number of vegetable crops within this rooting depth and circumference can be grown.

CONCLUSION

The wetting characteristics of sandy loam were determined using drip irrigation system. As a result of high percentage of sand in the soil the hydraulic characteristics were high because of large pore spaces. The low initial moisture content and low organic matter also contributed to high water movement. The wetted depth of 35 cm was achieved. The maximum mean wetting radius of 10.38 cm was at the surface while the minimum of 1 cm was at the depth of 10 cm. This depth can sustain vegetable crops.

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DETERMINATION OF INFLOW DESIGN FLOOD OF NAKA EARTH DAM IN THE LOWER BENUE RIVER BASIN, NIGERIA.

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ABSTRACT

This paper discusses the determination of inflow design flood of River Ana on which the Naka Small Earth Dam in Benue State, Nigeria was built. A study of the initial design of the dam was carried out to identify reason(s) for its failure by overtopping shortly after completion of construction work. In the absence of comprehensive hydrological data, the peak flood of the river was estimated using physical indicators of past floods (historical method). Direct stream measurement was carried out for two years to determine the peak flood of the river. Flow stage measuring gauges were installed on the river; gauge readings were collected and collated. The cross-section of the river at points of stable embankments was plotted. With the determination of the slope of the river bed and the velocity of flow, suitable hydrological equations were used to compute the peak flow of the river. The Unit Hydrograph (UH) method was also used in the determination of the peak flood. ***.*** *The unit Hydrograph method gave a peak flood of 9.076m^3/s/km^2. In 1997, the peak flood was 5.45 m^3/s and 2.15 m^3/sec in 2015. Adequate reliable hydrological data is necessary for design and construction of efficient hydraulic structures. It is unsafe to base designs of sensitive engineering structures like dams, bridges, culverts on only one or two years discharge measurements. This practice has led to the washing away of many dams, bridges and culverts.*

Keywords: *Dam, unit hydrograph, inflow flood, hydraulic structures, design flood.*

INTRODUCTION

For sustainable agricultural production to achieve food security, there must be a shift from rainfed agriculture to irrigation agriculture. Water impoundment through the use of dams is a key activity for irrigation agriculture. The essential requirements of design of an earth dam are safe and stable structure at a minimum construction and maintenance cost (Chanson, 2009; Sharma et al, 2008 and Santosh, 2007). There are some important criteria that must be satisfied and accounted for in order to obtain a safe design and construction of earth dams. Stephens (2010) opined that it may become essential for a dam to be constructed on a river or stream to allow for off-season storage of vital water supplies. Although primarily for irrigation, such structures can be used, either separately or combined, for fish farming, stock and domestic water purposes, drainage sumps, ground water recharge, flood amelioration and conservation storage. FAO (2010), Adesiji and Jimoh (2012), Murthy *et al*, 2013) and Punmia *et al*, (2006) recommended that the planning, design and management of water resources requires knowledge of the time characteristics of flow, hence it is important to have a continuous hydrological record of stream flow data for many years at points of withdrawal and use.

Osnos (2011) reported that dam failures are rare but can cause immense damage including loss of life when they occur.

Overtopping due to insufficient discharge capacity of spillways is the cause of 52% of ruptures on embankment dams. Estimating the magnitude of design and peak floods in a river system is of utmost importance in any dam design. Dam sites that have no long periods of records, estimation of peak flow can be made by the historical method using physical indication of past floods, stream flow measurements and the use of flood discharge formulae. Zielinski (2011) agreed that dam safety assessment methodology of spillway capacity is based on design flood criteria associated with classification systems reflecting either hazard potential or consequences of dam failure. The spillway system is of critical importance in ensuring that the dam is safe and its safety can be compromised if the system is inadequate. Available information on dam failures indicates that overtopping resulting from spillway system inadequacy accounts for over 40% of all failures.

Sonuga (1990) and Ocheja (2016) reported that hydrologic decisions are made to evaluate values of key variables and parameters needed for design of water resources systems to make it perform adequately in terms of safety and provision of the expected benefits. However, the degree of reliability of the hydrologic data used in decision making process is of great significance. Unreliable data will seriously affect results. In Nigeria and indeed many parts of the developing countries, there are problems of data inadequacy, frequent gaps in the data available and nonexistent data at some development sites. Despite the problem of non-availability of needed data, factor of safety to maximum historical flood is the earliest method of estimating flood discharge. High flood marks across sectional area of the river is computed, water surface slope determined and flood discharge calculated by slope-area method.

Objective of this paper is to determine the peak flood of the river Ana on which the Naka dam is built using the direct stream flow measurement and the conventional unit hydrograph methods.

MATERIALS AND METHODS

Stream Flow Measurements

The Naka small earth dam which was constructed in 1986 is situated on latitude 7 º35ʾ N and longitude 8 º 12ʾ E. It is 40 Km from Makurdi, the Benue State capital. A stage gauge was installed on the upstream channel of the dam for two seasons both in 1997 (June 1997 – January 1998 a year after completion of the dam) and in 2015 (June – December) to enable stage measurements. At the station, stage readings were taken 3 times daily; at 6.00 am, 12.00 and 6.00 pm to obtain the average for a day. The velocities of flow at the gauging station were obtained using cross-section and slope method. Using the Manning Equation, this velocity was used in the computation of daily discharges at the station. The longitudinal profile of the stream cross section and bed at the upstream (for 2015) were obtained with leveling instrument and plotted. The profiles were used to compute the cross-sectional area and bed slope at the guage station. The cross-sectional area (A) for each stage of the stream as obtained was multiplied by the flow velocity to obtain the discharge of stream. The highest values for each month were used to plot the peak hydrograph at the spillways of the dam.

***Determining Unit Hydrograph*:**

This is a physically-based method. A synthetic unit hydrograph was derived based on known physical properties of the basin. The parameters required and used to sketch the hydrograph are:

Basin Lag, $t_{PR} = C' e^{m'} t_R$ (1)

Time to Peak, t_P (2)

Peak Discharge, $Q_P = q_{PR} (A)$ (3)

Base Width of hydrograph, $T = 5 (t_{PR} + t_R/2)$ in hours (4)

where

t_{PR} is lag in hours from centroid of net rain to hydrograph peak;

t_R is the time from the beginning to the end of rain and is taken to be 3.0 hrs;

e is exponential factor and is taken as 2.7183.

Lag of instantaneous unit hydrograph, $C' = (0.6/\sqrt{S_{st}})$

Slope of the main water course, $S_{st} = [n / (1/\sqrt{S_1} + 1/\sqrt{S_2} + 1/\sqrt{S_n})]^2$,

S_{st} is defined as the slope of a uniform channel having the same length as the longest watercourse and equal time of travel; S_1, S_2 etc. are the slopes of individual section of equal length, into which the main watercourse may be conveniently divided.

Rate of change of lag with storm duration, $m' = 0.212 / (L.L_{ca})^{0.36}$

L is the distance from station to catchment boundary measured along the main stream channel L_{ca} is distance from gauging station to centroid of catchment area, measured along the main stream channel to the nearest point, n is Manning's coefficient of roughness for the water course

RESULTS AND DISCUSSION

Discharge Measurement at upstream of dam

Figure 1 is the plot of the longitudinal profile of the stream cross section and the bed at the upstream, while Figure 2 is the cross sectional area and bed slope at the guage station.

S/No	MONTH	DISCHARGE (m^3/s)
1	Apr., 1997	0.000
2	Jun., 1997	4.260
3	Jul., 1997	1.811
4	Aug., 1997	0.959
5	Sept., 1997	5.538
6	Oct., 1997	4.367
7	Nov., 1997	3.621
8	Dec., 1997	0.959
9	Jan., 1998	0.107

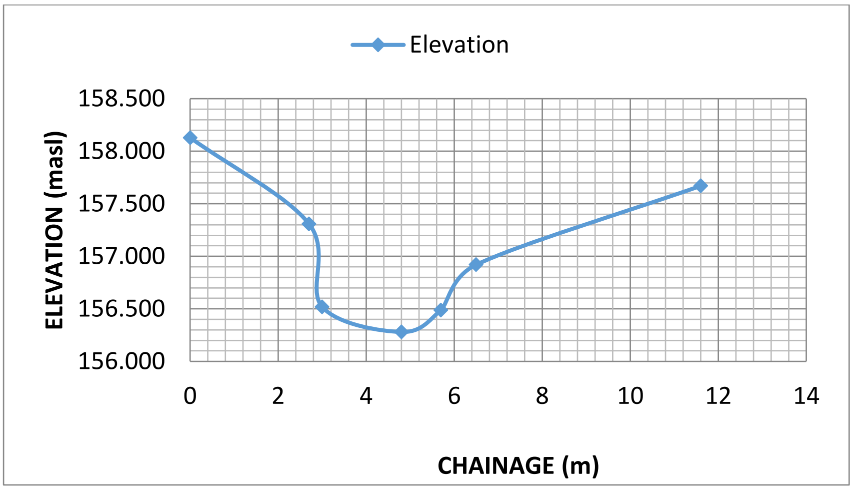

Fig. 1: Longitudinal Profile of Stream Cross-section at Upstream of Dam

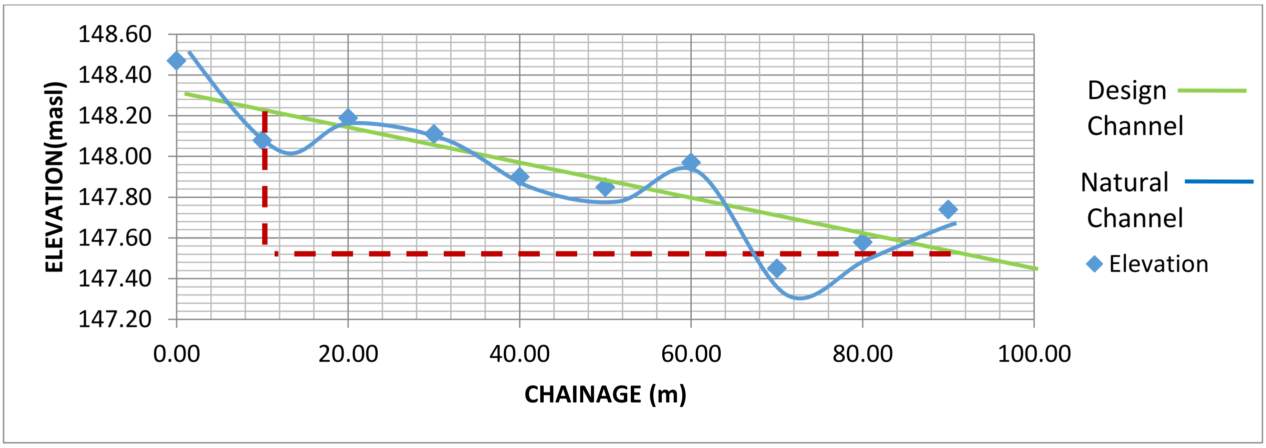

Fig 2: Longitudinal Slope of the Bed of the River at Upstream of Dam

Tables 1 and 2 are the peak monthly daily discharges at upstream of dam in 1997 and 2015 while Figures 3 and 4 are the hydrograph of peak monthly daily discharges at upstream of dam in 1997 and 2015 respectively. From the hydrograph, the peak monthly daily discharge at the upstream of the dam in 1997 is approximately 5.45 m^3/s and 2.05 m^3/s in 2015 respectively. Table 1: Peak Monthly Daily Discharge (m^3/s) at upstream of dam in 1997

Table 2: Peak Monthly Daily Discharge at Upstream of Dam in 2015

S/No	MONTH	PEAK DISCHARGE (m^3/sec)
1	Jun., 2015	0.278
2	Jul., 2015	0.554
3	Aug., 2015	1.993
4	Sept., 2015	2.048
5	Oct., 2015	0.996
6	Nov., 2015	0.831
7	Dec., 2015	0.111
8	Jan., 2016	0.000

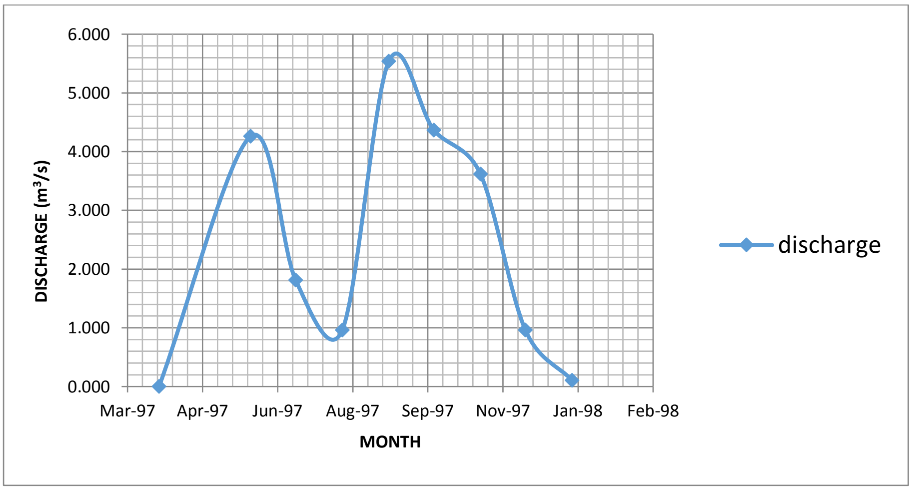

Fig. 3: Hydrograph of Peak Monthly Daily Discharge at Upstream of Dam in 1997

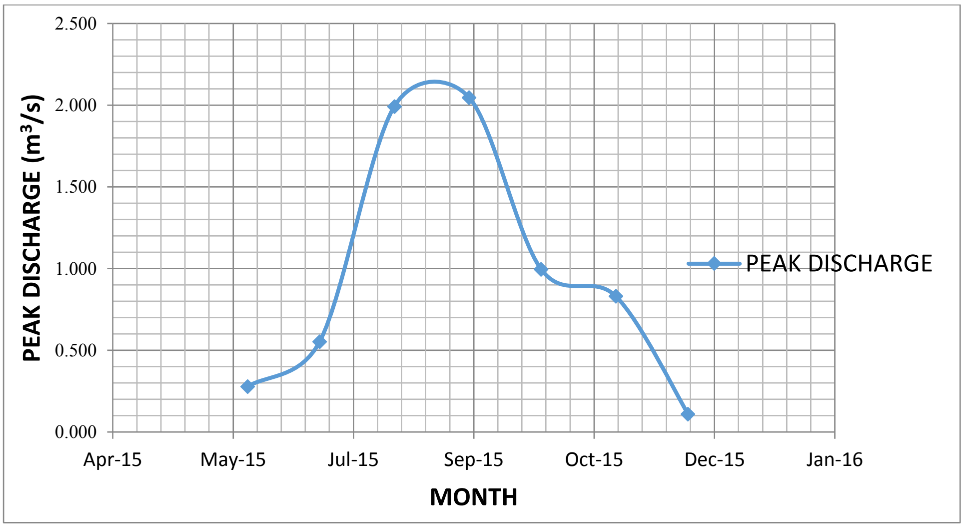

Fig. 4: Hydrograph of Peak Monthly Daily Discharge at Upstream of Dam in 2015

The presence of a reliable historical structure along the path of a stream is a very useful tool in the measurement of peak flood in the stream if adequate hydro-meteorological are not available. The peak floods of 5.45 m^3/sec obtained from flow records of 1997 and 2.05 m^3/sec in 2015 are rather low. This is as a result of low rainfall within the periods.

The Unit Hydrograph of the upstream of the dam

The following parameters were obtained for the catchment.
i) Catchment area, A, in square miles = 3.861 mi^2.
ii) Distance from station to catchment boundary, L =2.2 m
iii) Distance from gauging station to centroid, L_{ca} =1.0 m
iv) Slope of main watercourse, S_{st} = 0.0076
Also using appropriate formulae as indicated, the following parameters for the synthetic hydrograph were obtained.
a) Basin Lag, t_{PR} = 24.22 hrs
b) Time to Peak, t_P = 25.72 hrs
c) Peak Discharge, $Q_P = q_{PR}$ (A) = 95.30 m^3/s
d) Base Width of hydrograph, T = 5 (t_{PR} + t_R/2) = 185.40 hrs
f) q_{PR} = 9.07 m^3/s
Based on these parameters, inflow/unit hydrograph was developed (Table 3 and Figure 5). Synthetic Unit Hydrograph method based on known physical properties of the basin gave rise to the development of inflow/Unit Hydrograph with a peak flood of 9.08 m^3/sec.
Apart from the year 2015 when as a result of very low rainfall, the peak flow was low giving rise to a spillway size of 2.45 m, all the other peak floods had spillway sizes bigger than the 3.25 m which was provided at the time of the construction of the dam in 1986. This was why the dam was overtopped almost immediately after construction.
In the process of repairing the dam in 1987 after the rains, a second spillway was constructed to provide auxiliary services to the main one. The size of the second spillway was 7.44 m . This brought the size of combined spillways to 10.69 m

Table 3: Development of Inflow/Unit Hydrograph

Time Ratio	**Discharge Ratio**	**Time, T (hrs)**	**Discharge, Q (m^3/s) Catchment (10.5 km^2)**	**Discharge/Unit Area (m^3/s/km^2)**
0.0	0	0	0	0
0.2	0.075	5.14	7.15	0.681
0.4	0.28	10.29	26.69	2.542
0.6	0.6	15.43	57.18	5.446
0.8	0.89	20.58	84.82	8.078
1.0	1	25.72	95.30	9.076
1.4	0.75	36.01	71.48	6.808
1.8	0.42	46.30	40.03	3.812
2.0	0.32	51.44	30.50	2.905
2.6	0.13	66.87	12.39	1.180
3.0	0.075	77.16	7.15	0.681
4.0	0.018	102.88	1.72	0.164
5.0	0.004	128.60	0.38	0.036

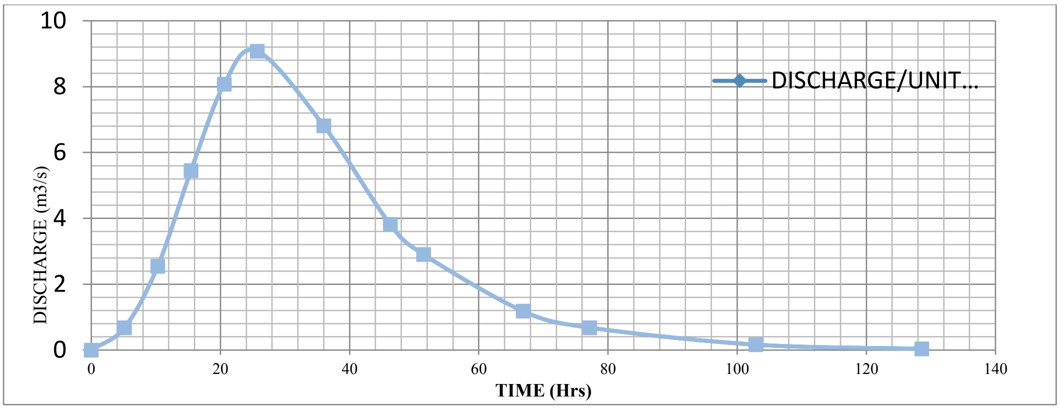

Figure 5: Unit Hydrograph of the synthetic method

CONCLUSION

1. The Naka small earth dam was constructed without adequate hydrological data which led to failure with attendant loss of lives and property.

2. Availability of adequate hydro meteorological data and knowledge of physical properties of the dam sites are essential in determination of peak flood in a dam construction.
3. Sample flow measurements on a stream for a year or two prior to commencement of dam construction and using result obtained to determine peak flood is dangerous as the results obtained may not be true reflection of actual situation at the site.
4. Historical method of determination of peak flood of stream may be helpful in the absence of a reliable data if there is a reliable permanent structure along the path of the stream.

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DETERMINATION OF OXYGEN DEFICIT ALONG NWORIE STREAM USING DISSOLVED-OXYGEN MODEL OF FINITE ELEMENT

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ABSTRACT

The increase of Oxygen Deficit in rivers used for irrigating agricultural land, aquaculture and domestic purposes is of great concerns to Nigerian watershed. To determine this effect along the Nworie River, physiochemical and biological water quality analysis was conducted at three random locations namely: Amakohia bridge road where biodegradable and non biodegradable wastes are discharged; Assumpta, Holy Ghost college road where municipal waste and sewage are discharged into the river; and Umezurike Hospital road where household and medical wastes are discharged. The average dissolved oxygen from the lab experimental result was used to compute the oxygen deficit at the discharge point using dissolved – oxygen model of finite element by applying Galerkin's weighted residual method approach. The oxygen deficit result at the five discretized nodes includes: 2.528 mg/l at first node, 2.49789 mg/l at the 2nd node, 2.3953mg/l at the 3rd node, and 2.3252 at the 4th node and 2.2516 mg/l at the end node. The result in this research is invaluable for water resources and irrigation engineers in predicting the effect of water pollution on the downstream users.

***Keywords*:** Discretize, Oxygen Deficit, Dissolved Oxygen, wastewater, downstream,

INTRODUCTION

It is increasingly being recognized that the issues of wastewater management and water quality have cross-linkages with a range of other water- and non-water issues, not least in respect of the water, energy and food nexus. Organisation for Economic Co-operation and Development acknowledged that wastewater management clearly plays a role in achieving future water security in a world where water stress will increase (OECD, 2012). This is accompanied by the realisation that the focus on drinking-water and sanitation without due attention being paid to the end products of water and sanitation provision (i.e. wastewater) may have exacerbated some of the water quality problems seen globally. It is therefore crucial that wastewater management and water quality stop being the 'poor relations' and receive attention in their own right. According to the UNEP/UNHABITAT document, waste water is referred to as "Sick Water". Thus, wastewater is defined as "a combination of one or more of:

- domestic effluent consisting of blackwater (excreta, urine and faecal sludge) and greywater (kitchen and bathing wastewater); .
- water from commercial establishments and institutions including hospitals;
- industrial effluent, stormwater and other urban run-off; agricultural, horticultural and aquaculture effluent, either dissolved or as suspended matter" (Corcoran *et al*., 2010)

These definitions clearly describe the nature of Nworie stream in Owerri today. The city around Nworie river that is Owerri and its environs have experienced immense population, agricultural and industrial growth since it became the capital of Imo state in 1976. This growing population and industrial activities have caused, and will continue to cause, great stresses on water resources in the area (Ibe *et al*., 1998).

In 2014, Okore, *et al*., investigated the Impact of disposal of hospital waste into Nworie River in Imo State Nigeria. It was discovered from the research that hospital wastes pose severe effects on the environment and health of the surrounding neighbourhood, and to agricultural users who make use of it for irrigation and for aquaculture downstream.

Wastewater discharge from sewage and industries are major component of water pollution, contributing to oxygen demand and nutrient loading of the water bodies, promoting toxic algal blooms and leading to a destabilized aquatic ecosystem (Morrison *et al*., 2001; DWAF and WRC, 1995). However, with these challenges enumerated there is need to determined the level of BOD and dissolved oxygen in the stream from the point of effluent discharge to the downstream along the river. Thus, the aim of this paper is to determine the physiochemical and biological parameters of the river and using one of these parameters at the point of discharge to determine the effects downstream by applying Galerkin's weighted residual finite element method.

Materials and Methods

***Area of Study*:**
From geographical area survey of the Nworie River Figure 1, it is shown to be a first order stream that runs about a 5km course across Owerri metropolis in Imo State, Nigeria before emptying into another river, the Otamiri River (Umunnakwe, *et al*., 2011). Its watershed is subject to intensive human and industrial activities resulting in the discharge of a wide range of pollutants. The river is used for various domestic applications by inhabitants of Owerri (Acholonu *et al,*. 2008). When the public water supply fails, the river further serves as a source of direct drinking water, especially for the poorer segment of the city. Owerri, the capital of Imo State of Nigeria lies between 4^0 55'N and 5^0 35'N, and between 6^0 35'E and $7^0$30'E parallels. It falls within the rainforest zone of 2290mm per annum, relative humidity of 55-85% and temperature of 27^0C.

Sample Collection:
A reconnaissance visit to the river was carried out after which three sample stations were established for comparative analysis. The first Station was taken to be Amakohia bridge road where biodegradable and non biodegradable wastes are discharged. Station two is the Assumpta, Holy Ghost college road where municipal waste and sewage are discharged into the river. Station three is at Umezurike Hospital road where household and medical wastes are discharged. Samples of water were collected in 4 litre gallon container from these stations during the rainy season in the month of June. These samples were labelled, packed inside an ice cooled container and transported to Federal University of Technology, Owerri (FUTO) and Imo State University (IMSU) laboratories for analysis. Standard analytical methods were used for all the physiochemical and biological analysis (APHA, 1992).

Methods

Physiochemical and Biological Analysis
In situ measurement of pH, temperature and conductivity for water was taken in the field during sampling with pH meter (Suntex model TS-2). Other parameters were analysed in the laboratory with the use of Multiparameter bench photometer (Hanna HIDR 83200), using their various specific methods. Statistical tools such as mean, standard deviation and variance were used to analyse the data obtained to ascertain how representative and close the data obtained were. Two way analysis of variance were used to show the significant different between the samples and the stations.

Galerkin Weighted Residual (GWR) Analysis
(GWR) method of finite element was applied in determining the level of oxygen deficit along the River, and described with WRM approach as:

$$\int_o^L \left(\Psi \frac{d^2Q}{dx^2} + \Psi F\right) dx = 0 \qquad (1)$$

This equation can be written or express as

$$\int_R (\text{Basic function})^T (\text{Residual})\, dR = 0 \qquad (2)$$

Where, R = region of interest or domain, dR = derivative of R and T = transpose (in matrix sense). For one dimensional model, Equation (2) becomes:

$$\int_R N_k^{e^T} \left(\frac{d^2\phi}{dx^2} + F\right) dx = 0 \qquad (2b)$$

where $N_k^{e^T}$ transpose of the weighing function $\left(\begin{array}{c}\text{same as the transpose of the basis function for} \\ \text{element, e and node, k}\end{array}\right)$ $F = \text{constant}; \ \phi = \text{field variable};$
$e = \text{element number}; \text{ and } T = \text{transpose}$

The Dissolved-Oxygen Model of the Nworie Stream is given as proposed by Streeter and Phelps in 1925. The model predicts changes in the deficit, D as a function of Biological Oxygen Demand (BOD) exertion and stream reparation. The rate of change in the deficit is given as

$$\frac{dD}{dt} = K_1 L_t - K_2 D \qquad (3a), \quad \text{Or}$$

$$\frac{dD}{dt} + K_2 D - K_1 L_t = 0, \qquad D(0) = D_0 \qquad (3b)$$

The application of the Galerkin's weighted residual finite element method to Equation (3b) yields:

$$\int_0^L N^T \left(\frac{dD}{dt} + K_2 D - K_1 L_t\right) dt = 0$$

Or

$$\int_0^L N^T\left(\frac{dD}{dt}\right)dt + \int_0^L N^T(K_{2.}D)\,dt - \int_0^L N^T(K_1L_t)\,dt = 0 \qquad (4)$$

Where the upper limit of the integration, L stands for length of an element and N^T is the transpose of the basis function. Thus, evaluating the individual terms of equation (4) using linear interpolation (basis) function results as follows:

1st Term of Equation (4)

$$\int_0^L N^T\left(\frac{dD}{dt}\right)dt \qquad (5)$$

The linear basis function is :

$D = [N]\{D_i\} = \left[\left(1-\frac{t}{L}\right) \quad \frac{t}{L}\right].\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix}$ and

$$\frac{dD}{dt} = \frac{1}{L}[-1 \quad 1]\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix}$$

Where D is the continuous Variable and D_i is the piecewise continuous equivalent.

Substituting the linear basis function as approximate in Equation (5a) gives:

$$\int_0^L N^T\left(\frac{dD}{dt}\right)dt$$

$$= \int_0^L \begin{pmatrix} 1-\frac{t}{L} \\ \frac{t}{L} \end{pmatrix}\frac{1}{L}[-1 \quad 1]\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix}.dt$$

$$= \int_0^L \begin{bmatrix} -\left(1-\frac{t}{L}\right) & \left(1-\frac{t}{L}\right) \\ -\frac{t}{L} & \frac{t}{L} \end{bmatrix}\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix}.dt$$

$$= \frac{1}{2}\begin{bmatrix} -1 & 1 \\ -1 & 1 \end{bmatrix}\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix}$$

2nd Term of Equation (4)

$$\int_0^L N^T(K_{2.}D)\,dt = K_{2.}\int_0^L N^T D.dt \qquad (6)$$

$$K_{2.}\int_0^L N^T D.dt = K_{2.}\int_0^L \begin{Bmatrix} 1-\frac{t}{L} \\ \frac{t}{L} \end{Bmatrix}\left[\left(1-\frac{t}{L}\right) \quad \frac{t}{L}\right].\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix}.dt$$

$$= K_{2.}\int_0^L \begin{bmatrix} \left(1-\frac{2t}{L}+\frac{t^2}{L^2}\right) & \left(\frac{t}{L}-\frac{t^2}{L^2}\right) \\ \left(\frac{t}{L}-\frac{t^2}{L^2}\right) & \frac{t^2}{L^2} \end{bmatrix}.\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix}.dt$$

$$= \frac{LK_2}{6}\int_0^L \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}.\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix}.$$

3rd Term of Equation (4)

$$\int_0^L N^T(K_1L_t)\,dt = K_1L_t\int_0^L N^T\,dt \qquad (7)$$

$$K_1L_t\int_0^L N^T\,dt = K_1L_t\int_0^L \begin{bmatrix} 1-\frac{t}{L} \\ \frac{t}{L} \end{bmatrix}dt$$

$$= \frac{L_tK_1L}{2}\begin{Bmatrix} 1 \\ 1 \end{Bmatrix}$$

Combining the 1st , 2nd and 3rd terms of Equation (4) gives the element equation:

$$\frac{1}{2}\begin{bmatrix} -1 & 1 \\ -1 & 1 \end{bmatrix}\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix} + \frac{LK_2}{6}\int_0^L \begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}.\begin{Bmatrix} D_1 \\ D_2 \end{Bmatrix} = \frac{L_tK_1L}{2}\begin{Bmatrix} 1 \\ 1 \end{Bmatrix} \qquad (8)$$

Assemblage of the element equations (Equation 8) was carried out and also some selected distance discretized along the stretch of the stream from the point of discharge.

Node = 1 2 3 4 5

$$\frac{1}{2}\begin{bmatrix} -1 & 1 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 & 0 \\ 0 & -1 & 0 & 1 & 0 \\ 0 & 0 & -1 & 0 & 1 \\ 0 & 0 & 0 & -1 & 1 \end{bmatrix}\begin{Bmatrix} D_1 \\ D_2 \\ D_3 \\ D_4 \\ D_5 \end{Bmatrix} + \frac{LK_2}{6}\begin{bmatrix} 2 & 1 & 0 & 0 & 0 \\ 1 & 4 & 1 & 0 & 0 \\ 0 & 1 & 4 & 1 & 0 \\ 0 & 0 & 1 & 4 & 1 \\ 0 & 0 & 0 & 1 & 2 \end{bmatrix}\begin{Bmatrix} D_1 \\ D_2 \\ D_3 \\ D_4 \\ D_5 \end{Bmatrix} - \frac{K_1 L}{2}\begin{Bmatrix} L_t + L_{2t} \\ L_{it} + L_{(i+1)t} \\ L_{(i+1)t} + L_{(i+2)t} \\ L_{(n-1)t} \end{Bmatrix} = 0 \quad (9)$$

Where:

L= length of an element, t = time and $L_t = L_0 e^{-k_1 t}$ $L_{(i+1)t} = L_0 e^{-k_1 (i+1)t}$

Expanding the Equation (9) to get the first nodes, interior nodes, the last two nodes and generating recursive equations which would be solved without matrix reduction (Gaussian elimination) technique.

1st two Nodal Equation

$$\left(-\frac{1}{2} + \frac{LK_2}{3}\right) D_1 + \left(\frac{1}{2} + \frac{LK_2}{6}\right) D_2 = \frac{K_1 L}{2} . L_t \quad (10)$$

Interior Nodal Equation

$$\left(-\frac{1}{2} + \frac{LK_2}{6}\right) D_i + \left(\frac{2LK_2}{3}\right) D_{i+1} + \left(\frac{1}{2} + \frac{LK_2}{6}\right) D_{i+2} = \frac{K_1 L}{2} . (L_{it} + L_{(i+1)t} \quad (11)$$

Where: i assumes the values of 1,2,3 and so on for the 1st, 2nd and 3rd rows of the interior nodes.

Last two Nodal Equations

$$\left(-\frac{1}{2} + \frac{LK_2}{6}\right) D_{n-1} + \left(\frac{1}{2} + \frac{LK_2}{3}\right) D_n = \frac{K_1 L}{2} . L_{(n-1)t} \quad (12)$$

Oxygen deficit, D = Saturation DO – Actual DO. However, the saturation DO value for fresh water depends upon the temperature and total dissolved salts present in it; and its value varies from 14.62 mg/L at 0° C to 7.63 mg/L at 30° C, and lower DO at higher temperatures. The relationship between saturation DO (S.DO) and temperature of the stream is given as:

$$\frac{0 - 30}{T - 30} = \frac{14.62 - 7.63}{S.DO - 7.63} \quad (13)$$

Therefore, putting Temperature, (T) 24°C, BOD 3.30mg/l, actual DO 6.5 mg/l, deoxygenation and reaeration constant as is 0.26 and 0.42 respectively gave S.DO as:

$$\frac{0 - 30}{24 - 30} = \frac{14.62 - 7.63}{S.DO - 7.63},$$

$$\therefore\ S.DO = 9.028 mg/l$$

Thus, oxygen deficit 'D' at that point = Saturation DO – Actual DO

$$\therefore D = (9.028 - 6.5) mg/l = 2.528 mg/l$$

Considering the linear element at the first node D_1 = D = 2.528mg/l, we proceed to obtain the value of L_t at node 2 and taken time t at the respective nodes:

$L_t = L_0 e^{-k_1 t} = 3.30 e^{-0.26(0.25)} = 3.09232$

Next is to evaluate Equation (10) in order to obtain the value of D_2, that is,

$$\left(-\frac{1}{2} + \frac{LK_2}{3}\right) D_1 + \left(\frac{1}{2} + \frac{LK_2}{6}\right) D_2 = \frac{K_1 L}{2} . L_t$$

$$where\ L = \frac{1}{4} = 0.25$$

$$\left(-\frac{1}{2} + \frac{0.25\ (0.42)}{3}\right) 2.528 + \left(\frac{1}{2} + \frac{0.25\ (0.42)}{6}\right) D_2 = \frac{0.25\ (0.26)}{2} . 3.09232$$

$$D_2 = \frac{1.2760}{0.51083} = 2.49789$$

For the 1st interior nodes (1,2 and 3), Equation (11) is evaluated as:

$$\left(-\frac{1}{2} + \frac{LK_2}{6}\right) D_i + \left(\frac{2LK_2}{3}\right) D_{i+1} + \left(\frac{1}{2} + \frac{LK_2}{6}\right) D_{i+2} = \frac{K_1 L}{2} . (L_{it} + L_{(i+1)t}$$

Where i = 1 and the term $(L_{it} + L_{(i+1)t}$ on th right hand side equals:

$$(L_t + L_{2t} = L_0 (e^{-k_1 t} + e^{-k_1 2t})$$

$$= 3.3(e^{-0.26(0.25)} + e^{-0.26(0.5)}) = 5.990061$$

Substituting the values of D_1 and D_2 into Equation (11) gives:

$$\left(-\frac{1}{2}+\frac{0.25\,(0.42)}{6}\right) * 2.528 + \left(\frac{2(0.25)(0.42)}{3}\right)*2.49789$$
$$+\left(\frac{1}{2}+\frac{(0.25)(0.42)}{6}\right) * D_3 = \frac{0.25\,(0.26)}{2} * 5.99$$
$$= -0.4825(2.528) + 0.07(2.498) + (0.5175)D_3$$
$$= 0.19468$$
$$\therefore D_3 = \frac{1.23959}{0.5175} = \mathbf{2.3953}$$

For the last two nodes in Equation (12) is evaluated where i = 4, 5 and the term $L_{(n-1)t}$ for n = 4

$$L_{(n-1)t} = L_{(4-1)t} = L_{3t} = L_0(e^{-k_1 3t} = 3.3e^{-0.26(0.75)}) = 3.3(0.82283) = 2.7153$$

Substituting it into the Equation (12) gives: $\left(-\frac{1}{2}+\frac{0.25\,(0.42)}{6}\right)D_3 + \left(\frac{1}{2}+\frac{0.25\,(0.42)}{3}\right)D_4 =$

$$\frac{0.25\,(0.26)}{2}.\,2.7153$$
$$= -0.4825(2.3953) + 0.5350D_4 = 0.08825$$
$$\therefore D_4 = \frac{1.24398}{0.5350} = 2.3252\ mg/\boldsymbol{l}$$

For n = 5,

$$L_{(n-1)t} = L_{(5-1)t} = L_{4t} = L_0(e^{-k_1 4t} = 3.3e^{-0.26(0.75)}) = 3.3(0.77105) = 2.5444$$

Substituting it into Equation (12) gives

$$\left(-\frac{1}{2}+\frac{0.25\,(0.42)}{6}\right)D_4 + \left(\frac{1}{2}+\frac{0.25\,(0.42)}{3}\right)D_5$$
$$= \frac{0.25\,(0.26)}{2}.\,2.5444$$
$$= -0.4825(2.3252\,) + 0.5350D_4 = \mathbf{0.082693}$$
$$\therefore D_5 = \frac{\mathbf{1.2046028}}{\mathbf{0.5350}} = \mathbf{2.2516}\ \boldsymbol{mg/l}$$

RESULTS AND DISCUSSION

Results

The results of the physiochemical, biological and GWR analysis are presented in Tables 1 and 2 respectively showing the three sample locations, the WHO standards for parameters, the mean concentrations and their standard deviations.

DISCUSSION

Tables 1 showed the concentrations of the physicochemical and biological variables from surface water samples along Nworie River. For the surface water, the mean of the measured parameters were within the WHO standard limits with the exception of turbidity, color of water, TSS; dissolved oxygen, nitrate, nitrite and calcium concentrations that were observed to exceed the WHO limits for water samples. The exceeded mean concentrations were given respectively to be 114.83 mg/l as in turbidity, 262.67 NTU as in TSS, 5.9mg/l as in Dissolved Oxygen, 348.40 mg/l as in nitrate, 5.269 mg/l as in nitrite and 90 mg/l in calcium. From the recorded exceeding values during water analysis, it was observed that the second sample location (Assumpta- Holy Ghost college road) had the highest concentrations in turbidity 146.3 NTU, colour of water 640 PCU, conductivity 141 µs/cm, TSS 368 mg/l and Nitrate 520.30mg/l respectively).This is an indication of increased water pollution which reduces the dissolved oxygen of the river thus endangering those aquatic species requiring specific oxygen content for survival. Besides, the loaded rivers are murky or clouded and thus reduce light penetration.

The results of the oxygen deficit at the first node which is the point of effluent discharge gave 2.528 mg/l. As pollutants moves a distance of one fourth of the distance under consideration as our linear global domain element, reoxygenation occurs. This brings about a reduction in the oxygen deficit along the downstream of the river with the following results at the respective nodes: 2.49789 mg/l at the 2nd node, 2.3953mg/l at the 3rd node, and 2.3252 at the 4th node and 2.2516 mg/l at the end node. The dissolved oxygen along the river was calculated by subtracting the value of each oxygen deficit from the saturation dissolved oxygen (S.DO) of 9.028 mg/l. The results were observed to be increasing as the oxygen deficit reduces. However, this is quite different from the DO of the three sample analyzed at the laboratory. This observation is so, due to other source of effluent into the river thereby reducing the dissolved oxygen at some point and increasing at another point as seen in the three samples analyzed.

CONCLUSION

In conclusion this research has demonstrated how Galerkin's weighted residual finite element method can be used in determining or predicting the effect of effluent discharge downstream of Nworie River. Thus this research is recommended for predicting the effect of sewage discharge downstream of a river. In water resources engineering and irrigation engineering, this study helped in checking the consequences of water pollution at the downstream users for water resources planning and development. To determine or predict these effects, Galerkin's weighted residual finite element modeling becomes essential.

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Figure 1: Area Survey of Nworie Stream (*Source: Google Earth*)

Table 1: The physiochemical and biological result of Nworie water analysis is given below

Parameter	WHO Standard	Mean	Range	Amakohia bridge road	Assumpta, Holy Ghost college road	Umezurike Hospital road	Standard Deviation
pH	6.5-8.5	7.133	7.1-7.3	7.1	7.0	7.3	0.0694
Alkalinity (mg/l)	200	10	5-15	15.0	10.0	5.0	5.0
Temperature	ambient	24.67	24-25	24.0	25.0	25.0	0.577

Colour of Water in PCU	500	568.67	431-640	431	640	635	119.249
Conductivity (µs/cm)	100	111.3	60.5-141	60.5	141.0	132.50	44.23
TSD(mg/l)	250	53.667	40-73	40	48	73	17.21434
turbidity NTU	50	114.833	5-65	63.50	146.30	134.70	44.83273
BOD(mg/l	40	3.233	2.9-3.5	3.30	3.50	2.90	0.305505
DO(mg/l)	4.0	5.9	5.4-6.5	6.50	5.80	5.40	0.556776
TSS (mg/l)	50	262.667	85-368	85	368	335	154.746
Nitrate(mg/l)	40	348.418	259.15-520.30	265.8	520.30	259.155	148.891
Nitrite (mg/l)	1.0	5.269	3.04-6.384	6.384	6.384	3.04	1.931
Sulphate (mg/l)	250	5.6	1.8-10	1.8	10	5	4.133
Hardness (mg/l)	150	53.667	39.5-64.2	39.50	57.30	64.20	12.74454
Iron(Fe)(mg/l)	0.3	0.1967	0.12-0.25	0.22	0.12	0.25	0.0681
Manganese mg/l	0.5	0.5	0.2-0.8	0.2	0.5	0.8	0.3
Calcium mg/l	70	90	80-100	100	90	80	10
Zinc mg/l	5	0.5533		0.55	0.43	0.68	0.12503
Copper mg/l	1.0	0.3333	0.2-0.5	0.2	0.3	0.5	0.152753
Chlorine (mg/l)	200	11.23333	9-11.5	9	13.2	11.5	2.11266

Table 2: Determined Oxygen deficit along Nworie River using GWR finite element method

Node No / **Parameter**	1	2	3	4	5
Oxygen Deficit (mg/l)	2.528	2.49789	2.3953	2.3252	2.2516
Dissolved Oxygen	6.500	6.53011	6.6327	6.7028	6.7764

DETERMINATION OF WATER USE EFFICIENCY OF SELECTED CROPS IN A DRIP IRRIGATION SYSTEM

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ABSTRACT

Water use efficiency estimation is one of the best technical options that can lead to a more effective use of water for optimal crop production during irrigation season. In this research work, water use efficiency model developed was employed by using the crop evapotranspiration model developed from a hydraulic weighing lysimeter and water supply model from a drip irrigation system established at National Centre for Agricultural Mechanization, Ilorin, Kwara State. In order to address the challenge of achieving optimum yield, water use efficiency model was maximized in this research work so as to use water more effectively at various levels of the water yield pathway for the growth of selected crops, namely cowpea and maize. This paper illustrates how water use efficiency model was maximized so as to use water more effectively at various levels of growth of crops. The amount of water supplied during irrigation of cowpea in a plot of 50m^2 was 0.75 x 10^{-3} ℓ/s while that of maize was 0.77 x 10^{-3} ℓ/s. Water use efficiency determined for irrigating cowpea ranged from 33 % to 94 % and that of maize ranged from 58 % to 96 % respectively. By maximizing water use efficiency model, the optimum water supplied during irrigation of cowpea ranged from 2.51 x 10^{-4} ℓ/s to 7.24 x 10^{-4} ℓ/s while that of maize ranged from 4.47 x 10^{-4} ℓ/s to 7.38 x 10^{-4} ℓ/s. For an optimum crop growth during irrigation of selected crops, the crop water demand was then used to determine the irrigation water value of the crops at different stages of growth.

***Keywords**: Drip, Irrigation, Lysimeter, Evapotranspiration, Crop water demand and Water use efficiency.*

INTRODUCTION

Cereals have been considered as efficient user of water in terms of total dry matter production as outlined by researchers like Ayotamuno *et al*. (2000). Among these cereals are maize and cowpea, while maize is considered as potentially the highest yielding grain crop of all cereals as confirmed by Ayotamuno *et al*. (2000). For several years now, much research has been carried out on a variety of problems associated with the role of water in aiding growth and enhancing the yields of plants. For example, Ayotamuno *et al*. (2000) outlined some factors that limit crop growth such as soil type, nutrient content and climate, but observed that water has been the principal yield limiting factor. Various researchers like Stone et al.(2001) have revealed that water as the most important single factor limiting the production of crops has received global attention in the efforts to increase its production. Therefore a good knowledge of water requirement is needed for good water management in crop production. Nwa (1994) also affirmed that knowledge of water requirements at the critical stages of crop growth is essential in the supply of water at the appropriate time and amount to crops in order to avoid serious reduction in crop yield especially under conditions of limited water supply.

To estimate the amount of water required for crops, it is necessary to know the amount supplied by rainfall or irrigation, the amount used in evapotranspiration and the amount lost to deep percolation. One of the practicable methods for measuring evapotranspiration rate and determining the deep percolation is by using lysimeter which has been described as probably the best for determining the actual crop water requirement (Nwa, 1994).

Crop evapotranspiration (E_C) is commonly measured with lysimeters installed in fields (Benli *et al*., 2006; Miranda *et al*., 2006; Williams and Ayars, 2005). The use of lysimeter for the determination of crop evapotranspiration (E_C) at various growing stages and computation of reference crop evapotranspiration (ET_o) by making use of developed empirical relationship would help to determine crop coefficients at various stages of crop growth. This will ultimately help to determine the actual crop water requirement at various stages of growth (Allen *et al*., 1994; Nwa, 1994).

A number of crops are being grown under irrigation in the country at the moment and as irrigation facilities expand, additional crops will be advantageously grown under irrigation (Duru and Adewumi, 1980). In practicing irrigation in an environment where water supplies are limited, drip irrigation technology has been developed for agriculture as a technique to improve the efficiency of water delivered to plants. This technique involves delivering the quantity of water the plants actually need into the root zone, and relies on horizontal as well as vertical movement through the soil to distribute the water.

There is a need for proper use of water in the effort to increase food and fiber production under rain fed or irrigated condition. There is also the need for accurate measurement of crop water use, so that water can be justifiably applied to the crop at a given point in time. In order to determine the amount of water required at the critical stages of a crop growth, a clear knowledge of its crop water requirement is essential. By achieving this, there would be available crop water use data to practice irrigation especially during the off-season planting period. The estimated crop evapotranspiration value can be used on daily, decade (ten day) and monthly basis for the farmers as well as researchers who are practicing irrigation in order to give them good yield. It is also applicable during the period of drought in the rainy season. This is achievable by determining the area of irrigation and the value of evapotranspiration estimated from the lysimeter at any given period of growth to get the volume of water needed for the irrigation of the area concerned.

In order to meet water demands for crops such as cowpea and maize, irrigation water supply needs to be improved upon by increasing its efficiency (Stone *et al.*, 2001). The implication of this is that irrigation water losses need to be reduced through the introduction of appropriate technology and improved water management and cultural practices. The adequate transportation, distribution and optimal use of water at appropriate time and in proper amount through drip irrigation systems would help to reduce the risk of crop failure and to increase production of the crop (Adeogun, 2008).

The use of a simple drip irrigation system for adequate water supply and management of crop water demand so as to ensure uniformity of application by the system on the field is highly appreciated for adequate yield of the crop. Also adequate irrigation practices through timely and proper application of water to the crop by a simple and well developed drip irrigation system would play a key role in achieving good water use efficiency.

Stone *et al*. (2001) affirmed that measurement of water use efficiency by crops is important in developing strategies and decision making for use by farmers and researchers for irrigation management under limited water condition. The limited water supply and competitive demand for it makes it imperative for researchers to have a better understanding of actual water requirements of crops. This will lead to the knowledge of evapotranspiration (ET) which is playing an increasingly important role in irrigation science, since crop yields are known to be highly dependent upon the availability of water at certain stages of growth.

There is a need for more effective use of water for optimal crop production through the use of drip irrigation system that is affordable, simple to install, easy to operate and maintain, so that farmers can be encouraged to engage in irrigation practices with ease and use the available water efficiently. The development of affordable drip irrigation systems that supply appropriate amount of water to the field during irrigation is a good agricultural option that can lead to a more effective use of water for optimal crop production. More accurate estimates of crop water use can be made possible through the use of hydraulic weighing lysimeter in order to meet crop water demand at any stage of growth (Adeogun*, et al*., 1998).

The knowledge of water requirements at the various stages of crop growth through the use of lysimeter makes it possible to manage rainfall, even with its inherent uncertainties in amount, duration and distribution, to the best advantage of the crop. However, under irrigation conditions, it is particularly important to know the water requirements at the critical stages of crop growth so that water could be provided at these stages to avoid serious reduction in crop yield under conditions of limited water supply.

The objective of this research was to determine water use efficiency for maize and cowpea in a drip irrigation system.

METHODOLOGY

Site Description

The Drip Irrigation System (DIS) was developed to provide an efficient application of water to crops grown during dry period. This system was installed on half an hectare of land on the lysimeter research field at the National Centre for Agricultural Mechanization (NCAM), Ilorin, Nigeria. The soil of the site was sandy clay with a natural slope of 0.2 %.

A buffer area of 100 m x 100 m was used on the lysimeter research field, which was planted with crop as on the lysimeter area of 3.24 m^2 (Adeogun *et al.*, 1998). The lysimeter was located at the centre of the field with a uniformly cropped surface to provide a reasonable fetch. Daily manometer readings (x) were obtained from the weighing sensor in the lysimeter compartment on the research field and the crop evapotranspiration (E_C) was determined.

The estimation of water use efficiency of selected crops for this research involved the use of a developed drip irrigation system and the estimation of crop evapotranspiration (E_C) through the use of hydraulic weighing lysimeter. The crop evapotranspiration (E_C) for the selected crops were determined directly from the measurement carried out on the hydraulic weighing lysimeter at NCAM, Ilorin. The manometer values obtained daily were averaged over a ten-day period and used to compute the crop evapotranspiration values from the E_C model equation.

Model Description

Water use efficiency is defined as the fraction of the total water made available by both rainfall and irrigation that is used by the crop for evapotranspiration (Bos *et al.*, 2005).

$$\xi_W = \frac{\omega_C}{\phi_S} \tag{1}$$

where : ξ_W is the Water Use Efficiency, ω_C is the Crop Water Demand and ϕ_S is the Water Supply

The functional relationship between the crop evapotranspiration measured on the hydraulic weighing lysimeter and the incoming and outgoing water flux is represented in the equation below (Adeogun *et al.*, 1998)

$$E_C \alpha f(P_t, I, R_o, D_w, \Delta W) \quad (2)$$

where: E_C = crop evapotranspiration, P_t = precipitation, I = irrigation, R_o = surface runoff, D_w = drainage water, Δ W = change of water content and x = manometer value.

Adeogun *et al.*, (1998) developed a calibration equation for determining the E_C using hydraulic weighing lysimeter. The equation is expressed as:

$$E_C = 8.6x - 0.7 \quad (3)$$

$$x = f(P_t, I, D_w) \quad (4)$$

Manometer readings were taken after irrigation or precipitation and at the end of the drainage period which is usually at the end of a 24hr period. The difference between manometer readings (x) was then substituted in Eqn (3) and the water depth used within that period was determined. This is the amount of crop evapotranspiration that took place within that period.

In determining the crop water demand for the irrigation purpose, a plot with an area of 50 m^2 was modelled from the series of plots laid out for the whole experiment. The crop water demand for a plot to be modelled was determined by multiplying the E_C value over the total coverage area of the drips. The lateral length was 10 m while the dripper length was 5 m with a velocity of flow of 3.14 x 10^{-3} m/s, while the pipe discharge of the drip system was 4.17 x 10^{-7} m^3/s (Adeogun, 2008). Depending on the crop water demand at stage of growth of the crop, the amount and time of supply was determined by the amount of crop evapotranspiration at a given stage of growth. In determining the amount of water required for a plot, the followings were taken into consideration (Adeogun, 2008):

Average coverage diameter for a drip = 210 mm

Coverage area of the drip = 3.46 x 10^4 mm^2

Number of dripper lines on a plot = 10

Number of drips in a dripper line = 8

Total coverage area for drips on a plot (G) = 2.77 x 10^6 mm^2

Crop evapotranspiration on a plot = (E_C) x G

Crop water demand (ω_C) on a plot = E_C x K,

where: K is conversion factor to m^3 / s. (1.16 x 10^{-14})

Therefore, the equation for crop water demand is expressed as:

$$\omega_C = E_C G.K \quad (5)$$

Using the water supply model developed for the drip irrigation system (Adeogun, 2008), the amount of water supplied by the drip system in a given plot were determined. The water supply model is given in Equation. 6

$$\phi_s = 0.287vL^4 - 0.001\frac{H\sqrt{L^5 g}}{d} + 8.87x10^{-3}\sqrt{L^5 g} \quad (6)$$

where ϕ_S is the water supply by the drip irrigation system, v is velocity of flow, L is the dripper length, H is the water head in the reservoir, d is the diameter of pipe, g is the acceleration due to gravity.

The development of expression for water use efficiency was carried out by combining the models developed for hydraulic weighing lysimeter and the drip irrigation system. By substituting Equations.3, 5 and 6 into Equation. 1, the water use efficiency (ξ_W) is obtained as follows:

$$\xi_W = \frac{E_c GK}{0.287vL^4 - 0.001H\frac{\sqrt{L^5 g}}{d} + 8.87x10^{-3}\sqrt{L^5 g}} \quad (7)$$

where: ξ_W is the water use efficiency, E_c is the crop evapotranspiration, G is the total coverage area for drips in a plot (mm^2), K is the conversion factor to m^3/s. Other parameters are as earlier defined.

RESULTS AND DISCUSSION

The data for crop evapotranspiration (E_C) of maize (Table 1) throughout the growing season showed relatively lower values at the beginning of the growing season and increased to maximum during the flowering and fruiting stages and then declining at maturity (Fig.1). During the vegetative growth stage, the E_C increases to full maturity.

During the irrigation of maize, the crop water demand in the first decade was 5.15 x 10^{-4} ℓ/s with equivalent 67 % of water use efficiency, which increased to 7.43 x 10^{-4} ℓ/s as the maximum value at the third decade with 96 % of water use efficiency. These values declined to a minimum on the fifth decade with a crop water demand of 4.50 x 10^{-4} ℓ/s and thereby increased again before it finally declined to 7.07 x 10^{-4} ℓ/s at the eleventh decade with 92 % of water use efficiency.

The irrigation water supply to a plot was in the order of 7.7 x 10^{-4} ℓ/s at a given point in time. In order to achieve the desired crop water demand, the time of application was increased to reach the desired value at 100 % water use efficiency. The optimum water supply for maize ranged between 4.47 x 10^{-4} ℓ/s to 7.38 x 10^{-4} ℓ/s.

Table 2 showed the estimated values of crop evapotranspiration (E_c) for cowpea for the decades (ten days basis) during the month of July to October. The E_c for cowpea through the growing season indicate relatively lower values at the early stages of crop growth. These values increased during the period of rapid growth to a maximum and thereafter declined after maturity. A short term fluctuation was experienced during the early stages as observed in the values for the first three decades of the growing season. Thereafter, a steady increase was maintained up to maturity on the sixth decade during the growth period. The short-term fluctuation during the growing stages is as a result of variations in the prevailing weather condition.

It was observed that the crop evapotranspiration of cowpea increased from the first decade to the sixth decade. The implication of this result is that the water use for cowpea is critical on the sixth decade of planting (during the seed formation period) and any shortage of water for the crop at this critical period may result in poor yield. This also determined the highest value for the water use efficiency as observed in fig. 2. Therefore in the absence of rainfall at this stage of growth, supplemental irrigation should be applied for enhanced growth and yield.

During the irrigation of cowpea, as observed in Table 2, the crop water demand in the first decade was 2.51 x 10^{-4} ℓ/s with equivalent 32 % of water use efficiency, which increased to 7.24 x 10^{-4} ℓ/s as the maximum value at the sixth decade with 94 % of water use efficiency before it finally declined to 4.47 x 10^{-4} ℓ/s at the tenth decade with 58 % of water use efficiency. In order to achieve the desire crop water demand, the time of application was increased to reach the desired value at 100 % water use efficiency. The optimum water supply for cowpea ranged between 2.51 x 10^{-4} ℓ/s to 7.24 x 10^{-4} ℓ/s.

CONCLUSIONS

It is considered that the most important achievement of this work is that the determination of consumptive use of crops has been made easy by measuring crop evapotranspiration (E_C) of any given crop by the use of the hydraulic weighing lysimeter at NCAM research field. This is possible as shown in the experiment carried out on maize and cowpea during the growing season. Hence, the determination of E_C was carried out using the E_C model developed for the lysimeter.

The crop water demand of the selected crops was then used to determine the irrigation water value of the crop during irrigation season at different stages of growth. Using water supply model developed from the drip irrigation system designed for the experiment, the water use efficiency of the crops was determined at different stages of crop growth.

By maximizing water use efficiency model, the optimum water supplied during irrigation of cowpea ranged from 2.51 x 10^{-4} ℓ/s to 7.24 x 10^{-4}ℓ/s while that of maize ranged from 4.47 x 10^{-4} ℓ/s to 7.38 x 10^{-4} ℓ/s.

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Table 1.Decade Values of Water Use Efficiency and other Parameters for Maize

Decade (d)	x (mm)	E_C (mm/d)	ω_C x 10^{-4} (ℓ/s)	ϕ_S x 10^{-3} (ℓ /s)	ξ_W	Opt. ϕ_S x 10^{-4} (ℓ/s)
1	1.9	16	5.15	0.77	0.67	5.03
2	2.3	19	6.11	0.77	0.79	6.13
3	3	25	7.43	0.77	0.96	7.38
4	3	25	7.43	0.77	0.96	7.38
5	1.7	14	4.50	0.77	0.58	4.47
6	2.6	23	7.39	0.77	0.96	7.36
8	2.5	21	6.75	0.77	0.88	6.68
9	2.8	30	7.43	0.77	0.96	7.38
10	2.8	31	7.43	0.77	0.96	7.38
11	2.6	22	7.07	0.77	0.92	6.96

Table 2. Decade values of water use efficiency and other parameters for irrigating cowpea.

Month	Decade (d)	x (mm)	ET_{crop} (mm/d)	E_{pan} (mm)	ET_o (mm/d)	k_c	ω_C x10^{-4} (ℓ /s)	ϕ_S x10^{-3} (ℓ /s)	ξ_W
July	1	1.0	7.8	41.92	29.34	0.3	2.507	0.769	0.33
	2	1.0	8.34	49.15	34.4	0.2	2.680	0.769	0.35
	3	1.4	11.34	40.12	28.1	0.4	3.645	0.769	0.47
August	4	1.9	15.22	35	24.5	0.6	4.892	0.769	0.64
	5	2.2	18	33	23.1	0.7	5.785	0.769	0.75
	6	2.7	22.53	42.2	29.54	0.8	7.241	0.769	0.94
Sept.	7	2.5	20.76	46	32.2	0.7	6.672	0.769	0.87
	8	2.0	16.8	44	30.8	0.9	5.399	0.769	0.70
	9	1.8	14.81	44	30.8	0.4	4.756	0.769	0.62
Oct.	10	1.7	13.91	58	40.6	0.3	4.471	0.769	0.58

Table 3. Monthly values of water use efficiency for irrigating cowpea

Month (M)	x (mm)	ET_{crop} (mm/M)	E_{pan} (mm)	ET_o (mm/M)	k_c	ω_C x 10^{-4} (ℓ /s)	ϕ_S x 10^{-3} (ℓ /s)	ξ_W
July	2.8	23.4	125.76	88.03	0.3	2.504	1.225	0.20
August	4.1	34.9	124.27	86.99	0.4	3.734	1.225	0.30
Sept.	7.2	61.29	121.2	84.84	0.7	6.558	1.225	0.54
October	5.4	45.52	146	102.22	0.4	5.778	1.225	0.47

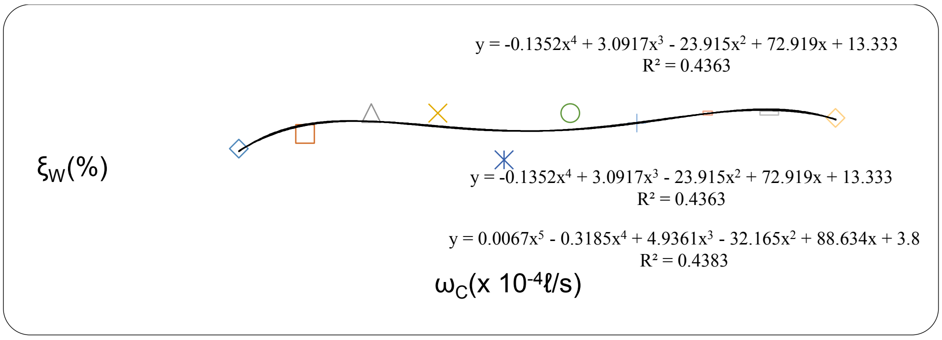

Figure 1. Graph of ξ_W vs ω_C of Maize

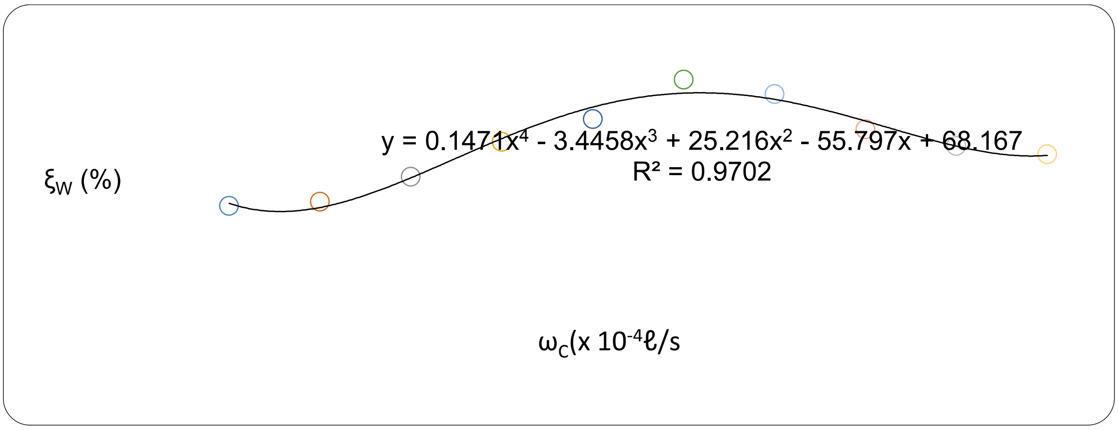

Figure 2. Graph of ξ_W vs ω_C of Cowpea

AN APPRAISAL ON THE METHODOLOGIES FOR ASSESSING IRRIGATION SYSTEM SUSTAINABILITY

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ABSTRACT

This paper presents methodology for assessing the sustainability of irrigation systems. Irrigation system being complex in nature consists of many sub-units, but the management objective is the most sustaining part of the system. Sustainability assessment is a tool that directs decision makers towards sustainability of a system. The most prolific tools used in assessment of irrigation systems are the sustainability development and composite indicators, but the choice of any preferred indicator is a function the goals and targets of the analyst. The process of sustainability analysis involves ecological, economic, social, and institutional dimensions respectively. The obligatory information related to sustainability indices construction strategy are data assembly, computation of missing data, multivariate analysis, normalization, weighting and aggregation, robustness, and sensitivity analysis. Owing to the dynamic nature of the farming system, this paper suggests that any irrigation system should be subjected to such sustainability assessment on routine basis to establish its sustainability trends to inform decision making processes, and guarantee efficient resource utilization and optimum productivity.

INTRODUCTION

To sustain literally means to 'keep in existence, keep up, Maintain or prolong. Becker (1997) reported scholars such as Peters and Wiebecke (1983) to have identified the most commonly agreed equivalent term of sustainability "*Nachhaltigkiet*" (though not identical in meaning and etymology), was first introduced in forestry by the minor Von Cartowitz in the Eighteenth century to describe the maintenance of long term productivity of timber plantations so as to continuously provide construction poles for the mining industry. The concept of sustainability gained much interest in recent years by the academic, scientific and policy making communities as a result of the conference held by WCED in the 1980's titled 'Our Common Future' in which they emphasized the economic aspects of sustainability and linked the term to development. This interest has accompanied several attempts to develop useful systems for measuring sustainability which includes various aspects of Agricultural systems such as irrigated farming.

Irrigated agriculture has the greatest potential for increasing food production and rural income, given that irrigated crop yield is double or more compared to the yields obtainable from rainfed agriculture. Irrigation development is judged an important corner stone for agricultural development in the arid and semi-arid regions of the world. But unless the irrigation system performance is monitored, it cannot be assessed; and lack of routine assessment can lead to failure of the system at any time (Sannida *et al*., 2011)

Sustainability development indicators are the most prolific tools used for the assessment of irrigated Agriculture. Thus, an appropriate framework should be used for the evaluation of indicators. The indicators have to be assigned reference values and aggregated using a statistical technique to form an index in order to determine which of these sustainability levels could be achieved.

Several studies have indicated the dissatisfaction with performance of irrigation systems in the developing countries despite their ability to yield greater output compared to rain fed Agriculture (Lieslie and Svendsen, 1990). This was mainly attributed to either mismanagement of the systems, and/or the impact of the environment on the irrigation system. Sustainability being a concept cannot be measured directly, it has therefore become necessary for researchers to recognize the different approaches and procedures sustainable for empirical examination of the sustainability of irrigation system at various hierarchical levels Frisco (1998). This work focused on the review of the methodologies used in evaluating the sustainability of irrigation systems to direct decision-making and planning of irrigation systems.

SUSTAINABLE DEVELOPMENT (SD)

MAF (1997) discovered so many definitions of sustainability exist in literatures, which depends on the view point and objectives of the group trying to define it.

However, despite these numerous definitions, Kellet *et al.* (2005) pointed that sustainability is an evolving concept and they identified that the following points as integral to the definitions:

- Equity between members of the present generation.
- Equity between members of the current and future generation.
- Balance between system elements, social, economic environmental, institutional, cultural and
- System capacity limit to support human populations.

The earliest and most frequently used definitions of SD when judged by its frequency of citation were made by the world Commission on Environment and Development (WCED) in the early 1980's. They defined SD as 'Development that meets the need of the present generation without compromising the ability of the future generations to meet their own needs (WCED,1987).

Katone *et al.* (2005) later reviewed the meaning of SD, and he was of the view that, there must be no single focus on sustainability, but instead all of the economic, social and environmental systems must be simultaneously sustainable themselves.

Fig 1. Illustrates environmental, economic and social development where the environment is assumed to define the limit for economic and social development. He added the different types of capitals to figure as the three pillars can be measured through these capitals.

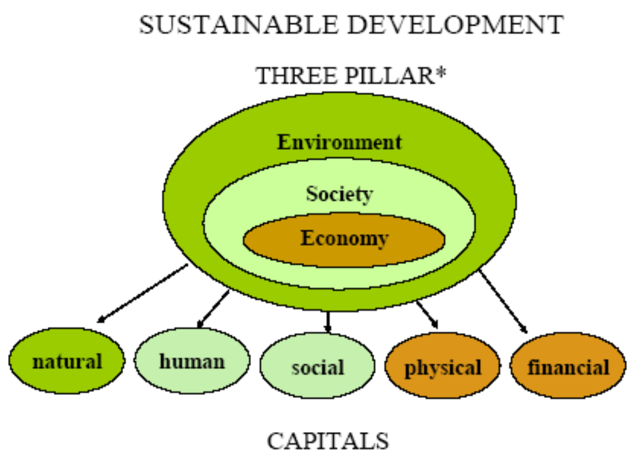

Figure 1 Sustainability Development Source: Katone et al. (2005)

Charles (1994), viewed sustainability development as an integrating idea and a bridge between conservation and development it recognizes that development can be damaging, but also in the current context of population growth and raising human goals, development must happen and must prosper. Therefore, the search for a sustainable development generally identifies the types and intensities of developments, and corresponding modes and levels of operation and management practices that seem capable of being continued without significant reduction of their benefits and causing substantial harm to others.

Definition of Sustainable Agriculture (SA)

Numerous definitions of Sustainable Agriculture (SA) exist Zhen and Routray (2003), reported at least about70 definitions. These definitions were found to defer in subtle ways emphasizing different aspects of agriculture, values, priorities, and goals in the context of different countries and regions.

FAO (1995) defined SA as the management conservation of natural resource base as well as the orientation of technological and institutional dimensions towards satisfying human needs for the present and future generations. Such SD in our agriculture promotes the conservation of our land, water and animal genetic resources. This development is economically non-degrading, technically appropriate, economically viable, and socially acceptable.

Izac and Swift (1994) proposed initial and revised sustainability definitions for agriculture. They initially defined a sustainable cropping system as one that achieves an acceptable level of production of harvestable yield, which shows a non-declining trend from cropping circle to cropping circle over the long term.

Based on these various definitions it could be concluded that a sustainable farming practice is one that adopts management practices that will maintain or improve its performance over the long term by meeting these three fundamental goals namely Ecosystem undegradable; to manage, protect and sustain the natural resources, and to achieve intergenerational equity. Economic viability; maximize net profit over the long term; Social acceptability; to respects human beings rights and promote development in the rural areas.

Irrigation Sustainability

The Irrigation system is a complex system with different independent but interrelated sub units; these sub units must work simultaneously with one another in order to function efficiently. A failure of one unit, if not identified and corrected on timely, may result into the failure of the whole system in the long term. To sustain the performance of an irrigation system generally implies that there are a number of forces which would otherwise threaten to bring it down; identifying these threats should be the key to various protective actions by managements (Charles, 1994). Irrigation sustainability can therefore be viewed from two different but complimentary perspectives viz-a-viz: the Irrigated crop production system, and the irrigation system. The two are intimately connected. The irrigation system consists of the infrastructure and institutions which serve as a supportive mechanism for the irrigated crop production system and the sustainability of the later is crucially depended on the continued capacity of the former to serve the crop land. It was further pointed that in practical terms, the sustainability concern of irrigation system generally involves enhancing or maintaining: the hydraulic structures responsible for delivering irrigation water, the removal of excess water from the service area, functionality of the supportive infrastructure; and financial capacity for water service and social equity.

Irrigation System management

Irrigation management refers to the proper utilization of water, through an efficient method of distribution, and on-farm application (Sanidda, 2010). The term water management involves planning, developing, distribution and optimum use of water resources under defined water policies and regulations.

Twieoty (2011) reported that irrigation system management activities can be focused on (a) the water itself, (b) the physical structures that capture, convey, distribute and remove water and(c) the social organization such as water users association. All these physical defined activities are interactive and interdependent.

Irrigation Sustainability Assessment

Hacking et al. (2008), defines Sustainability assessment as a process that directs decision making towards sustainability. It assists decision or policy makers on which actions should be taken in an attempt to reach some certain level of sustainability, it also acquaint them the current sustainability status.

Steven et al. (2011) identified some sustainability assessment tools which exists such as monetary tools example is Cost benefit analysis, used by economist; Biophysical models example is the Index of Sustainable Economic Welfare and the Genuine Savings and Ecological Footprint; and Sustainability indicators used by scientist and researchers, well-known examples of sustainability indicator sets are developed bythe UN (United Nations, 2001), OECD (OECD, 2006) and the EU (EuropeanCommission, 2005).

The concept of scale is of major importance with regard to sustainability assessment. According to Gibson et al.(2000) the term "scale" refers to the spatial, temporal, quantitative or analytical dimensions used by scientists to measure and analyze objects and processes whereas "Levels" refer to locations along a scale, sustainability assessment usually takes place at a specific level (e.g. firm level) to support decision making by a specific end-user group (e.g. firm managers) Steven et al. (2012). Quantitative indicators can generally be understood as something that points to an issue or condition. Its purpose is to show how well a system is working towards the defined goal. Sustainable development indicators (SDI) provide for judgment of the exact nature of change, and determine trend of development on the economic, environmental and social conditions of a system is increasing or decreasing within a specific spatial and temporal scale. Based on literatures, (SDI) are the most productive and available method for sustainability evaluation of Agricultural systems.

Below are some of the important stages involved in the development of the composite indicator

Developing a Theoretical framework

A theoretical framework provides the basis for the selection and combination of variables into a meaningful composite indicator under a fitness-for-purpose principle (involvement of experts and stakeholders is envisaged at this step) OECD (2008).A (SDI) structured in a list, table, diagram, or model constitute a SI framework. How SDI are structured is what determines the functions of a SI framework.Kellet et al. (2005) proposed eight key criteria for assessing the usefulness of nine resource sustainability indicator frameworks. The criteria are as follows:

1. Incorporates or allows the incorporation of threshold values
2. Illustrates balance between states of SIs
3. Identifies specific relationships between SIs
4. Uses hierarchy to promote systemic thinking and assist in SI selection
5. Can be used to review systems at a range of spatial scales
6. Facilitates participatory research
7. Integrates scientific and experiential knowledge
8. Simulates and tests planning and management scenarios

Out of the nine natural resource sustainability indicator frameworks analysed (State and control, Driving force, state and response, Condition and trend, System Division, Sustainability criteria, Threat identification model, Risk assessment triggers, Bayesian belief networks and Amoeba), with each sustainability indicator framework described, its use explained, and tested against the criteria listed above. The Benefits and shortcomings of each sustainability indicator frameworks were presented. The AMOEBA satisfies six criteria whereas the Bayesian belief network satisfies 7 out of the eight assessment criteria. He therefore recommends the adoption of the AMOEBA SI Framework and Bayesian Belief Network. However, many more frameworks now exist such as DPSIR framework and the SAFE framework which are frequently used for sustainability evaluation of irrigation system.

Selection of Sustainability Development indicators (SDI)

The next stage after developing a frame work is the selection of acceptable indicators that would cover the three components of sustainability, namely the economic, social, and environment components. In addition to these elements (Ecological, Economic and Social aspects) the institutional and cultural elements were also considered (North, 1990; Rajesh et al. 2009; Rigby et al., 2000; Bell and Moore 1999; and Charles 1994). Charles (1994), reported that the essential identification of human institutions as" the keys to sustainability". He says "over a period of a few seasons, no piece of infrastructure is stable or sustainable without instructions to operate, repair, adapt and maintain it". This is a very important point that should always be taken into consideration in respect of irrigation systems, yet it is rarely incorporated into literatures about sustainability.

According to Becker (1997), Rigby et al (2000), Zhen and Routray (2003) the criteria for the selection of indicators are:

- Specific: Indicators must relate to the desired outcome, i.e. fit the purpose for measuring.
- Measurable: Indicators should be quantified.
- Pedagogical: Indicators should be practical and designed for those who are going to use them.
- Sensitive: Indicators must readily change as circumstances change.
- Reliable: The information that an indicator is providing must be reliable. Data upon which the indicator is based must therefore be collected using a systematic method.
- Based on accessible data: In order to create good indicators it is important that the necessary information is available or can be gathered on a regular basis and while there is still time to act.
- Cost-effective: The cost of gathering necessary data should not exceed the benefits of using the indicator.
- Relevant and Usable: Indicators should show what is needed to know. This includes the need for a clear definition of the objective that the indicators are meant to achieve. It also means that it is important to focus on those issues that a region, or a regional development project, can control or influence, or that is of specific importance to the project.
- Predictivity: they must be able to predict changes that can be averted by management action.
- Integratability: they must be able to be aggregated to form composite or index before they can adequately represent the level of sustainability of an system.
- Analytical soundness: they must be based on sound science.
- Ease of interpretation: they must communicate essential information in a way that is unambiguous and easy to understand.
- Existence of Threshold Values and Guidelines; the evaluation of each indicator should ideally be based on threshold values given or established locally by research institutes, government agencies, and NGOs working at the local levels. Meaning they must have analytically based reference values.
- To compare across place and situations. Indicators should be able to be compared across different farms
- They must be able to assess conditions and changes;
- They must be able to assess conditions and trends in relation to goals and targets;
- They must be able to anticipate future conditions and trends.

Data gathering

Accurate data gathering based on the selected sustainability indicators to calculate empirical values of these indicators is the second step. Data includes both primary and secondary data. Primary data are collected from the fields using questionnaires and interviews, while the secondary data is collected from evaluation of primary data, publications, and Maps.

Imputation of missing data
This is needed where the indicator data set is incomplete and missing data need to be interpolated to repair gaps. (*e.g.* by means of single or multiple imputation.)

Multivariate Analysis
This basically involves the use of statistical analysis (Multivariate analysis) such as Principal Component analysis and the Cluster Technique to check if there is no significant correlation between the selected indicators to avoid problems of double counting in the aggregation stage and to identify groups of indicators or farms that are statistically similar in order to simplify interpretation of results.

Normalization of Indicators
Before aggregation of indicators it is essential to normalize indicators since they have usually being calculated using different units of measurement. There are a number of normalization techniques which includes ranking, standardization, min–max, distance to a reference country etc, OECD (2008) provides a detail on normalization of indicators.

Assignment of weights and aggregation of Indicators
After normalization of indicators the assignment of weights and aggregation of the indicators is what follows, it is the most important stage in the development of the composite indicators. Since no individual indicators can adequately represent the level of sustainability of a complex system, thus, combining several indicators to form a composite index is a significant step to adequately assess the sustainability of such complex systems (Beaker 1994; Farrel and Hart 1998). Nardo et al. (2005) suggested a number of alternative techniques for this purpose and he pointed that almost all these alternative methods have being used empirically. They include; the weighted sum of indicators, principal component analysis, analytical hierarchy process, geometric average or multi attribute utility functions

Robustness and sensitivity.
The development of a composite indicator involves stages where subjective judgements have to be made: the selection of individual indicators, the treatment of missing values, the choice of aggregation model, the weights of the indicators, *etc*. A sensitivity analysis is the study of how the variation in the output can be apportioned, qualitatively or quantitatively, to different sources of variation in the assumptions, and of how the given composite indicator depends upon the information fed into it. Uncertainty analysis, which aims to quantify the overall uncertainty in country rankings as a result of the uncertainties in the model input. A combination of uncertainty and sensitivity analysis can help to gauge the robustness of the composite indicator ranking, to increase its transparency, to identify which countries are favoured or weakened under certain assumptions and to help frame a debate around the index. (OECD, 2008)

CONCLUSION
This paper focuses on the methodologies for assessing Irrigation system sustainability. It first placed emphases on maintaining the management of the irrigation system to be goal of the policy or stake holders in order to reach sustainability. It further high lights the major stages involved in assessing irrigation system management.The concept of agricultural sustainability is dynamic in nature, in the sense that what is considered as sustainable, varies with space and time in response to environmental changes and human behaviours. Routine sustainability monitoring using some essential set of indicators over reasonable seasons thus becomes a necessary tool in studying the nature of change of a particular farming practice. This will enable researchers determine trend in sustainability.

RECOMMENDATION
There is need for the government to undertake such sustainability assessment on river basins where irrigation farming is being practiced at different spatial and temporal scales in order to boost our agricultural production.

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EVALUATION OF QUALITY PARAMETERS OF WASTEWATER-IRRIGATED ONIONS (*Allium cepa*)

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ABSTRACT

Onions were grown on 4 x 5 m plots, spaced 0.15 m plant to plant and 0.30 m row to row at 0.025 m depth at the University of Maiduguri sewage pond to investigate the use of untreated wastewater for irrigation. The interacting effect of salinity and sodium hazards and the bacteria content were low and within acceptable levels. The electrical conductivity of the soil saturation extracts, EC_e were 0.39, 0.40 and 0.40 dS/m, indicate no dangerous salt levels, while the pH is within normal range of 6.30, 5.61 and 5.60. The wastewater electrical conductivity, EC (0.69, 0.75, 0.82 dS/m) and Sodium Adsorption Ratio, SAR (2.5, 2.80, 3.00) in 1988/1989, 1997/1998 and 2008/2009 respectively are both within acceptable limits. The study showed that the wastewater was still suitable for irrigation and the onions produced were fit for consumption. However, it is necessary to monitor the quality of this wastewater periodically. It is also recommended that a treatment plant be established due to increased volume of wastewater generated occasioned by the growing students' and staff population on the campus.

Keywords: *Wastewater, Irrigation, Onions, Quality*

INTRODUCTION

Agriculture consumes about 70 % of freshwater while industries make use of 20 % leaving 10 % for domestic use in most countries of the world (UNEP and UN-Habitat, 2010). Water is needed in large quantity for a crop or plant to establish and mature. For example, Food and Agriculture Organization (FAO, 2005) reported that it takes between 1, 000 to 2, 000 L of water to process 1 kg of wheat and 260 to 300 L to produce 1 kg of cassava.

The increase in world population and the demand for water are of great concern. Water is a very scarce commodity in the arid and semi-arid regions where precipitation is low. Therefore, conservation of available water is imperative. Re-use of wastewater is a promising alternative, especially for irrigation purposes. The United Nations Environmental Programme (UNEP, 2010) reported its intention to invest US$20 million in low-cost water technologies such as drip irrigation, to lift 100 million poor farming families worldwide out of extreme poverty. The major constraints to the use of wastewater for irrigation are possible environmental pollution and health hazards posed to both the farmers and the consumers of the irrigated crops. Thus, before any sewage effluent is used for irrigation, its quality must be ascertained and compared with the existing water quality standards. Chemical quality is assessed in terms of total salt concentration represented by electrical conductivity (EC) and the sodium absorption ratio (SAR); a measure of the relative concentration of sodium ions to those of Calcium and Magnesium and other contents of the water.

Onion (*Allium cepa*) can be said to be one of the most consumed vegetable crops in Africa, especially Nigeria. They belong to the wildly cultivated genus group called *"Allium"*. This is because it is used as a flavouring and seasoning agent in almost all dishes. Several researches have evaluated its growth under different conditions. It can be grown in both rainfed condition and dry season irrigation. However, better yield is obtained during the dry season because of less cases of pests and diseases (Sani and Jaliya, 1995). Researchers such as Moyo (2008) and Stasinos, & Zabetakis, (2013) have worked extensively on the use of wastewater in growing onions.

Table 1 illustrates the guidelines used in determining the suitability of any water for irrigation (FAO, 1994). The salinity of the irrigation water influences the plant osmotic activity which consequently reduces absorption of water and nutrients. On the other hand, high SAR brings about the accumulation of sodium ions which tends to displace Calcium and Magnesium ions resulting in soil dispersion and reduced infiltration. Also, trace elements such as Boron though required by the crops in minute quantities may be toxic if it exceeds 2.0 mg/L.

Table 1: Guidelines for Interpreting Quality of Irrigation Water

Category	Unrestricted	Restricted	Adverse effects
A. Physical			
Turbidity (TB), NTU	10	50	Emitter clogging
Total Dissolved Solid (TDS), mg/L	500	2000	Emitter clogging
Total Suspended Solids (TSS), mg/L	100	150	Emitter clogging
B. Chemical			

Electrical Conductivity (EC), dS/m	0.75	3.00	Toxic
Sodium Adsorption Ratio (SAR)	3	9	Soil dispersion
pH	6.50-8.40	8.40-14	Indirect HCO_3 effect
Boron (B), mg/L	0.75	2	Leaf burn
Chlorine (Cl), mg/L	4	10	Leaf burn
Bicarbonate (HCO_3), mg/L	1.50	8.50	Leaf drop
Nitrogen (N), mg/L	5	30	Excessive growth
Phosphorus (P), mg/L	2	6	Yellow leaves
Potassium (K), mg/L	5	40	Reduced yield
Aluminium (Al), mg/L	5	20	Excess growth
Cadmium (Cd), mg/L	0.01	0.05	Affects solubility of minerals
Lead (Pb), mg/L	0.20	2.00	Health effects
C. Biological			
Coliform count (CC), cells/100 mL	100	5000	Health effects

Source: FAO (1994)

It is pertinent to note that the quality of irrigation water can be partly assessed by the coliform count and is a very reliable measure of bacteriological contamination. The World Health Organization (WHO, 2003) recommends that for any sewage water to be used for unrestricted irrigation, the coliform count should not exceed 100 cells/per 100 mL. Studies at the University of Maiduguri have shown that the use of wastewater for irrigation is a viable alternative source of water especially for small-scale irrigation (Musa, 1990 and Musa *et al.,* 1993). This is partly due to the fertilizing effect of using such water and the scarcity of irrigation water in the study area which lies in semi-arid region. It was reported in these studies that the wastewater irrigated onions were fit for human consumption.

The objectives of this study are to determine the chemical and biological characteristics of the wastewater; determine the quality of irrigated onion and its suitability for consumption and compare the results obtained in 2008/2009 with those of 1997/98 and 1988/89 seasons to ascertain whether there is any appreciable change.

MATERIALS AND METHODS

Study area

The study was conducted at the wastewater disposal of the University of Maiduguri located on Latitude 11° 48' N and Longitude 13° 12' E. The wastewater flows to the pond from students' hostels, laboratories and offices without any treatment. Maiduguri and its immediate environs is known for its dryness, with semi-arid climate, savanna or tropical grasslands vegetation, light annual rainfall of about 300-500 mm and the average daily temperature ranging from 22 – 31°C, with mean of the daily maximum temperature exceeding 40 °C between March and June before onset of the rains in July to September. It has mainly sandy loam soils.

Method of cropping

Six-week old onion seedlings were sourced from local nurseries in the metropolis. The onions were grown on plots of 4 x 5 m, spaced 0.15 m plant to plant and 0.30 m row to row at 0.025 m depth. Irrigation commenced every October and ended March, the subsequent year as the common practice in the study area. The wastewater was drawn using a 0.50 kVA pump directly from the wstewater pond and irrigated by flooding in-between the furrows on weekly basis to ensure that the crops were not water-stressed. The water, soil and crop parameters measured and methods used for their determination are shown in Tables 2, 3 and 4 respectively.

Table 2: Methods used for Evaluating Wastewater Characteristics

Characteristics	Methods of Evaluation
Suspended solids	Filtration
Electrical Conductivity	Conductivity meter
Sodium	Atomic Absorption Spectrometry (AAS)
Calcium	Atomic Absorption Spectrometry (AAS)
Magnesium	Atomic Absorption Spectrometry (AAS)
Coliform Count	Most Probable Number (MPN)
Boron	Atomic Absorption Spectrometry (AAS)
Chlorides	Titration using standard Silver Nitrate

pH	Electric pH meter

Table 3: Methods used for Evaluating Soil Characteristics

Characteristics	**Methods of Evaluation**
Textural Composition	Hydrometer
Infiltration Rate	Infiltrometer
Moisture Content	Oven Dry
pH	Electric pH Meter
Electrical Conductivity	Calorimeter

Table 4: Methods used for Evaluating Major and Trace/Heavy Metals Evaluated in the Irrigated Onion

Elements	**Methods of Evaluation**
Major Elements	
Calcium	AAS
Sodium	AAS
Manganese	AAS
Iron	AAS
Potassium	AAS
Phosphorus	Calorimeter
Trace/Heavy Metals	
Copper Zinc	AAS
Cadmium	AAS
Lead	AAS
Chromium	AAS
Manganese	AAS

The soil and water parameters were measured just before commencement of the irrigation, while the crop parameters were measured after the harvest. Mean values of four replicates of the data obtained were analyzed. Comparisons were then made with the results in 2008/2009, 1997/98 and 1988/89 seasons.

RESULTS AND DISCUSSION

Table 5 shows that there is no appreciable change in all soil parameters measured in 2008/2009, 1997/98 and 1988/89 cropping seasons. For example, the electrical conductivity of the soil

Table 5: Some Physical and Chemical Characteristics of the Soils in the Study Area before Irrigation

Characteristics	**Measured Values**				
Textural Composition, %	1988/1989	% change	1997/1998	% change	2008/2009
-Sand	66.30	-1.66	65.20	1.23	66.00
-Silt	16.70	3.59	17.30	-0.31	17.10
-Clay	17.10	2.34	17.50	-3.43	16.90
Infiltration rate (I), mm/hr	114.00	9.65	125.00	2.40	128.00
Available Moisture Capacity (AMC), %	12.00	10.83	13.30	-1.50	13.10
Bulk Density (ρ), g/cm^3	1.49	-6.04	1.40	1.43	1.42
pH	6.30	-10.95	5.61	-0.18	5.60
Electrical Conductivity of saturation extract (EC_e), dS/m	0.39	0.26	0.40	0.00	0.40

saturation extracts, EC_e were 0.39, 0.40 and 0.40 dS/m, indicate no dangerous salt levels, while the pH is within normal range of 6.30, 5.61 and 5.60 in 1988/1989, 1997/1998 and 2008/2009 respectively. The slight increase except in sand content (1.23%) and bulk density (1.43%) may be attributed to the addition of organic materials and some salts into the soil over the years as a result of wastewater irrigation. Similar trends were also reported by Idike and Onoja (1990). The increase in values of different parameters may be advantageous or otherwise in the long run but the net effect can only be discerned through continuous monitoring and evaluation.

Table 6 shows that the wastewater parameters except for chloride content did not change appreciably over the years. The electrical conductivity, EC (0.69, 0.75, 0.82) and sodium adsorption ratio, SAR (2.5, 2.80, 3.00) in 1988/1989, 1997/1998 and 2008/2009 are both within medium and low levels respectively. The EC and SAR interact to determine the suitability of water for irrigation.

Table 6: Quality of Raw Sewage Water Measured in the Study Area before Irrigation

Parameters	**Measured Values**				
	1988/1989	% change	1997/1998	% change	2008/2009
Suspended Solids (SS), mg/L	375.00	12.00	420.00	1.91	428.00
Electrical Conductivity (EC), dS/m	0.69	8.70	0.75	9.33	0.82
Sodium Absorption Ration (SAR)	2.50	12.00	2.80	7.14	3.00
PH	8.20	2.44	8.40	1.19	8.50
Boron (B), mg/L	0.82	9.76	0.90	22.22	1.10
Chloride (Cl), mg/L	2.20	81.82	4.00	20.00	4.80
Coliform Count (CC), cells/100 mL	25.00	28.00	32.00	12.50	36.00

Other chemical quality parameters determined are pH, Boron and Chloride contents and are all within the acceptable limits when compared to the values shown in Table 1. However, these values fall within the class where problems are likely to develop with time.

The bacteriological quality was assessed using coliform counts in the MPN method. The presumptive coliform count indicates pollution. The average coliform counts of 25, 32 and 36 cells/100 mL during 1988/89, 1997/98 and 2008/2009 seasons respectively are all low and acceptable for irrigation purposes. From the results presented, it can be said that the wastewater under study is suitable for irrigation 10 years and 20 years after the first and second researches respectively. However, it should be borne in mind that the water quality may change if the volumes of contaminants increase especially due to increase in students' population and other activities on the campus.

Quality of the Irrigated Onions

The major source of concern in the area of using crops irrigated using wastewater lies mainly in bacterial contamination of the produce and the accumulation of heavy metals that may be toxic to the human body. Table 7 shows that there were considerable changes in levels of some major elements such as Calcium (1.10, 0.50, 0.87 mg/L), Sodium (0.72, 0.48, 0.49 mg/L), Iron (0.13, 0.29, 0.35 mg/L) ,Manganese (0.79, 0.46, 0.46), Potassium(176.70, 120.75, 126.00 mg/L) and Phosphorus (39.50, 20.07, 18.54 mg/L) for the 1988/89, 1997/98 and 2008/2009 seasons in the irrigated onions respectively. However, they are generally within acceptable limits. Therefore, they do not usually constitute any dietary problem since they are required by the human body in relatively large quantities.

Trace or heavy metals are the main source of concern. In Table 8, a comparison of the levels of some trace or heavy metals in the onions was made with their maximum permissible levels in irrigation water as recommended by Ayers and Westcot (1985) and FAO (1994). For Chromium (0.00, 0.0947, 0.095 mg/L), Lead (0.00, 0.020, 0.00 mg/L), Zinc (0.0029, 0.0142, 0.152 mg/L), Copper (0.036, 0.2200, 0.386 mg/L) and Manganese (0.010, 0.0590, 0.0630 mg/L) in 1988/89, 1997/98 and 2008/2009 seasons respectively, the levels detected increased remarkably though still far less than the maximum permissible levels in irrigation water. Stasinos and Zabetakis (2013) reported that Potatoes and onion shoots and leaves contained nickel and chromium when they were collected from tubs that were irrigated with contaminated water. Stasinos and Zabetakis also noted that uptake of heavy metals varied depending on the vegetable and contamination level of the water used. For example, onion leaves from plants irrigated with the mostly highly-contaminated water contained 61% more chromium and 90% more nickel than onion leaves from plants irrigated with clean water. Carrots, on the other hand, did not contain higher levels of heavy metals when the plants were watered with contaminated water.

Table 7: Levels of Major Elements in the Irrigated Onion

Elements	Measured Values (mg/L)				
	1988/1989	% change	1997/1998	% change	2008/2009
Calcium (Ca), mg/L	1.10	-53.64	0.51	70.59	0.87
Sodium (Na), mg/L	0.72	-33.33	0.48	2.08	0.49
Iron (Fe), mg/L	0.13	123.08	0.29	20.69	0.35
Manganese (Mn), mg/L	0.79	-41.77	0.46	0.00	0.46
Potassium (K), mg/L	176.60	-31.71	120.75	4.35	126.00
Phosphorus (P), mg/L	39.50	-49.19	20.07	7.62	18.54

Table 8: Comparison of Trace Elements/Heavy Metals in the Irrigated Onion with Maximum Levels in Irrigation Water

Elements	Levels in the Irrigated Onion Bulbs (mg/L)					*Maximum permissible levels in irrigation water, (mg/L)
	1988/89	% change	1997/1998	% change	2008/2009	
Chromium (Cr), mg/L	0.00	9.47	0.0947	0.32	0.095	0.10
Lead (Pb), mg/L	0.00	2.00	0.0200	-100.00	0.00	5.00
Zinc (Zn), mg/L	0.0029	389.66	0.0142	900.70	0.152	2.00
Copper (Cu), mg/L	0.036	601.11	0.2200	75.46	0.386	0.20
Manganese (Mn), mg/L	0.010	580.00	0.0590	6.78	0.0630	0.20

**Sources: Ayers and Westcot, (1985)*

CONCLUSION

So far, the results of the study indicate that the untreated wastewater available in the University of Maiduguri wastewater pond is suitable for irrigation. From these findings, it can also be concluded that the wastewater- irrigated onion is suitable for consumption in all cases. After the above findings, agricultural activities at the study area near the sewage pond increased due to the fact that local farmers started using wastewater for their crops with certain confidence.

RECOMMENDATIONS

Since the quality of wastewater changes continuously, it is necessary to check the quality of water from time to time. It is also recommended that the University makes provision for a wastewater treatment plant due to increased volume of wastewater generated as a result of staff and students' population increase. This will enhance the effective use of the wastewater and thereby harnessing its optimum potentials.

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EFFECT OF TILLAGE PRACTICES ON SOME PHYSICAL PROPERTIES OF A *FADAMA* SOIL OF BAUCHI, NIGERIA.

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ABSTRACT

An experiment was carried out on four different tillage practices for land preparations in Bayara river flood plains (Fadama), Bauchi State, to determine their effect on some soil physical properties. The tillage practices were; Plough and Harrow (PHT); Plough tillage (PT); Harrow tillage (HT); Farmers' practiced hoe tillage (L). Randomized Complete Block Design (RCBD) experimental procedure was adopted. The results of the study indicated that depth of tillage for land preparations significantly affects physical properties of alluvial soils ($p < 0.001$). The alluvial soil with treatment PHT consistently had minimum (1.50 gcm^{-3}) bulk density and minimum (13.22 Ncm^{-2}) penetration resistance, while the alluvial soil with treatment L had the highest (1.58gcm^{-3}) bulk density and highest (72.37 Ncm^{-2}) penetration resistance. The results also revealed that soil moisture retention and total porosity increased with increased pulverization. It was therefore suggested that deeper tillage by plough and harrow better improves soil physical properties for the continuously cultivated field of the Fadama in Bauchi State, Nigeria.

***Key words**: Hoe-tillage, density, porosity, penetration resistance*

INTRODUCTION

Bayara river flood plain (*Fadama*) is one of the major irrigation sites in Bauchi sub-urban areas. Mainly small scale farmers cultivate vegetables in the dry season, green cob maize in the mid-season and rice during the rainy season on the plains (BSADP, 2007).

Most of the soils on the flood plains of the river systems in Bauchi state are Entisols with moderate to high productivity and are under laid by shallow aquifers. The soils are intensively cultivated during both dry and rainy seasons. Entisols developed on alluvial flood plains are among the world most productive soils. However, the productivity of most entisols is restricted by inadequate soil depth, clay content or water availability (Brady and Well, 2002).Tillage is one of the farm operations that improve productivity of intensively cultivated alluvial soils. Soil tillage is an important agricultural activity because of its positive impact on crop production, soil properties and environmental sustainability (Lal, 1997). The impact of tillage on crop production is related to the creation of ideal seed condition for plant emergence, development and unimpeded root growth (Licht and Al-Kaisi, 2005). Soil tillage is also among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid *et al.,* 2006). Tillage method affects the necessary plant growth conditions in the soil through its influence on soil physical properties (Licht and Al-Kaisi, 2005). Tillage enhances root growth by encouraging the vertical and horizontal proliferation of root through reduction in soil strength in the subsoil. Tillage increases aeration and water infiltration due to increase pore volume, remove impedance, which can inhibit root proliferation (Lio, 2006).The search for good tillage systems had led to the development of different tillage systems usually classified into conservation and conventional system (Kay and VandenBygaart, 2002). Conventional tillage practices modify soil structure by changing its physical properties as soil bulk density, soil penetration resistance and soil moisture retention. Conservation tillage may reduce disruption of continues pores whereas conventional tillage decreases soil penetration resistance and soil bulk density (Khan *et al*., 1999). Conventional tillage also improves porosity and water holding capacity of the soil to a favorable environment for crop growth (Khan *et al*., 2001). It is therefore essential to select a tillage practice that sustains the soil physical properties required for successful growth of agricultural crops as suggested by Jabro *et al*., (2009).

In Bauchi State, survey has revealed that the average land holding in the *Fadama* was 0.1 to 0.25 ha over the last decades (BSADP, 1999). Therefore for economy, the majority small scale fadama farmers prefer tilling their land with local tools (*Fartanya*-hoe and *Garma*-Hoe). In the recent times, however, after various World Bank intervention projects (*Fadama* I, *Fadama* II and *Fadama* III Projects) irrigated agriculture has proved more economically attractive than the rain fed agriculture to the farmer (BSADP, 2007). Therefore some farmers expand their farm lands and cultivate for three seasons (wet, dry and mid seasons) despite the continuous cultivation some farmers traditional tillage practices still remained.

The objective of this study is to evaluate the tillage systems practiced by the small scale *fadama* farmers in Bauchi sub-urban area (Bayara) and the conventional practices in terms of soil physical properties.

MATERIALS AND METHODS

Experimental Design

The experiment was conducted at Bayara village, Bauchi State Nigeria. The location lies at latitude $10^0 22$ N and longitude $09^0 47$ E. Four tillage practices as treatments were imposed in a Randomized Complete Block Design (RCBD) with three replications. These treatments are; PHT: Plough and Harrow Tillage; PT: Plough Tillage; HT: Harrow Tillage and L: Hoe Tillage. The size of each plot was 10.0 m × 6.0m.

Ploughing involves the use of a disc plough mounted on a 60 Hp tractor to adequately pulverize the soil to a level sufficient for seed germination and seed establishment. Plough plus harrowing was carried out using a disc plough followed by disc harrow. The device was adopted to enhance more effective and improve soil tilth to ensure sufficient seed-soil contact

Determination of Soil Texture

The soil texture of the study area was determined by hydrometer method (Gee and Bauder, 1986) and the soil was classified according to United States Department of Agriculture (USDA) soil texture classification. Particle size distribution of soils from four depths (0-15, 15-30, 30-45 and 45-60cm) in the selected plots was determined and the soil textures classified using soil textural triangle as described by Gee and Bauder (1986).

Determination of Bulk Density

Density of the soil was determined following the procedure suggested by FAO (1977). Soil core samples from the 0-15, 15-30, 30-45 and 45-60 cm depths were collected using core sampler of known volume which was driven in to the soil and carefully dug out. The soil cores were collected, weigh and reweighed after oven drying for 24 hours. Then the soil bulk density was determined using equation (1):

$$BD = \frac{M_s}{V_t} = \frac{M_s}{V_s + V_a + V_w} \quad (1)$$

Where:
$\mathrm{BD} = $ Bulk density $(\mathrm{g/cm^3})$
$\mathrm{M_s} = $ Mass of solid (g)
$\mathrm{V_t} = $ Total volume $(\mathrm{cm^3})$
$\mathrm{V_s} = $ Volume of solid $(\mathrm{cm^3})$
$\mathrm{V_a} = $ Volume of air $(\mathrm{cm^3})$
$\mathrm{V_w} = $ Volume of water $(\mathrm{cm^3})$

Determination of soil moisture

Soil moisture on dry basis was determined using the gravimetric method. The soil moisture content (volume basis) was determined using equation (2) according to USDA (1999):

$$MC\ (dry\ basis) = MC\ (vol.basis) \times BD \quad (2)$$

Several measurements were made every 24 hours after saturation and the mean values of the moisture content were recorded for each treatment.

Measurement of Soil Penetration Resistance

The procedure laid down by American Society of Agricultural Engineers [ASAE] (1977) was followed. The penetration resistance was measured by ten insertions in each plot. A penetrometer (SP 1000) was used with 12.83 mm core diameter and 30^0 angle based. The cone was pushed by hand into the soil at a steady rate of 2 ms^{-2}. Rated cone index was calculated by dividing the penetration force value with the base area of cone. Several readings were recorded and mean values were obtained to determine representative value of rated cone index.

Determination of Soil Porosity

Soil porosity was calculated using equation (3) as suggested by USDA (1999):

$$Soil\ porosity = \left(1 - \frac{\rho_b}{\rho_p}\right) \times 100\% \quad (3)$$

Where:
ρ_b= Bulk density, g/cm^3
ρ_p= Particle density = 2.65 g/cm^3

Data Analysis

Data collected were statistically analyzed using the Analysis of Variance (ANOVA) of SPSS software and the means of the soil physical properties were separated using the Duncan Multiple Range Test (DMRT) at 0.05 level of significance.

RESULTS AND DISCUSSION

Soil Texture of the Study Site

Table 1 shows the result of the particle size analysis of the soils of the four experimental plots in this study.

Table 1: Textural class of the soil in the experimental site

Tillage practice	Percentage (%)			Soil texture
	Sand	Silt	Clay	
Hoe tillage (L)	82.00	1.10	16.90	Sandy loam
Plough tillage (PT)	76.55	2.02	21.43	Sandy loam
Harrow tillage (HT)	75.80	13.20	11.60	Sandy loam
Plough plus harrow (PHT)	81.22	1.10	17.60	Sandy loam

The soil at the four experimental plots was homogeneous with sandy loam texture at the depth 0 – 60 cm.

Bulk Density

The mean bulk density values of the various treatment plots are provided in Table 2. The plots with treatment L, HT, PT and PHT have recorded bulk density value of 1.58, 1.53, 1.51 and 1.50g/cm^3 respectively. From the result it could be seen that hoe-tillage had the maximum bulk density while the plough plus harrow plot had the minimum. This finding shows that change in soil physical properties differ among tillage practices as suggested by some researcher; Hill (1990), Hemmat and Taki (2001), Elder and Lal (2008). Though differ from result reported by Khurshid *et al.,* (2006) and Rashidi and Keshavarzpour (2007).

Penetration Resistance

The mean values of the cone index obtained for hoe tillage was statistically higher ($p<0.001$) than the mean values obtained for the other three tillage practices although the cone index was higher in harrow plot and plough plus harrow plot as shown in Table 2. From the Table treatments; L, HT, PT and PHT have recorded 72.32, 14.93, 14.02 and 13.21N/cm^2 penetration resistance respectively. There was significant difference between means of penetration resistance across all treatments. The significant decrease in penetration resistance across treatment suggested the level of soil pulverization and change in the soil micro-environment. This suggests that pulverization level is low when farmers use hoe-tillage on the Fadama. On the other hand, the higher values of penetration resistance recorded on the hoe- tillage treatment plots could suggest lower soil moisture in the root zone. Ghuman and Lal (1984) have reported that penetration resistance decreases with increase in soil moisture and vice versa.

Moisture Content

Table 2, also presents the means of soil moisture contents of the four treatment plots. It can be observed that the soil moisture content (by volume) was significantly higher (25.65%) in plough plus harrow plot than in other three tillage treatments. The mean values of moisture content were least on the hoe-tillage plot (21.01%). There was no significant difference in percentage soil moisture between the PT and HT treatment plots. It could be suggested from this study that moisture retention in the root zone varies with soil pulverization method.

Porosity

Soil porosity results are also presented in Table 2. Heo-tilled plots recorded a significantly lower (40%) porosity level compared to the other treatments. The other three treatments (PT, HT and PHT) had not shown any significant difference between in percentage porosity. A similar trend was reported by Aikins and Afuakwa (2012) when conducted a tillage study on cowpea plots in Kumasi, Ghana.

Table 2. Means of bulk density, moisture content, penetration resistance and porosity as affected by tillage operations

Tillage	Bulk Density (g/cm^3)	Moisture Content (%)	Penetration Resistance (N/cm^2)	Porosity (%)
Hoe Tillage (L)	1.58[a]	21.01[a]	72.32[a]	40[a]
Plough Tillage (PT)	1.51[b]	23.10[b]	14.02[b]	43[b]
Harrow Tillage (HT)	1.53[c]	23.00[bc]	14.93[c]	43[bc]
Plough plus harrow (PHT)	1.50[bd]	25.65[d]	13.21[d]	43[bcd]
Standard error	0.01	0.51	7.61	0.00

Values followed by the same letter are statistically similar

CONCLUSION

The experiment was conducted to determine the effects of both conventional and other tillage operations practiced by Bayara *Fadama* farmers on the agricultural soil physical properties. Results obtained showed that the hoe-tillage practiced by the small scale Fadama farmers in Bauchi State does not sufficiently improve soil physical properties required for optimum crop growth and yield. The most favorable soil physical properties (the lowest bulk density and highest total porosity) were recorded under conventional tillage system (plough followed by Harrowed) while a moderate change in soil physical properties was under reduced tillage system (Plough or Harrow only). Therefore a more proper root and crop growth is expected under the conventional tillage system (plough thereafter harrow) in the fadama due to reduced soil penetration resistance and bulk density with increased soil moisture content and enhancing soil productivity.
Accordingly, disc ploughing followed by Disc harrowing was found to be more appropriate tillage practice in improving the soil physical properties in the Fadama. Therefore, farmers in the study area would be encouraged through the agricultural extension system to adopt the recommended tillage practice for optimum crop production.

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RELATIONSHIP BETWEEN OPTIMUM DRAIN DEPTH AND EFFECTIVE DRAIN SPACING IN SUBSURFACE DRAINAGE SYSTEMS

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ABSTRACT

An investigation was carried out to determine drain depth and drain spacing that will yield optimum drain discharge and crop yield. A 2x2m² with a buffer zone of 30cm allowed in between the plots were established on 180m² land. The experimental design was Randomised Complete Block Design (RCBD) replicated four times. Treatments imposed include drains installed at 1.0m (S_1), 1.5m (S_2), 2m (S_3), 2.5m (S_4) drain spacing and 15cm (D_1), 20cm (D_2), 25cm (D_3) and 30cm (D_4) soil depths. Leafy amaranth (Amaranthus cruentus) was planted to monitor the effects of drainage on the crop yield. The peak discharges obtained was 3,420ml for plot (S_1D_1) while peak crop yields obtained was 275.07g for plot (S_2D_3). Statistical analysis at 5% level of significance indicated that there were significant differences in the discharges and average crop yields. Analysis shows that the drain depths D_1 (15cm) > D_3 (25cm) > D_4 (30cm) > D_2 (20cm) and the drain spacing S_1 (1.0m) > S_2 (1.5m) > S_3 (2.0m) > S_4 (2.5m). Drain spacing1.0m and drain depth 15cm were recommended for effective removal of water.

***Keywords**: Optimum drain depth, Effective drain spacing, crop yield, Leafy amaranths*

INTRODUCTION

Agricultural drainage is the removal of excess water, known as free water or gravitational water, from the surface or below the surface of land so as to create favourable soil conditions for plant growth and development (Michael and Ojha, 2006). Drainage is to create a soil moisture regime and salt balance in the soil root zone for optimum growth of crops for sustaining them without adverse effects on the environment and ecology. Plant roots must have a favourable environment to be able to extract water and water soluble nutrients to meet the plant's requirement. Excess water and concentration of salts in the root zone or at the land surface do not permit the plant roots to function properly, resulting in poor growth and yield of plants. Excess soil moisture (water logging conditions) affects crop growth mainly because of deficient aeration. Wright and Sands (2001) reported that planning an effective drainage system takes time and require considering a number of factors such as soil factors, wetland impact, adequacy of system outlet, field elevation, slope (grade), and topography assessment, economic feasibility, cropping strategies, environmental impacts associated with drainage discharge, accessibility and quality of the installation. The goal of agricultural drainage is to bring soil moisture to field capacity (James, 1993). Field capacity is the moisture content after drainage of gravitational water from the soil has become very low and moisture content relatively stable. It was also observed that the field capacity is achieved one to three days after the soil has been thoroughly wetted by rain or irrigation (Michael, 2006; Schwab *et al*., 1993). Schwab *et al*. (1993) and Wright and Sands (2001) reported that a definite relationship exists between hydraulic conductivity, depth and spacing of drains.

Drainage coefficient of a drainage system is a function of soil properties, minimum water table depth, depth of the drains, and the spacing between drains.

The primary objective of this study was to determine drain depth and drain spacing that will yield optimum drain discharge and crop yield for a sandy-loam soil. Determination of optimal drain depth and drain spacing is the primary objective in drainage system design, with respect to efficiency and crop yield (Talukolaee *et al.* 2016).

MATERIALS AND METHODS

Description of Study Site

The study was carried out on a sandy-loam soil located beside the Department of Agricultural and Biosystems Engineering Annex Building, University of Ilorin, Kwara State. Experimental plot of 180m² (30m x 6m) was established on the Engineering Research land. The area has an average monthly temperature of between 23^{0}C and 32^{0}C. It lies on latitude 08^0 30'N, longitude 04^0 35'E with mean elevation of 340m above the sea level in the Southern Guinea Savannah Ecological Zone of Nigeria (Adeniran, 2007). Kwara State is a transitional zone between Northern and Western part of Nigeria and is dominated by humid tropical climate except in the extreme North-East characterized by tropical climate. Rainfall distribution pattern is bi-annual, giving a period of long drought (dry season) from October to March. The average annual rainfall is 1,200mm (Akintola, 1986).

Drainage Pipe Installation

The land physical features (Table 1) were carried out such as land size, slope and divided into 16 mini-plots. Drainage pipes installed using singular drainage system approach (Egharevba, 2009). Drainage area was 2x2m² with a buffer zone of 30cm allowed in between the plot. Drains installed at 1m (S_1), 1.5m (S_2), 2m (S_3), 2.5m (S_4) drain spacing and 15cm (D_1), 20cm (D_2), 25cm (D_3) and 30cm (D_4) soil depths. Experimental design was Randomised Complete Block Design (RCBD) replicated four times (Murray and Larry, 2000). The slope along the length was 1.63% and across the length was 7.05%. Drains were installed manually to a specified design for each plot using American Society of Agricultural and Biological Engineers (ASABE) Standards (2006).

Hydraulic Conductivity Measurement

The hydraulic conductivity, K of the soil was determined using the auger hole method. These measurements were used to estimate the hydraulic conductivity. According to Schwab *et al*, (1993), determination of hydraulic conductivity could be done using equation (1) below.

$$K = 523000a^2 (Y_0/Y_t)/ t \quad (1)$$

where; a = Radius of hole (m), Y_0 = Initial water level in the auger at t_0=0,

Y_t = Final water level at t_1 , t = Change in time from t_0 to t_1

The above variables determined were given as:

a = 0.03m, t = 20 sec, Y_0 = 0.69m Y_t = 0.64m

By substituting the values into equation 1, K= 0.39m/day

Water Table Measurement

There is a wide range in the cost of the many methods that have been used to measure water table levels. Cost of monitoring devices is directly related to the frequency with which measurements are taken and to the accuracy required. Methods range from a ruler used to measure water depth in an observation well to electronic sensors attached to data loggers. The method adopted for this study was a ruler to measure the water table level in the observation wells. Average depth of the water table before installation of drains was 1.8m. Groundwater depth measured from the soil surface is about 0.2m. The water table depth at the peak of drainage fell to 1.2m.

Water Application And Drain Flow

The system of irrigation was surface and water was admitted into the experimental plots through a hose into the graduated buckets to determine the volume of water. A watering can of 30 litres capacity was then used in applying the measured quantity of water into each drainage plot. The drain discharge from each plot was measured at field capacity after two to three days.

Soil Moisture Measurement

In determining the soil moisture content of the research plot, 5 samples at a depth 10cm were obtained for each plot. Soil samples were weighed (wet basis) and the values recorded before putting into an oven at a temperature of 250°C. The weight of the oven-dried soil samples were computed using weight of water-soil ratio for the soil moisture content for each treatment plots.

Crop Agronomic Practices

The performance of leafy amaranths (*Amaranthus cruentus*) was studied on sixteen treatment plots. It was planted in December, 1st 2011 and monitored till February, 22nd 2012. Seeds were broadcast on the plots and organic manure (poultry dropping) was applied. The aim of planting *Amaranthus cruentus* was to estimate the relative crop yield per each plot with respect to the drainage design. Leafy amaranths crop was physiologically matured for harvesting 4 weeks after planting. Harvesting was done three times at week 4, week 7 and week 9 across the entire experimental plots and weighed on wet basis separately.

Drain Design

The discharge released by each drain pipe was collected periodically as Q and calculated using equation 2 below.

$$Q = qA/1000 \times 3600 \times 24 \quad (2)$$

$A = L \times S$, $q = 5.5$ mm/day, $L = 1.8$m

$Q_1 = 1.90 \times 10^{-3}\ m^3/s = 0.0019 m^3/s$, $Q_2 = 2.9 \times 10^{-3}\ m^3/s = 0.0029 m^3/s$

$Q_3 = 3.8 \times 10^{-3}\ m^3/s = 0.0038\ m^3/s$, $Q_4 = 4.8 \times 10^{-3}\ m^3/s = 0.0048\ m^3/s$

Discharge Design (Q_d)

In order to solve the problem of siltation or sedimentation, a factor of safety of 30% was introduced according to Schwab *et al*. 1993 in the design;

$Q_{1d} = Q_1/0.70 = 0.0027 m^3/s$, $Q_{2d} = Q_2/0.70 = 0.414\ m^3/s$, $Q_{3d} = Q_3/0.70 = 0.00543\ m^3/s$, $Q_{4d} = Q_4/0.70 = 0.0068\ m^3/s$

Drain Pipe Internal Diameter
Pipe internal diameter was calculated by considering optimum condition of flow as stated in equation 3 below:

$Q_{design} = 50\ d^{2.71}\ i^{\ 0.57}$ (for smooth pipe) (3)
where; $Q_{design} = 0.00686\ m^3/s$, i = 0.0705m/m and
d = internal diameter of the drain pipe (m) = $\{(0.00686/\ (50 \times (0.0705^{\ 0.57})\}^{\ (1/2.71)}$
d = 68.75mm

Internal diameter of 76mm (3 in) Ultra PVC pipe was considered appropriate that very close and available based on ASABE Standards, 2006.Minimum size of 127mm (5 in) for main and sub mains and 76mm (3 in) for laterals.

Design Loads on Conduit
Loads bearing capacity of the conduits was calculated using equations 4 and 5;

$W_c = C_d\ w\ B_d^2$ (4)
Where: C_d = 1.5 (for sand and gravel) by Schwab *et al*., 1993, B_d = 0.24m,
w = loads on the conduit per unit length = 1,922 kg/m
W_c = 1.5 x 1,922 kg/m x (0.24m x 0.24m) = 166 kg/m or 1,660 N/m
The total loads on the conduit per unit length W_c = 1,660 N/m
then; Design load on conduit = Load factor x W_c (5)
=1.5 x1, 660 N/m =2,490 N/m
To allow for variations and bedding conditions, a factor of safety is included, resulting in a design load of 2,490N/m which is sufficient to support the total load of 1,660N/m, since 2,490N/m > 1,660N/m.
The load factor of 1.5 based on bedding condition was selected (Schwab *et al.*, 1993) due to effective movement of farm implement to prevent breakage of the drain pipe.

Design of Drain Spacing and Drain Depth

Computation of wetted perimeter, μ, estimated by equation 6;
Wetted perimeter (μ), $\mu = \pi r_0$ (6)
Where r_0 = internal diameter of the pipe, μ= (22/7) 0.76 = 0.24m
An analytical expression for derivation of equivalent depth (d_e) i.e water table depth below the drain pipe, using equation 7;
$d_e \leq \{\Pi S[9(\ln S/\mu)]\}$ (7)
$de \leq 0.42$
d_e = equivalent depth
Equivalent depth (d_e) is a function of the drain spacing, drain tube radius and depth (d) to the impermeable layer below the drain centres (Chieng, S-T *et al.* 1981).

Drain spacing(S) was calculated using equation 8 adopted from Smedema and Rycroft (1983).

$$S^2 = \{\left(\frac{10Ktd_e}{\mu}\right) [\ln h_o(2d + h_t)/h_t\ (2d + h_o)]\}^{-1} \quad (8)$$

Where;
S= Spacing between the drain laterals (m)
K= Hydraulic conductivity (m/day)
t = Drainage period (day)
d_e = Equivalent depth (m)
μ = Wetted perimeter (m)
h_o = Minimum water table from drain pipe to the soil surface (m)
h_t = Maximum water table from drain pipe to the soil surface (m)
d = Distance from drain pipe to the impermeable layer (m)
Using the values, K = 0.39 m/day, t = 1 day, μ = 1.2m, d = 0.3m, h_t = 1m, h_o = 1.5m
Calculated Drain Spacing ($S_{calculated}$) = 1.30m

The drain spacing of 1m – 2.5m was considered appropriate for sandy loam soil (Schwab *et al.*1993).

RESULTS AND DISCUSSION

Soil Properties of the Study Site
The results from the laboratory processes on physical properties of soil used for the study are shown in Table 1. Soil analysis indicated that the soil contained 61.38% sand, 22.2% silt and 16.42% clay. This meant that the soil was predominantly sandy loam. The soil bulk density was 1.71g/cm^3 and average optimum moisture content at field capacity ranged from 64% to 76% .The soil properties such as water table variations had influence on the drainage discharge and

crop growth based on the result (Adebayo, 2013).

Drain Flow

Results indicate the highest cumulative discharges as 3,420ml for plot S_1D_1, 2,965ml for plot S_3D_2, 2,855ml for plot S_3D_1 and 2,840ml for plot S_1D_2 which represent 10.04%, 8.71%, 8.38% and 8.33% respectively with respect to overall cumulative discharges. Meanwhile, the lowest discharges were 1,275ml for plot S_4D_3, 1,140ml for plot S_4D_2 and 721ml for plot S_4D_4 which represent 3.74%, 3.35% and 2.12% respectively. The best drain depths based on their performances are D_1, D_3, D_4 and D_2 (Fig. 1a) while the best drain spacing are S_1, S_2, S_3 and S_4 (Fig. 1b). Fig. 2 shows the relationship between the mean of discharge and the means of two factors (drain depth, DD and drain spacing DS). From the plot there is a significant difference in the means of $S_4 – S_1$, $S_4 – S_2$, $S_4 – S_3$ and $D_4 – D_1$. Distance between each point shows a significant difference in the means of the factors i.e. the farther the points from the mid-line of the graph, the stronger the significant difference in the means of the factors compared.

Turkey Multiple Comparison of Means at 95% family-wise confidence level for drain spacing (DS) = (S_1, S_2, S_3, S_4); shows that there are significant difference in S_4-S_1, S_4-S_2, S_4-S_3. The Multiple Range Test (MRT) for drain depth (DD) = (D_1, D_2, D_3, D_4) shows that there is a significant difference in D_4-D_1.Meanwhile, MRTs for interaction DS: DD show that there are significant differences. Table 2 is an Analysis of Variance (ANOVA) that shows no significant differences existed between the treatment means of DD and DS ($P \leq 0.05$).

Crop Yield

The highest yields in week 4 are S_1D_2 (43.50g), S_1D_1 (40.72g), S_2D_3 (30.17g) while the lowest yields are S_4D_2 (11.30g) S_4D_3 (10.70g) and S_4D_4 (10.20g). The highest yields in week 7 are S_2D_3 (419.51g), S_1D_1 (368.71g), S_1D_2 (287.49g) and S_2D_2 (266.75g) while the lowest yields are S_4D_1 (138.01g), S_4D_2 (135.12g), S_4D_3 (123.50g) and S_4D_4 (121.10g). The highest yields in week 9 are S_2D_3 (375.52g), S_1D_1 (325.08g), S_2D_1 (321.33g) and S_1D_2 (305.02g) while the lowest yields are S_4D_1 (185.41g), S_4D_2 (164.10g), S_4D_3 (162.50g) and S_4D_4 (159.34g).The statistical analysis performed on the crop yield was homogeneity of variances (Bartlett test) that lead to the ANOVA. The test result gave K-squared = 6.7117 > P-value = 0.08168. The box-plot (Fig. 3) gave the maximum, minimum, the 1st quartile, 3rd quartile and the mean of the yield at different weeks.

The ANOVA (Table 3) gave the P-value of smallest level of significance that lead to the rejection of the null hypothesis of the equality of mean of yields. Interactions of the DD and the weeks are not significant which lead to the rejection of the hypothesis that the means of the yield taken at different weeks are equal.

Fig. 4 compares the mean yield on the factors (DD, DS and WKS), the distance they have between each other determines their relationship to each other. For 7-week and 9-week, P-value (0.12788) > (α = 0.05) shows that the mean yields at 7-week and 9 – week are not significant i.e. are not equal. The relationship between 4 – week and 9-week or 7-week and 9-week shows a great distance from the plot and the P-value supports to reject the hypothesis that the means of yield at 7-week and 9-week are not equal.

CONCLUSIONS

For the four drain spacing and depth used, the best drain spacing according to the study was S_1 (1.0m) > S_2 (1.5m) > S_3 (2.0m) > S_4 (2.5m) while the best drain depths based on their results were D_1 (15cm) > D_3 (25cm) > D_4 (30cm) > D_2 (20cm) in order. Their combined effect based on their discharges show that plots 1m x 15cm (S_1D_1), 2m x 20cm (S_3D_2), 2m x 15cm (S_3D_1) and 1m x 20m (S_1D_2) produced highest drain outflow. Meanwhile, the results of crop yields show that plots 1.5m x 25cm (S_2D_3), 1m x 15cm (S_1D_1), 1.5m x 20cm (S_2D_2) and 1.5m x 15cm (S_2D_1) produced the best yield. The study shows that the lowering of the water table influenced the drain yield and crop yield. In conclusion, drainage system of 1.0m drain spacing and 15cm soil depth performed excellently for optimum discharges and crop yield.

Table 1. Drainage Characteristics and Soil Physical Properties

Drainage Characteristics	Values
Drain area (ha)	0.432 ha
Date of installation	Dec. 2011–Feb. 2012
Drainage machinery	Manual
Drain length (m)	1.80
Drain material	PVC Pipe
Drain Ø (mm)	76
Drain thickness (mm)	2.0
Drain depth (cm)	Vary from 15 – 30
Drain spacing (m)	Vary from 1.0 – 2.5
Drain slope (%)	2.0
Surface slope (%)	7.05
Soil type	Sandy loam

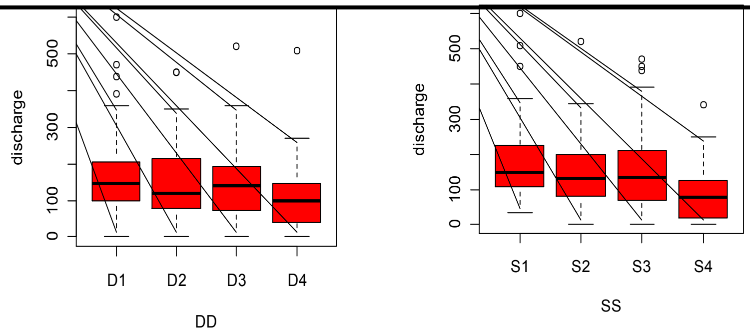
Hydraulic Conductivity (K)	0.39 m/day
Mass density	1.60g/cm^3
Porosity	33.47%
Bulk density	1.71g/cm^3
Field capacity	9.42%

Table 2. ANOVA Table for drain discharge using RCBD

SV	df	SS	MS	F	Pr (>F)
DS	3	305716	101905	10.9554	9.664e-07***
DD	3	132014	44005	4.7308	0.003203**
DS:DD	9	114790	12754	1.3712	0.202335
Residuals	224	20836079302			

Table 3. ANOVA Table for Crop Yield using RCBD

SV	**df**	**SS**	**MS**	**F**	**Pr(>F)**
DS	3	91205	30402	34.1520	1.218e-07***
DD	3	18027	6009	6.7502	0.003026**
WKS	2	469355	234678	263.6283	4.656e-14***
DS: DD	9	26375	2931	3.2921	0.015056*
DS: WKS	6	33442	5574	6.2612	0.0001086**
DD: WKS	6	7661	1277	1.4343	0.255940
Residuals	18	16023	890		



Figs. (1a and 1b): Effect of drain depth and spacing on drain discharge.

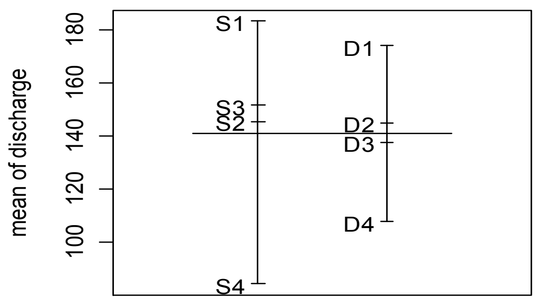
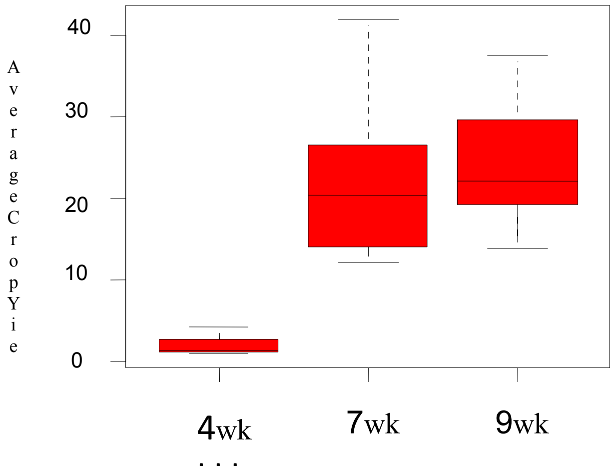


Fig. 2: Graph of mean discharge and the drainage factors.



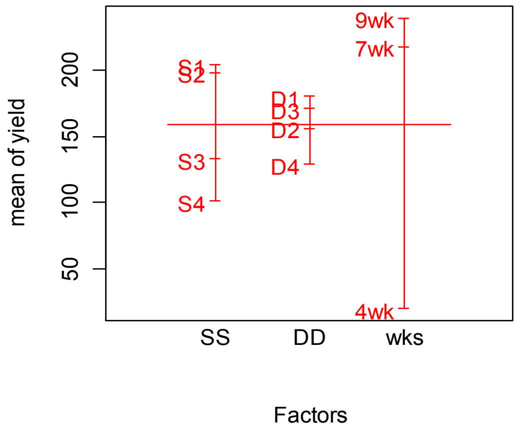


Fig. 3: Graph of average crop yields

Fig .4: Effect of drainage factors on mean yield

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STUDYING THE EFFECT OF SOIL MOISTURE CONTENT AND CUTTING DEPTH ON THE DRAFT REQUIREMENT OF A SINGLE ROW ANIMAL-DRAWN GROUNDNUT DIGGER

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ABSTRACT

The effects of soil moisture content and cutting depth on draft of a single row animal drawn groundnut digger were studied using a spring type dynamometer. The treatments used were two different soil cutting depths (15 cm and 10 cm) and 2 soil moisture content (12.4% db and 5.9% db). The effects of soil moisture content and digger cutting depth on draft measurements were investigated on a groundnut field trial laid out in a 2 x 2 factorial experiment in three replications. Significant differences (P<0.01) were observed between the soil moisture contents used and the implement cutting depth. The result from analysis of variance revealed a significant increase in draft of the groundnut digger implement with increase in cutting depth and decreased soil moisture content. Comparing the mean draft in treatments with Duncan's multiple range tests showed that groundnut digger implement in soil moisture content of 5.9% and cutting depth of 15 cm had maximum draft of 827 N. soil moisture content and implement cutting depth was found to play a significant role in the draft requirement of the groundnut digger.

Key words: *Draft, Cutting depth, Moisture content, Dynamometer.*

INTRODUCTION

Animal power accounts for about 20 percent of agricultural mechanization in developing countries; human power accounts for 70 percent, mechanical power 10 percent. The total number of draft animals in the world has been estimated to be about 400 billion head, mainly in Asia (Havard and Wander 1999). However, Oni (2011) reported thatAnimals commonly used in Nigeria are oxen, mules, buffalos, horses, etc., but work bulls (oxen) are the most common. Farming using animal draught power makes man the manager of farm operation rather than the source of power as is the case in the hand-hoe system. While man is only capable of supplying 0.07 kW on a continuous basis, a pair of working animals (work bulls) is capable of supplying an equivalence of one-tenth of their body weights working continuously for about 3 to 4 hours. (Attanda and Adinoyi 2016).

Animal drawn implements are employed predominantly in the northern part of Nigeria where socio-cultural conditions favour their utilization. The limited duration of work per day, coupled with feed requirements to maintain them, particularly in the dry season, tend not to make their choice a favorable economic proposition (Oni 2011). But According to Philip *et al.* (1988), the use of animal technology for agricultural practices is potentially useful and is also an appropriate means of improving the efficiency of the traditional farming system.The estimated areas under different power source in northern states of Nigeria were reported by Oni (2009) in table 1.

Hailu, (1990) stated that animal traction would increase crop yield through better and timely cultivation and planting as well reduce labor requirement per unit area and allow an increase in the area under cultivation. As labor cost account for over 70% of the total cost of production in most farming operations in rural setting, the search for an alternative source of farm power which will be cheap and affordable to the farmers therefore, became necessary (Arene, 1995).

The force required to pull a tillage implement through the soil is called draft force, the draft force is located at the point where the tool is attached to the power unit, called the hitch.When a tillage implement is pulled through the soil, the power unit must overcome draft forces created by soil resistance. The direction of the draft force is in the direction of travel (ASAE, 2003). Accurate knowledge of draft force is useful for optimal matching of power unit to tillage implement (Upadhyaya 1984). The ASAE standard D497.4 describes draft force as a function of implement type, soil type, implement width, tillage depth and operation speed (ASAE, 2003).The draft of tillage implements, like a plow, is dependent upon such factors as weight of the plow, its shape, sharpness and scouring properties of the plow, angle of draft, character of the soil, skill of the plow- man, presence of different attachments, speed of travel, and size of the furrow (Horse and Mule Association of America, 1946). Similarly, Abubakar *et al,* (2005) carried out a study on the draught requirements of some locally used oxen drawn implements in Zaria. They reported that different implements showed variation on their average draught requirements when tested on a sandy loam soil under same conditions using same pair of oxen.

Table 1: Estimation of Areas under Different Power Sources in Northern State of Nigeria

	Power Source		
	Human	Animal power	Tractor
Number of farmers (Million)	7.5	0.1	0.015
Area cultivated (ha/Farmer/yr)	1.0	5.0	50.0
Total area cultivated annually (Million ha)	7.5	0.5	0.75
Percentage of total area (%)	86.0	5.5	8.5

Source; Oni (2009)

Table 2: Normal Draught Power of Various Animals

Animal	Average weight (Kg)	Approximate draught (Kg)	Average Speed of work (M/s)	Power developed (Kgm/s)	Power developed (HP)
Light horses	400 – 700	60 – 80	1.0	75	1.00
Bullocks	500 – 900	60 – 80	0.6 – 0.85	56	0.75
Buffaloes	400 – 900	50 – 80	0.8 – 0.9	55	0.75
Cows	400 – 600	50 – 60	0.7	35	0.45
Mules	350 – 500	50 – 60	0.9 – 1.0	52	0.70
Donkeys	200 – 300	30 – 40	0.7	25	0.35

Source: (FAO 1969)

MATERIALS AND METODS

Instrumentation

The main instruments used during the field experiment were measuring tape, weighing machine, meter rule, spring dynamometer, and stop watches. The measuring tape was used for layout and marking of the experimental field in to the required plots. It was also used to take the anthropometric measurements of the bulls used during the research work.While Spring Dynamometerwas used to measure the pull on the developed groundnut digger at the two varying soil moisture content and implement cutting depths which were measured by the used of the meter rule.

The stop watch was used to measure and record the time taken to cover each run in seconds for each treatment during operation.

Field determination of draft of the animal drawn groundnut digger

In order to study the effects of soil moisture content and implement cutting depth on draft of an animal drawn groundnut digger implement, experiments were conducted at Agricultural Research and Experimental Farm of Faculty of Agriculture Bayero University Kano (11^0 973″ N, 8^0 415″ E and 444 m above sea level). The soil compositions at the experimental site were 68.8% sand, 19.28% silt and 11.92% clay, while the soil classification shown to be sandy loam. Soil moisture content was obtained using the method described by FAO (1994).

The draft on the developed single row animal drawn groundnut digger was measured using a spring-type dynamometer. This was achieved by fitting the dynamometer in to the towing arrangement that is between the two work bulls and the digger. The two soil moisture contents of 12.4% and 5.9% (M_1, M_2) and two depths of soil cut 15 cm and 10 cm (C_1 and C_2) which are arranged in a 2 x 2 factorial experiment in three replications were chosen for the field study. Each of these treatment has a plot size of 0.75 m wideand 10 m long. Soil samples were collected during the draft experiments to determine the average moisture contents. The samples were weighed using a balance, and the weight of each sample was recorded. Then the samples were placed in an oven maintained at 105°C for 24 hrs. The initial moisture contents 12.4% (C_1) was calculated on a dry weight basis. This procedure was repeated after delaying for 10 days to vary the soil moisture content to 5.9%.

The pull (N) value was read at minimum of three times along each treatment, due to the variations in moisture content and cutting depth. The mean values were recorded for each treatment. Measurements were also taken on the total length between hitch point and the pulling point of harness, height to the pulling point of harness, height of attachment at the implement and from all these measurement, the angle of pull with the horizontal and the horizontal component (Draft) was computed. The draft for each treatment was calculated using equations1 and 2 as given by FAO, (1994).

The results of the draft obtained from the field experiment were subjected to analysis of variance using a statistical software of Genstat 17 edition for the analysis.

$$\sin\theta = \frac{H-h}{L} \qquad 1$$

$$\sin\theta = \frac{1.85-0.6}{2.17} = 0.5760$$

$$\theta = \sin^{-1} 0.5760 = 35.2^0$$

Therefore;

$$\text{Draft} = Pull \times \cos\theta \qquad 2$$

Where;

L = total length between hitch point and the pulling point of harness

H = height to the pulling point of harness

h = height of attachment at the implement

θ = angle of pull with the horizontal

RESULTS AND DISCUSSION

The results obtained from the Analysis of variance of effect of moisture content and cutting depth on draft of the animal drawn groundnut digger implement is presented in Table 3.

The effect of soil moisture contents and cutting depths is highly significant on the implement draft of the animal drawn groundnut digger, Table 3. The mean effects of soil moisture content and cutting depth on the implement draft are further analyzed using LSD as presented in Table 4. A significantly higher mean draft of 740.7 N was obtained at soil moisture content of 5.9%as compared to 551.2 N obtained at 12.4% soil moisture content. The results of cutting depths show that the mean implement draft reduced significantly from 754.1 N at cutting depth of 15cm to 573.9 N at implement cutting depth of 10 cm below the ridge surface. This shows that the deeper the depth of cut, the higher the draft required in pulling the groundnut digger. A similar finding was reported by Kawuyo (2011) which states that draft increased with increase in tillage depth.

The effect of soil moisture content and digger cutting depth on draft of the single row animal drawn groundnut digger is presented in Figure 1. The interactions between soil moisture content of 12.4% and implement cutting depth of 10 cm account for the lowest draft of 421.8 N while, a significantly higher mean draft of 827.5 N was obtained at soil moisture content of 5.9% and implement cutting depth of 15 cm. The result shows that soil moisture content and cutting depth plays a significant role in the draft developed on the implement. Similar results were reported in their respective studies by Majid *et al* (2013), KarimiInchebron *et al* (2012), Naderloo *et al* (2009) and Loukanov *et al* (2005) that implement draught increases by increasing plowing depth and reduction in soil moisture content. While Attanda and Adinoyi (2016) reported that soil moisture content and implement cutting depth plays a significant role in groundnut digging operation.

Table 3: Analysis of Variance for Draft of Implement (N)

Source of variation	Degree of freedom	Some of square	Mean square	F probability.
Replication	2	684.0	342.0	
Moisture	1	107757.1	107757.1**	<.001
Cutting Depth	1	140248.8	140248.8**	<.001
Moisture x Cutting Depth	1	5472.3	5472.3*	0.05
Residual	6	5472.3	912	
Total	11	259634.5		

NS = Not significant
**= Significant at 5% probability level*
***= Significant at 1% probability level*

Table 4: LSD on the Main Effects of Draft Implement (N)

Treatments		
Implement Draft (N) at different soil moisture content (%)	M_1 (12.4 %) 551.2^A	M_2 (5.9 %) 740.7^B
Implement Draft (N) at different cutting depth (cm)	C_1 (15cm)	C_2 (10cm)

	754.1[B]	537.9[A]

Note: Means with the same letter in the same column are not significantly different

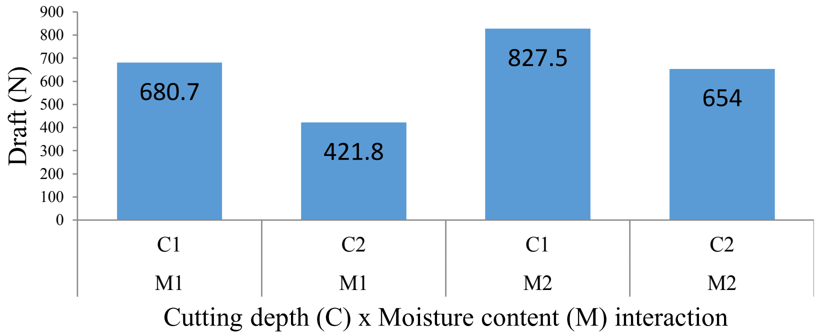

Figure 1: Interaction effect of cutting depth and soil moisture content on implement draft

CONCLUSIONS

On the bases of significant results obtained from the field experiments, the following conclusions can be drawn;

i. Soil moisture content significantly affects the draft requirement of the groundnut digger.
ii. Implement cutting depth was found to affect the draft requirement of the developed groundnut digger.
iii. The groundnut digger implement draft was found to be within the minimum draft requirement for the two work bull used.

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INFLUENCE OF POULTRY MANURE ON AGGREGATE STABILITY AND INFILTRATION RATES OF A DISTURBED SANDY LOAM SOIL

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ABSTRACT

Intensive agriculture is known to cause a decline in soil organic matter content and alter soil structure. An evaluation of soil aggregate stability and infiltration rate is significant in the assessment of soil management practice. The objective of this study was to evaluate the influence of poultry manure on aggregate stability and infiltration rate on a disturbed sandy loam soil in Bauchi at 0 - 20 cm layer. Poultry manure was applied at 0, 10, 15, 20, and 25 Mg/ha at three replications in a completely random design. Four weeks after, aggregate stability and infiltration rates were determined by wet sieving method and double ring infiltrometer respectively. Compare with the control plots, treatment levels showed an increase in aggregate stability of the soil as measured by mean weight diameter (MWD) indices from 0.337mm (control plot) to 0.473 – 0.934mm (for 10 – 25Mg/ha treatments).Infiltration rates as well showed a significant increase as the manure was added from 1.3mm/min for the control plot, to 2.7 – 3mm/min for 10 – 25 Mg/ha treatment levels respectively. The results also indicates that application of poultry manure did significantly ($P < 0.05$) affects aggregate stability and infiltration as determined by ANOVA using the SPSS software. It was then concluded that poultry manure was statistically effective in increasing soil aggregate stability and infiltration rates, but decreasing bulk density from 1.35g/cm3 for control plot to 1.33 – 1.25 g/cm3 for 10 – 25M g/ha treatment levels in the tillage zones.

Keywords – Aggregate stability, Poultry manure, Infiltration rates, Treatment levels, Sandy Loam and Bulk density.

INTRODUCTION

Restoring the native vegetation is the most effective way to regenerate soil health. Under these conditions, vegetation cover in areas having degraded soil may be better sustained if the soil is amended with an external source of organic matter (Paloma, *et al.,* 2016). The addition of organic material to soils also increases infiltration rates and reduces erosion rates (Paloma, *et al.,* 2016).Soil organic matter is important in maintaining soil structural stability, aiding the infiltration of air and water, promoting water retention and reducing erosion (Li, *et al.,* 2007). Soil aggregate stability is one of the main factors controlling topsoil crushability and erodibility. The most important soil properties influencing structural stability are texture and organic matter content (Le Bissonmais, 1996). Intensive agricultural production is known to cause a decline in soil organic matter content, that leads to the alteration of soil structural stability. The addition of exogenous organic matter generally results in the improvement in the soil organic matter content and soil stability (Metzger, *et al.,* 1987).The effects observed on aggregate stability vary with the characteristic of both exogenous organic matter content and the soil. Organic matter increases aggregate stability by enhancement of aggregate hydrophobicity and the inter – particle cohesion. Hydrophobic compound diminish the rate of aggregate wetting, while microbial activity influences both aggregate properties (Lynch and Bragg, 1985). Aggregate analysis is often used in experiments where various tillage methods are applied and then evaluated by examining the resulting stable aggregates. Because of their direct relation to cohesive force, aggregate size and stability are important to understanding soil erosion and surface sealing. Analysis of dry aggregates may be used to estimate possible wind erosion effects, while wet analysis may be more appropriate to evaluate or predict erosion due to rainfall impact and runoff. The stability of wet aggregates can be related to surface seal development and field infiltration, as water stable fraction may restrict water entry from the surface seals (Loch, 1994). Aggregate analysis may aid us to understand most aspect of soil water behavior, including runoff, infiltration and redistribution as well as soil aeration and root growth. Increasingly, aggregate properties are being used in models that predict soil hydraulic properties, including water retention and unsaturated hydraulic conductivity (Kosugi and Hopmans, 1998). Poultry manure contains nutrient elements that can support crop production and enhance the physical and chemical properties of the soil. It increases the moisture holding capacity of the soil and improves lateral water movement and decrease general doughtiness of sandy soil (Amanullah, *et al.,* 2010). Ravikumar and Krishamoorthy, (1983), observed that poultry manure application at 10 t/ha improves the physical properties of soil. Soil physical properties such as bulk density, water holding capacity and percent water stable aggregation were noted to be favorably influenced by poultry waste addition to soil. Mbagwu, (1992) reported that poultry manure significantly decrease bulk density and increase total macro porosity, infiltration capacity and available water capacity. Most soils are vulnerable to compaction, crusting and erosion because of their low organic matter status and unstable aggregates (Mosaddeghi, *et al.,* 2009). The objectives of this study is to determine the influence of different level of poultry manure application on aggregate stability and infiltration rates on a disturbed sandy loam soil in Bauchi state, northeastern Nigeria.

MATERIAL AND METHOD

Field Site Description and Manure

The field experiment was conducted at the research and teaching farm of the Agricultural and Bioresource Engineering Department, ATBU, Bauchi (10o 16 56.1 N, 9o 47 54.1 E), located within Sahel/Sudan vegetation zone of Nigeria. The mean maximum temperature ranges between 20 – 29.3o, while the mean relative humidity and rainfall are between 80 – 90% and 950 -1000mm respectively. The soil type is sandy loam. The poultry manure was collected from smallholder poultry (layer and broiler) farmers within Bauchi metropolitan area. The poultry manure has a high content of litter, which resulted from accumulation of poultry dropping getting mixed up with the litter (sawdust, rice husk wood shavings and straws).

Experimental Procedure

The experimental design was a randomized complete block (RCB) design with three replication (blocks) and five manure treatment level (application rate). The treatment levels include; control – No manure, 10Mg/ha, 15Mg/ha, 20Mg/ha and 25Mg/ha respectively. All the experimental plots were tilled using a hand hoe. After the application of the poultry manure to each plot according to the treatment level, it was then irrigated and allowed to achieve compaction for a period of 30 days.

Soil Sampling

Soil samples for aggregate stability were obtained after the 30 day elapsed in February, 2016. A 5Kg composite air – dry sample (three sub – sample per plot) were taken from the top 20cm of the soil for mean weight diameter (MWD) determination.

Aggregate Stability Test

Water stable aggregate stability was measured using Yoder wet sieving machine, and sieves used had diameters of 4, 2.1, 0.5, 0.25 and 0.053mm. For each field sample triple analysis was undertaken on 100g sub – samples. The sub – samples were spread on the top most sieve of the nest and were oscillated vertically in distilled water for 10minutes. The fractions remaining on the sieve was oven dried at 105oC for 24 hours, weighed and corrected for sand to obtain the proportion of the true soil aggregates. The mean size of aggregate denoted d1 to d5 retained by each sieve was computed and the MWD of the soil samples was then computed according to Nyamangara et al., (2001) as

$$MWD = \sum_{i=1}^{5} di\ Wi \qquad 1$$

Where,
MWD is Mean weight diameter (mm), di is diameter of the ith size fraction and Wi is proportion of the total weight sample occurring in the ith fraction

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Field Infiltration Measurements

The experimental plots was divided into three strips at an equal interval and marked. The infiltration test was carried out at the marked points. Infiltration measurement was conducted using a double ring infiltrometer. The infiltrometer was driven into the soil to a depth of 10cm and a measuring tape was fixed inside the inner cylinder from were readings were taken. Readings were taken at intervals to determine the amount of was water infiltrated during the time intervals with an average infiltration head of 5cm sustained. The infiltration rate was then computed as;

$$Ir = I/t \qquad 2$$

Where,
Ir is infiltration rate (mm/min), I is infiltration (mm) and t is time (minute)

Statistical Analysis

The statistical analysis used in this study was descriptive statistics and analysis of variance (ANOVA) in accordance with SPSS software to determine the effect of poultry manure on soil aggregate stability and infiltration rate. Mean separation using least significant difference (LSD) at $P \leq 0.05$ was conducted to indicate significant F – value.

RESULTS AND DISCUSSION

Aggregate Stability

The soil aggregate stability index (MWD) was observed to be sensitive to change in soil organic (poultry manure) matter content. The MWD for the aggregate of the control plot of 0.337mm was significantly increased as the level of manure application rate increases from 10 – 25Mg/ha to 0.473 – 0.934mm (Table 1). These results indicates an improvement in the structural stability of the sandy loam soil, which correspond to Martens and Frankenberger, (1992) report, which observed a 22% of increase in aggregate stability with the application of 25Mg/ha of poultry manure on an irrigated Arlington soil. Similarly, Metzger et al., (1987) states that addition of exogenous organic matter generally results in the improvement in soil organic matter content and soil stability.

The bulk density of the soil was observed to decrease as poultry manure was amended with the soil with 1.35g/cm3 for the control plot to 1.33 – 1.25g/cm3 for treatment of 10 – 25Mg/ha (Table 1). Mbagwu, (1992) reports that poultry manure significantly decreased the bulk density and increased total and macro porosity, infiltration capacity and available water capacity. Also, Agbede et al., (2008) states that poultry manure significantly reduces soil bulk density and temperature and increase total porosity and moisture content in Nigerian soils. In determining the relationship between poultry manure and aggregate stability of sandy loam soil, Table 2 indicates that the application of poultry manure at different treatment levels has significant ($P \leq 0.05$) effect on aggregate stability of the soil. However, Elwell, (1986) reported that a strong relationship exist between soil organic carbon (C) and water stable aggregates (MWD).

Table 1. Means of Bulk density, Mean Weight Diameter and Infiltration Rates

Treatment Level (Mg/ha)	Bulk Density (g/cm3)	MWD (mm)	Infiltration Rate (mm/min)
0	1.35	0.337	1.30
10	1.33	0.473	2.70
15	1.31	0.639	3.00
20	1.28	0.672	2.70
25	1.25	0.934	2.50

Table 2. ANOVA on effect of poultry manure on aggregate stability.

Source of Variation	SS	df	MS	F	Sig
Between Groups	0.609	4	.152	1.522E5	.000
Within Groups	0.000	10	.000		
Total	0.609	14			

Infiltration Rate

Table 3 shows the results of infiltration rates for the sandy loam soil at various levels of poultry manure treatments. It was observed that the infiltration of water into the soil increased significantly as poultry manure was amended with the soil. The mean infiltration rate for the control plot of 1.3mm/min increases to 2.7 – 3.0 mm/min for the treatment levels. The result was clearly illustrated in figure 1. Martens and Frankenberger, (1992) reported an increase in infiltration rates, resulting from applications of organic materials, while the application of animal manure to the surface 130mm of soil was effective in increasing water infiltration as were the rooting system of cover crops. Ravikumar and Krishamoorthy, (1983) reported that soil physical properties such as bulk density, water holding capacity and water stable aggregation were noted to be favorably influenced by poultry waste addition to the soil. Similarly, Mbagwu (1992) reports that poultry manure increase infiltration capacity and available water capacity. Table 4 indicates that poultry manure application to soil has a significant ($P \leq 0.05$) influence on the soil infiltration. Martens and Frankenberger (1992) in their study showed that infiltration rates were increased more by decreased bulk density in the tillage zone and influenced less by increased aggregate stability.

Table 3 ANOVA on effect of poultry manure on infiltration rate.

Source of Variation	SS	df	MS	F	Sig
Between Groups	5.256	4	1.314	6.317	.008
Within Groups	2.080	10	0.208		
Total	7.336	14			

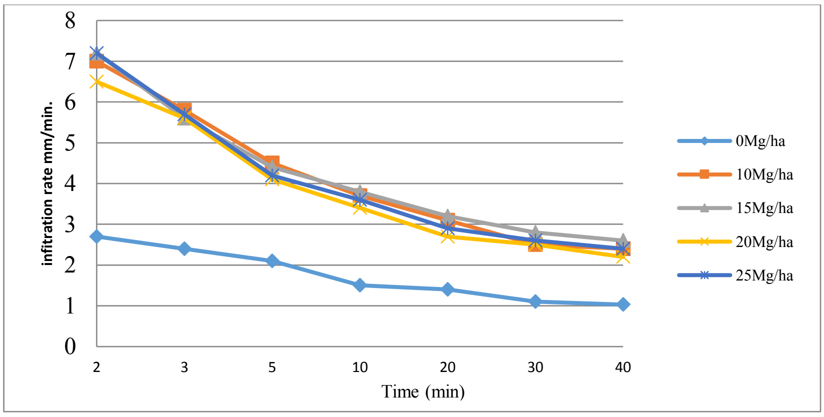

Fig. 1 : Infiltration rates curves of the sandy loam soil under different manure applications.

CONCLUSION

In this study, poultry manure improved the aggregate stability and infiltration rates of the disturbed sandy loam soil as indicated from the results obtained. Poultry manure can effectively be used to enhance physical fertility of soils with low organic matter. Hence, from the study, it can be conclusively stated that application of poultry manure at different levels of treatment restores soil structure by increasing its size aggregates and infiltration, as well decreasing bulk density. However, the application of poultry manure shows significant positive influence on soil physical properties (i.e. aggregate stability, infiltration rate and bulk density).

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SPECIATION STUDY OF HEAVY METAL POLLUTION OF ROAD SIDE DUST IN ILE-IFE, OSUN STATE, NIGERIA.

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ABSTRACT

Speciation study and evaluation of Aluminium-Al, Cadmium-Cd, Copper-Cu, Manganese-Mn, Lead-Pb, and Zinc-Zn in the road side dust of Oluorogbo Road-7, Obafemi Awolowo University, Ile-Ife, was carried out. Subsequently, the level of pollution of these metals and effect on the environment was evaluated using mobility factor, enrichment factor, pollution load index and geo-accumulation index. Sequential extraction procedure was used for the extraction and partitioning of these metals into F1 (water soluble fraction), F2 (exchangeable fraction), F3 (acid extractable carbonate bound fraction), F4 (reducible Fe-Mn oxides and hydroxide fractions), F5 (oxidizable organic matter bound fraction), and F6 (residue and inert fractions). These fractions were analysed in turn using the Atomic Absorption Spectrophotometer (AAS) for heavy metals deposits. From the results, Al, Cd, Cu, Mn, Pb, and Zn present in the analysed fractions fall below the international standard limit. Hence, animals and plants around the site are adjudged safe from heavy metal poisoning.

Keywords: *speciation, heavy metals, road-side dusts, poison and pollution.*

INRODUCTION

Street dusts are generally composed of automobile exhausts particles and particles transported by wind. Heavy metals found in street dust are significant environmental pollutants of growing concern in recent years. The use of leaded fuels gives a boost to the lead level especially in street dust even at the start of 21st century. Metals and metal compounds are natural constituents of all ecosystems, moving between atmosphere, hydrosphere, lithosphere and biosphere (Bargagli, 2000). The distribution of metals in the environment is as a result of natural processes such as volcanic eruption, erosion, wind, spring water, bacterial activity and anthropogenic activities like fossil fuel combustion, moving metal parts (as in vehicles for transportation), industrial and agricultural processes (Florea et al., 2004; Florea, 2005).

Prolonged exposure to metals and metal compounds could result in dysregulation of cellular pathways causing subsequent toxicity (Fitsanakis and Aschner, 2005). Even those metals that are essential, however, have the potential to turn harmful at very high levels of exposure; this is reflection of a very basic tenet of toxicology "the dose makes the poison." Exposure to metals can occur through a variety of routes. They may be inhaled as dust or fume (tiny particulate matter, such as the lead oxide particles produced by the combustion of leaded gasoline). Some metals can be vaporized (e.g., mercury vapour in the manufacture of fluorescent lamps) and inhaled. The toxicity of metals most commonly affect the brain and the kidney, though other health effects occur, e.g. metal, such as arsenic, are clearly capable of causing cancer. An individual with metals' toxicity, even if high dose and acute, typically has very general symptoms, such as weakness or headache (Vieira et al., 2011). Many studies have been reported on the contamination of roadside environments with various elements, especially heavy metals such as Cu, Fe, Cr, Zn, Pb and Ni. These elements are released into roadside environment as a result of combustion, mechanical abrasion and normal wear and tear (Carlosena et al., 1998). Lead, mercury, arsenic, and cadmium are arguably the most important metal toxins from a global perspective. Our immediate environment goes a long way to determine our health status, it is therefore pertinent to evaluate the extent to which industrialization, automobiles, agriculture, and other domestic activities of man impact negatively on our health and environment.

The aims of this study is to estimate the heavy metals contained in the road side dust of Oluorogbo- Road 7 road, to achieve this objectives, the levels of Aluminium, Cadmium, Copper, Manganese, Lead, and Zinc in the road side dust wasevaluated; speciation of each metal was carried out and the mobility and Enrichment factors including the pollution index and geo-accumulation index determined.

MATERIALS AND METHOD

Materials:

Reagents: Hydrogen Fluoride, HClO4, HNO3(Nitric Acid), CH_3COONa (Sodium Ethanoate), $NH_2OH.HCl$, CH_3COOH and $MgNO_3$. Other materials include: distilled water, test tubes, conical flask, Bunsen burner, filter paper, poly-ethene bags, measuring cylinder, homogenizer, 100 µm gauge sieve, grinder and Atomic Absorption Spectrophotometer.

Sterilization and Pre-Treatment of Apparatus

All glass wares used for this analysis were socked in chromic acid solution to oxidize off all the contaminants, they were thereafter washed with soap solution using test tube brush and were then thoroughly rinsed with distilled water, allowed to dry before use.

Location and Suitability of the Study Area

Oluorogbo – Road 7 road is an important entry and exit road to the Obafemi Awolowo University community as it serve as an alternative to Road 1(main gate OAU, Ile-Ife). The above importance of the road alongside its being residential and business area has resulted in a significant number of automobiles plying the route, increased automobile workshops causing more heavy metals released into the environment via indiscriminate disposal of used engine oil, which are known to contain heavy metals.

Experimental Procedure

Collected road side dust was thoroughly mixed to obtain a homogenous mixture, 20g was carefully weighed from the stock and sieved using a 100µm gauge sieve, 10g of filtrate was weighed out and grinded to fine powder. The grounded sample was used for the analysis. The sequential extraction procedure of heavy metals by Tessier et al (1979)was used for the extraction and partitioning of Al, Cd, Cu, Mn, Pb and Zn into exchangeable, bound to carbonate, bound to Fe-Mn oxides, bound to organic matter and residual fractions in this study. 0.5g of air dried and homogenised soil sample of ≤ 2.0mm diameter particle size was subjected to various leaching treatments. The method adopted is a modified method that extracts heavy metals into six geochemical fractions. After each successive extraction, the samples were centrifuged at 1000cycles/min. The supernatants were removed with a pipette and filtered with Whatman No 42 filter paper. The residue was washed with distilled water, hand shaken for 15 minutes before the next extraction. The volume of water for rinsing was left at a minimum to avoid excessive solubilisation of solid materials. The process was carried out in triplicate for each sample, appropriate blanks were prepared and analysed for each extraction type. Heavy metals concentrations in all fractions (F1-F2) were determined using Atomic Absorption Spectrophotometer available at International Institute for Tropical Agriculture, IITA, Ibadan, Nigeria.

Quality Control Work (Blank Determination)

The blank determination was carried out to ascertain the background levels of the analytes in the materials and reagents used for analysis. This was done by running a separate determination under the same experimental conditions employed in the actual analysis of the sample, but excluding the sample. The values obtained from running the blank determinations were subtracted from the analyte values as applicable.

Digestion Methods

Water Soluble Fraction (F1)

1.0g of air dried and powdered soil sample was collected into a polyethylene tube.10.00ml of distilled water was added. The mixture was agitated continuously using mechanical shaker for 1 hour. Then the supernatant solution was centrifuged and decanted to make up to 25.00 ml with the distilled water.

Exchangeable Fractions (F2)

The Residue from F1 was leached at room temperature with 10.00mL of 1.00M MgNO3 at PH 7.0 with continuous agitation for 1 hour. Then the supernatant solution was centrifuged and decanted to make up to 25.00 ml with the distilled water.

Acid Extractable Carbonate Bound Fraction (F3)

The residue from F2 was leached at room temperature with 10.00mL of 1.00M CH3COONa at PH 5, (adjusted with CH3COOH) with continuous agitation for 5 hours and then centrifuged.

Reducible Fe-Mn Oxides and Hydroxides Fraction (F4)

The residue from F3 was leached with 10.00mL of 0.10M solution of NH2OH.HCl (PH adjusted with 25% v/v CH3COOH) at 96oc for 6 hours with occasional agitation. Then the supernatant solution was centrifuged and decanted to make up to 25.00 ml with the distilled water.

Oxidizable Organic Matter Bound Fraction (F5)

The Residue from F4 was leached by adding 3.00mL of 0.02M HNO3 and 30% v/v H2O2. The mixture was heated to 85oc in a water bath for 3 hours. After cooling, 5.00mL of 1.00M CH3COONa was added to the extract with occasional agitation for 3 hours at 85oc. Then the supernatant solution was centrifuged and decanted to make up to 25.00 ml with the distilled water.

Residual and Inert Fraction (F6)

The residue from F5 was digested with a mixture of 8.00mL of 5:1 mixture of HF and $HCLO_4$ in a Teflon beaker. Then the residue was diluted to 25.00mL with distilled water.

Triplicate analyses of heavy metals in the sediment were carried out on both the total metal concentration and sequential extraction samples using Atomic Absorption Spectrophotometer, Bulk scientific 200A model.

Calibration of instrument: Atomic Absorption Spectrophotometer

Standards used to calibrate the AAS were obtained as commercial BDH (British Drug House) stock metal solutions from which working standards were prepared by appropriate dilution. Blank samples (i.e. sample containing all reagents except the soil sample) were carried through all methods, analysed and subtracted from the sample. This was done to check reagent and environmental interferences. The Al, Cd, Cu, Mn, Ni, Pb, and Zn contents were determined by preparing standard solutions of 30, 25, 20, 15,12, 9,7,5,3 and 1µg/mL concentrations of each metal, then the metal content of the sample was determined by automatic interpolation with respect to the calibration graph.

Pollution Indices Determination

Enrichment Factor

Enrichment factor analysis is a method used to differentiate between the metals originating from anthropogenic activities and those from natural procedure and to assess the degree anthropogenic influence (Sutherland, 2000). Enrichment Factor is given by;

$$EF = \frac{\left[\frac{Cx}{CAl}\right] sample}{\left[\frac{Cx}{CAl}\right] Background} \qquad (1)$$

Where, $\frac{Cx}{CAl} sample$ is the ratio of concentration of metal Cx to that of Al CAl in the soil, sample. $\frac{Cx}{CAl} Background$is the reference ratio in the background, these are obtained from shale (Turakian and Wedepohi, 1961).

Geo-accumulation Index (I-geo)

Road side dust pollution indices; geo-accumulation index (I-geo) and pollution load index (PLI) were employed to assess the pollution of metals in the dust of Oluorogbo –Road 7 road. Geo-accumulation index was determined by the following equations according to Müller which was described by:

$$I\text{-}geo = \log 2 \left(\frac{Cn}{1.5\ Bn}\right) \qquad (2)$$

Where, Cn is the measured concentration of heavy metal in the road side dust of Oluorogbo –Road 7 road,Bnis the geochemical background value in average shale (19) of element n. The factor 1.5 is used for the possible variations of the background data due to lithological variations. I-geo was classified into six grades:

i. I-geo ≤ 0 (grade 0), unpolluted.
ii. 0< I-geo ≤1 (grade 1), slightly polluted.
iii. 1 < I-geo ≤ 2(grade 2), moderately polluted.
iv. 2< I-geo ≤3 (grade 3), moderately severely polluted.
v. 3<I-geo ≤4 (grade 4), severely polluted.
vi. 4< I-geo≤5 (grade 5), severely extremely polluted.

Contamination Index

The contamination index of metals in the soil samples was determined using:

$$\text{Contamination Index} = \frac{Metal concentration in the soils}{Background value of the metal} \qquad (3)$$

According to Minolewa *et al,*2011, contamination index are grouped into 4 categories: When CF < 1 indicates low contamination; 1 ≤ CF < 3 refers to moderate contamination; 3 ≤ CF ≤ 6 indicates considerable contamination and CF > 6 implies very high contamination.

Pollution Load Index (PLI)

The Pollution Load Index (PLI) is obtained as Concentration Factors (CF); which is the quotient obtained by dividing the concentration of each metal. The PLI of a place is calculated by obtaining the n-root from the n- CFs that were obtained for all the metals according to Thomlinson et al, 1980:

$$CF = \frac{C_{metal}}{C_{backgroundvalue}} \qquad (4)$$

$$PLI = n\sqrt{(CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n)} \qquad (5)$$

Where, CF is the contamination factor, n is number of metals studied (seven in this study). The PLI value of > 1 is polluted, whereas <1 indicates a state of perfection or absence of pollution, PLI value of 1 implies that only baseline pollutants are present.

Mobility Factor
This is an index of potential mobility of metal ions in soil (Salbu B. *et al.,* 1979; Narwal R.P. and Singh B.R. 1998) determined on the basis of absolute and relative values of fractions (F1 and F2) weakly bound to soil components. The sequential extraction procedure by Tessier *et al.,* (1979) was used to fractionate solid speciation of the metals to enable evaluation of the metal mobility in the sediments using the relationship:

$$MF = \frac{F1+F2}{F1+F2+F3+F4+F5} \times 100 \qquad (6)$$

RESULTS AND DISCUSSIONS

(a) Levels of Metals in Various Fractions.
In this study, the sequential extraction procedure provides information on mobility and bioavailability of metals in the dust through metals partitioning pattern in the dust samples. Heavy metals in both exchangeable (F2) and carbonate (F3) fractions of the road side dust are relatively mobile and are readily available for biological uptake, a process facilitated by the low pH. The exchangeable and carbonate fraction (table 1) account for Al of about 0.4% of the total metal concentration while Cu, Pb and Cd contribution ranges from 1.035 – 17.65%. Mn has the highest value of 57.235%, followed by Zn with 45.35% of the total metal concentration in the fraction. This high concentration of carbonate – exchangeable Mn and Zn suggest that the Mn and Zn are probably due to anthropogenic sources, entered the roadside dust as absorbed ions or carbonate species (Ladigbolu et al, 2014). These limits are lower than the international standard as reported by WHO (1984); hence, constitute no health hazard to both plants and animals. However, long time accumulation of these metals at this reported limit could constitute unknown health/ environmental hazards. Reducible fraction (F4) metals associated with hydrous Fe-oxides and Mn-oxides, co precipitate or sorption onto pre-existing oxides coating. This fraction is a sink for heavy metals under oxidizing condition. Mobility of metals in this fraction is controlled by redox potential; that is relatively small changes in redox potential toward reducing conditions would cause reduction of Fe-Mn oxides and hydroxide species. This would cause dissolution of Fe and Mn oxide mineral, thereby releasing associated metals. Mn has the highest percentage in this fraction (table 1) 32.7% while Zn and Cu showed moderate affinity of 10.5% and 6.25% respectively for the oxides, Pb and Al exhibited low affinity of 0.5% and 0.10% respectively for the same fraction (table1). The predominance of Mn in the reducible fraction is in agreement with the reports of Fernandes, 1997, Li et al., 2001 and Ip et al., 2007. Oxidizable (organic matter / sulphide) fraction (F5) is the fifth fraction of the non-lithogenous phase and metals in this fraction in the dust sample are potentially available. Metals in organic bound fractions are not considered very mobile due to their association with higher molecular weight stable humic substances. Mobility of metals in this fraction can be achieved by decomposition processes and degradation of organic matter under oxidizing condition. Mn & Zn (table1) have higher percentage of their total metal concentration ranges from 14.25% - 4.95% in the fraction while medium to low percentage total metal concentration of Cu (4.95%) and Al(0.05%) were observed in the fraction. Lithogenous / residual (crystal lattice of silicate bound) fraction (F6) is the most stable metal fraction in the soil and dust sample due to the fact that the metals in these fractions are occluded in the crystal lattice of silicate and well crystallized oxide minerals. Metals in this fraction could be taken as a non – available metals and source of these metals in the fraction is natural source that has to do with soil or rock weathering. Less than 50% contribution of studied metals in the residual fraction has shown that natural source is not a major source of these metals in the road side dust of the studied area. The maximum permissible limit of Cd in soil for food crops production is 3μg/g (McGrath et al., 1994; EC, 2001). Cd present in the analysed fractions ranged between 0.30- 1.80μg/g (table 1), which is much lower than the maximum permissible limit of Cd in soil and food crops production. Hence, animal inhabitants as well as plants grown around this sample site are adjudged safe from cadmium poisoning. However, long time exposure to this traceable quantity could result in Cd poisoning arising from accumulation if consumed in food by animals over time. The levels of Mn determined in this study area ranged between 6.25-127.8 μg/g (table 1), this value falls within the range of the background levels (20-3000 μg/g) of Mn in an unpolluted soil. Lead is a highly toxic naturally occurring metal that has always been present in soils, surface and ground waters. Lead content of agricultural soils range between 2-200μg/g (Pais and Jones, 1997). UNEP and BMFT (1983) Standard limit of Pb in the soil for developing countries with respect to the health of vegetation, livestock and man is put at 0.1-2.0 μg/g. In the study, the measured Pb content ranged between 0.15-0.90 μg/g (table 1).
Hence, the studied area is safe from lead poisoning and its related hazards since its level in the soil is lower than the international standard limit.

(b) *Pollution Status*

i. Geo-Accumulation Index
According to the rating of geo-accumulation index is:

I-geo ≤ 0 (grade 0)- unpolluted; 0< I-geo ≤1 (grade 1)- slightly polluted;1 < I-geo ≤ 2(grade 2)- moderately polluted; 2< I-geo ≤3(grade 3)- moderately severely polluted;3<I-geo ≤4 (grade 4)- severely polluted;4< I-geo≤5- severely extremely polluted.

Manganese, Aluminium and Zinc in fractions F1- F6, falls below 0 (table 2), therefore it is unpolluted in these fractions. Copper is found to be slightly polluted in fractions F2-F6, for fractions F1, copper is found to be slightly polluted. Cadmium levels in these extracts range from slightly polluted to extremely polluted.

ii. Contamination Index
CI < 1 indicates low contamination; 1 ≤ CF < 3 refers to moderate contamination; 3 ≤ CF ≤ 6 indicates considerable contamination and CF > 6 implies very high contamination. Table 3 shows that fraction F1-F6 are largely uncontaminated with any metal, except for water soluble fraction (F1) of Cd, which suggests that it is slightly contaminated.

iii. Pollution Load Index
The PLI value > 1 is polluted, whereas <1 indicates a state of perfection or absence of pollution, PLI value of 1 implies that only baseline pollutants are present. The table 4 indicates a state of perfection or absence of pollution.

CONCLUSION

From the speciation study of the area, it was concluded that the roadside dust contained traceable quantity of these heavy metals and was not toxic. Geo accumulation of fractions F1-F6, suggests that Manganese, Aluminium and Zinc in fractions F1- F6, falls below 0, therefore it is unpolluted. Copper is found to be slightly polluted in fractions F2-F6, for fractions F1, copper is found to be slightly polluted.
Contamination Index of the sample show that fractions F1-F6 are largely uncontaminated with any metal, except for water soluble fraction (F1) of Cd, which suggests that it is slightly contaminated. Therefore the studied area is free from heavy metals (Al, Zn, Mn, Cd, Cu, and Pd) poisoning arising from wear and tear from vehicular moving parts and movement. However, long time exposure and accumulation in living tissues could result in heavy metals poisoning of animals. Precautions have to be taken to ensure that these levels do not rise beyond the recommended limits. Cadmium poisoning is observed to have potential of pollution.

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Table 1: Concentrations of heavy metals in fractions, F1-F6.

Heavy Metals	F1(µg/g)	F2(µg/g)	F3(µg/g)	F4(µg/g)	F5(µg/g))	F6(µg/g)
Mn	127.8	7.285	49.95	32.7	14.25	6.25
Zn	38.75	27.45	17.90	10.5	6.25	4.85
Cu	18.25	9.95	7.70	6.25	4.95	2.45
Pb	0.90	0.65	0.55	0.50	0.25	0.15
Cd	1.80	0.95	0.085	0.75	0.45	0.30
Al	0.40	0.25	0.15	0.10	0.05	0.05
Total	187.9	46.535	76.34	50.80	26.20	14.05

Table 2: Geo-accumulation factor F1-F6

Sample	Mn	Zn	Cu	Pb	Cd	Al
F1	-1.230	0.369	1.605	-3.906	5.10	-4.907
F2	-2.04	-0.128	0.729	-4.376	4.178	-5.585
F3	-2.586	-0.745	0.360	-4.617	0.695	-6.322
F4	-3.195	-1.515	0.060	-4.755	3.837	-6.907
F5	-4.396	-2.263	-0.278	-5.755	3.10	-7.907
F6	-5.585	-2.629	-1.292	-6.492	2.515	-7.907

Table 3: Contamination Index of Fractions F1-F6.

Sample	Mn	Zn	Cu	Pb	Cd	Al
F1	0.001278	0.03875	0.091	0.003	1.029	0.001
F2	0.007285	0.0275	0.09975	0.0044	0.035	0.000625
F3	0.004995	0.0179	0.8385	0.0012	0.4857	0.000375
F4	0.000328	0.0105	0.03125	0.0011	0.42857	0.00025
F5	0.001425	0.00625	0.02475	0.00055	0.257	0.000125
F6	0.000625	0.00485	0.01225	0.000333	0.171	0.000125

Table 4: Pollution Load Index of fractions F1-F6.

Fractions	Pollution Load Index
F1 (water soluble fraction)	1.179×10^{-5}
F2 (Exchangeable fraction)	5.46×10^{-6}
F3 (Acid extractable carbonate bound fraction)	4.048×10^{-6}
F4 (Reducible Fe-Mn oxides and hydroxide fraction)	3.56×10^{-6}
F5 (Oxidizable organic matter bound fraction)	6.269×10^{-8}
F6 (Residual and Inert fraction)	1.625×10^{-8}

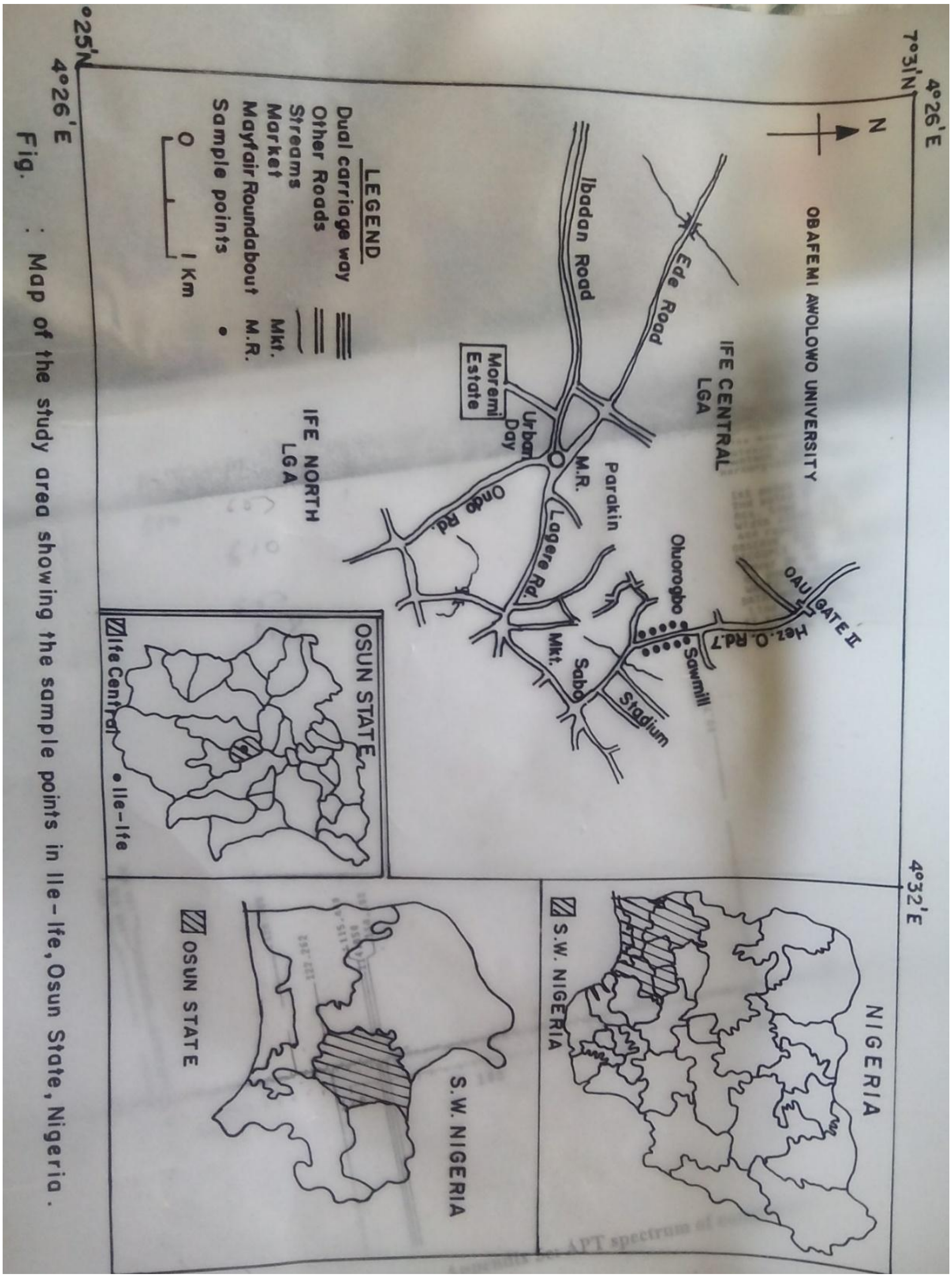

Figure 1: Map of the study area showing the sample points in Ile-Ife, Osun state, Nigeria.

ASSESSMENT OF SELECTED HEAVY METAL PRESENCE IN SOME DUMPSITES IN NIGERIA: A REVIEW

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ABSTRACT

This study attempts to investigate the presence and vertical migrations of Copper (Cu), Manganese (Mn), Lead (Pb) and Zinc (Zn) in some dumpsite with the view to elucidate the risk of contamination to the environment, also to underscore the factorial effects of pH and organic matter on the migration of heavy metals in the dumpsite in relation to soils of selected metropolitan towns. The metal migrations were randomly checked at different depth profile. These heavy metals were determined by Atomic Absorption Spectrophotometer (AAS) other parameters determined includes pH and organic matter (OM) content. Results show contamination of the dumpsites and indicated downward migration of the heavy metals investigated. The relationship between metal concentration against pH and % OM respectively show antithetical relationships. The result of this study shows that there exists risk for the environment due to notable migration of heavy metals across depth profile and that the migrations were also observed to be highly correlated with organic matter content.

Keywords: *ASS, Health Risk, Metal Migration, Municipal Dumpsites, Soil Contamination*

INTRODUCTION

The proliferation of open and unsafe dumpsites containing multiple disposals of domestic, municipal, industrial and medical wastes is a common practice in most cities in Nigeria (Lawan *et al*., 2012). These dumpsites have become feeding ground for diseases breeding animals especially rats, birds, and stray animals; thereby contributing greatly to their nourishment and growth (Bellebaum, 2005; Adewuyi and Opasina, 2015). Another problem of these waste dumps is air pollution which sometimes results in temporary limitations on movement of people and consequently slowing economic activities in urban areas (Elaigwu, 2007).

Furthermore the random deposition of these wastes, consequently leads to adjacent lands getting enriched with heavy metals such as copper (Cu), manganese (Mn), lead (Pb), chromium (Cr), cadmium (Cd), Nickel (Ni), Zinc (Zn) and salts. Thus, dumpsite soils eventually become the repository for metals released from municipal waste sludge and several similar wastes deposited on it (Khairah *et al.,* 2004; Sharma *et al.,* 2007). The severe problems associated with these are the infiltration of leachate into the surrounding environment, subsequent contamination of the land and groundwater (Kumar *et al*., 2002; Lawan *et al*., 2012). Another environmental problem with heavy metals is that they are unaffected during degradation of organic waste and have toxic effects on living organisms when exceeding a certain concentration (Lawan *et al*., 2012). Untreated discharge or partially treated wastes are often discharged into the environment with these Dumpsite soils serving as reservoir for all the metals present in these wastes, this call for an urgent action (Olaitan *et al*., 2013)

Heavy metals occur naturally as chemical elements in the earth's crust and surface soils in varying concentrations (Iyaka and kakulu, 2012), but of concern is their emissions through industrial, man's agricultural and urban activities into the environment and consequently into soils that serve as ultimate sink. Furthermore, the persistent accumulation of heavy metals in soils is of great concern because they constitute health threat and toxicity problems to human life and environment (Ngoc *et al*., 2009).

The action of such metal pollution in relation to agricultural soils can result not only in decreased crop output and quality and hurt human health through the food chain, but also further deterioration of air and water environmental quality (Turkdogan *et al*., 2002, Su and Wong, 2003; Xia *et al.,* 2004). Studies of heavy metal uptake by plants have often revealed their accumulation at a level toxic to human health (USDA, 2000). Generally, uptake is increased in plants that are grown in areas with increased soil contamination. Among the metals, Cd and Zn are fairly mobile and readily absorbed by plants (Cobb *et al*., 2000). Since a survey of trace metal contents might provide some vital information for environmental planning. Vast investigations of agricultural soils have been carried out in some countries and regions in recent years (Onweremadu and Duruigbo 2007; Olatunde *et al*., 2013). Agricultural soil contamination with heavy metals through the use of untreated or poorly treated wastewater from water bodies and the application of organic and inorganic fertilizers and pesticides is part of the most severe ecological problems in Minna (Ahaneku and Sadiq, 2014).

AN OVERVIEW OF HEAVY METALS

Heavy Metals are defined as elements in the periodic table having atomic number more than 20 or densities more than 5 gcm^{-3} generally excluding alkali metals and alkaline earth metals (Sherene, 2010). The environmental problems with heavy metals are that they as elements are undestroyable and the most of them have toxic effects on living organisms when exceeding a certain concentration (Xilong *et al*., 2005). Furthermore, some heavy metals are being subjected to bioaccumulation and may pose a risk to human health when transferred to the food chain (Vijaya *et al*., 2010). Soils, whether in urban or agricultural areas represent a major sink for metals released into the environment from a wide variety of anthropogenic sources (Sherene, 2010).

Sources of Heavy Metals in Soil

According to Sherene, (2010), the sources of some heavy metals are briefly discussed below:
Arsenic (As). It is poisonous and is used in herbicides, cattle and sheep dips and insecticides. Also as a desiccant for cotton crop to facilitate the mechanical harvesting of the crop.
Cadmium (Cd). Soil contamination occurs by the addition of phosphatic fertilizers. (Containing 2-200 mg $Cdkg^{-1}$) domestic and sewage sludge, wear of automobile tyres, lubricants and mining and metallurgical activities.
Chromium (Cr). Wastewater and sludge from dyeing and tanning industries are the major sources of chromium pollution to the environment.
Lead (Pb). Major sources of Pb pollution are exhaust gases of petrol engines, which account for nearly 80% of the total Pb in the air. Soils located near Pb mines may contain as high as 0.5 % Pb content. Apart from minerals, sources of Pb are pesticides, fertilizer impurities, emissions from mining and smelting operations and atmospheric fallout from the combustion of fossil fuels.
Mercury (Hg). Major contaminating sources of Hg are: Hg based funcides, sewerge sludge and atmospheric fall out resulting from combustion of fossil fuels and industrial processes.
Nickel (Ni). Sources of Ni pollution are: metal refining, smelting, burning of coal, and industrial sewage sludge.

Potential Health Risk of Heavy Metals

The toxicity of heavy metals in living organisms is a phenomenon somewhat complex. Toxic effects of a metal depend on a number of factors that often include: rate, exposure time, tolerance of the organism and Environmental conditions. In recent years, the effect of the interaction between heavy metals on the expression of toxicity has been considered very intensely. As a result of the interaction, a given metal may increase or decrease the negative effects of other metal in the organism (Alloway, 2013).

The relative importance of heavy metals toxicity was addressed by Alloway (2013) in terms of food chain contamination. Alysson and Fabio, (2014) identified Cd as the metal with greatest potential to contaminate plants and subsequently to be transferred to animals and humans that eat these contaminated plants either in part or full. This statement is based on the fact that Cd possess health risks to animal and human when present in plant tissue in high concentrations which generally are not phytotoxic and the concentrations of Cd in agricultural soils are increasing in many parts of world due to its inadvertent additions through the use of fertilizers, sewage sludge and soil amendments (Rodríguez-Serrano *et al.,* 2009). Due to the high risk of contaminating the food chain, the risk of Cd to cause toxicity is considered to be high as well. Despite increased concern with Cd, the toxicity risk of other heavy metals should not be neglected (Alysson and Fabio, 2014).

As a result of these complexities of toxic heavy metals in plants, animals and humans that eat such contaminated plants is primarily associated with environmental contamination. Soils may be contaminated with such hazardous elements by the use of sewage sludge. High concentrations of metals in the sludge increase the risks of contamination and therefore toxicity. Thus, it is important to know the chemical composition of sewage sludge (Alysson and Fabio, 2014). Table 1 present the WHO safe limits as regards the minimum and maximum limits for drinking water and their adverse effect.

CONCENTRATION OF HEAVY METAL IN VARIOUS DUMPSITES

Copper (Cu)

Lawal *et al*., (2012) stated that, Cu concentrations across depth profile at the different dumpsites of Table 2; revealed a steady downward increase in Cu concentration in all the dumpsites. The highest concentration of Cu was observed at 100cm depth in dumpsite B (1.65 mg/kg) and the lowest concentration at M and Z sites (1.32 mg/Kg), the obtained average value for soils from these dumpsites in these study is lower than 2.44 and 4.21 mg/kg, respectively reported for farm and fertilizer blending companies by Harami *et al*. (2004) in their study of heavy metal levels in industrial estate of Bauchi, Nigeria. The higher organic matter at these points could also be a contributing factor to the enriched concentration of Cu at these points. Increase in soil organic matter content lead to elevation of soil adsorption capacity hence, enhancing the accumulation of trace metals (Inobeme *et al*., 2014). Organic matters can therefore be considered as an important medium through which heavy metals are incorporated into the soil (Afshin and Farid 2007).

Lead (Pb)
The result of Pb concentrations across depth profile and at the different sites showed the presence of Pb in samples from all the sites. Pb was highest at dumpsite A (502.12 mg/kg) and the lowest at site O1 (0.22 mg/kg). The concentration of Pb obtained in A for both depths is higher than the intervention (210 mg/kg) as stated by DPR-EGASPIN (2002). It is only concentration of site N at the depth of 0-15cm (45.20 mg/kg) that is higher than the target value (35 mg/kg) as stated by DPR-EGASPIN (2002). All other sites are below the target and intervention values for a standard soil. Environmental contamination by Pb can constitute health problems especially in young children, due to its tendency to accumulate in the body and magnify to a toxic level as a result of continuous exposure (David et al., 2008).
Manganese (Mn)
The results of Mn in Table 2 revealed that Mn was highest in concentration at dumpsite B (1.74 mg/kg) and the lowest at site Z (1.36 mg/kg). Similar to Cu and Pb, the concentration of Mn was also observed to be accumulated at 100cm depth level (Lawan *et al*., 2012). The concentration of Mn in the soil sample for the different depths of 0-5cm, 5-10cm and 10-15cm were 13.76mg/g, 15.56mg/g and 19.96 mg/g respectively (Herk, 2012), he further stated that, the concentrations of heavy metals in the soil samples obtained during the his study were higher than the FAO standard. Mn analysis gave mean values of 58.76 mg/kg at Apir Auto Mechanic Workshop Cluster (AP cluster) and 272.2 mg/kg at Adekaa suburb Gboko (GBK cluster) at a depth of (0-40cm) which shows a significant migration of these metals, although the levels found for Mn are above the control levels (Pam et al., 2013).

Zinc (Zn)
The results of Zn with the highest concentration at dumpsite A (66.90 mg/kg) at the depth of 0-15cm which is below soil concentration ranges and regulatory guidelines by Riley *et al*., 1992 and NJDEP 1996 and the lowest at O_2 (0.01 mg/kg). Lawan *et al*., (2012) in their study of vertical migration of heavy metals in dumpsites soil also observed that Zn shows almost constant concentrations in all the locations (surface and 50cm depth). Iyaka and Kakulu, (2012) revealed in their study of heavy metal concentrations in top agricultural soils around ceramic and pharmaceutical industrial sites in Niger State, Nigeria that only few sampling points had zinc contents of less than 10 mg/kg in the soils of the vicinity of the two industrial sites studied. However, higher Zn values were obtained from the pharmaceutical industrial site than in the ceramic industrial site, probably due to the observation that the whole surrounding environment of the pharmaceutical industrial site has been converted to cultivated farmlands. Several researchers such as Andreu and Gimeno (1996) as well as Alloway and Ayres (1997) had stated that agricultural chemicals or materials such as impurities in fertilizers, pesticides and wastes from intensive poultry production constitute the very essential non-point sources of metal pollutants such as Zn in soils. Furthermore, the mean Zn contents of 36±28 and 22±14 mg/kg obtained by Iyaka and Kakulu, (2012) from the soil samples of the pharmaceutical and ceramic industrial sites respectively are within the natural concentration range of Zn in surface soils of 17-125 mg/kg recommended by Ward (1995). However, the obtained mean values from the two industrial sites of their study are less than average value of 42.4 Zn mg/kg reported by Golia *et al*. (2009) in their study of Zn and Cu in surface soils of Central Greece. Nevertheless, higher range Zn content of 30-3782 mg/kg than 5.4-106 mg/kg obtained from this study has been reported by Asaah *et al*. (2006) in their study of surface soils of the Bassa Industrial Zone.

Soil pH and Organic Matter
Table 6, presents the results of soil pH and % OM at the different dumpsites and across the various depth levels of sampling by Lawan et al., (2012). The results revealed that pH levels varied only slightly from one dumpsite to another and the average pH range between 11.05±1.09 to 8.72±0.72. Despite the fact that pH level was generally higher at the REF dumpsite (10.4±0.54) and lowest at dumpsite M (9.66±0.31), there was generally a decreasing trend of pH across depth levels. Soil pH has been identified as a principal factor that affects the mobility and availability of metals in soil (Schulin *et al*., 2007). Inobeme *et al*., 2014 stated that, the pH of the soil ranging from 6.50±0.20 to 8.03±0.20, indicates a slightly acidic to slightly alkaline soil. Such pH values are characteristic of soils in areas were leaching is less pronounced due to low precipitation, resulting in the concentration of base forming cations in the place of acid contributing cations such as Al^{3+} and H^{+} (Akoji, 2010).

Relationship of pH, % OM and Metal migration profile at dumpsites.
Figures 1 and 2 illustrate the relationships between metal concentrations and pH, and metal concentrations and % OM respectively by Lawan *et al*., (2012) in their study of vertical migration of heavy metals in dumpsites soil. The Figures illustrated antithetical relationships; while metal concentrations tend to increase as pH increases the reverse was the case between metal concentrations and % OM.
Lawan *et al*., 2012 stated that, the contamination of the dumpsites was obviously indicated by the high concentrations of heavy metals and the downward migration against the reference site. This shows the presence of metal containing wastes contributing enormously to heavy metal pollution. The result of accumulated metals in soil showed that zinc has the highest value. All the heavy metals (Cu, Pb, Mn and Zn) determined showed higher concentration at dumpsite B, which is due to the fact that this dumpsite is close to the high way and a mechanical workshop that is likely to contribute to the increased level of heavy metals (Abubakar *et al*., 2004 and Lawan *et al*., 2012). The appreciable level of Pb at the REF

site is unclear, but may be due to proximity to unknown previous activities that are not palpable to the deduction in this study. However, it is unlikely to consider the geology of the area as a factor, but the varying concentrations of all metals studied in this work are within the common range (McLean and Bledsoe 1992).
The pH obtained in this study was generally alkaline; consequently the mobility of metal ions may not have been favored completely by the pH. However, there was correspondingly higher concentration of metals as the pH tends towards acidity. Heavy metal cations are said to be more mobile under acidic conditions (Alloway, 1990 and Lawan *et al*., 2012). Other factors, such as gravity, resulting from reoccurrences of heavy rainfall and constant leaching may be attributable. Acidic conditions in soil often enhance the solubility of heavy metals such as Cu, Zn and Pb. Also, the behavior of heavy metals in soil environments is dependent on the chemical speciation and the relative distribution of chemical forms of metals in soil solutions. These in turn influence the available and mobility of these metals in soils (McLean and Bledsoe 1992).
The concentrations of metals are observed to be favored by increase in % OM since it increases the rate of metal ion absorption. The decomposition of the organic components of waste by the action of microorganisms increases the level of organic matter in the dump soil. Organic matter acts as a major adsorbent for metals through the formation of chelates and renders them immobile (Alloway, 1990 and Lawan *et al*., 2012). Organic matter content of the dumpsites was also found to be higher than obtained from a farm land. This indicated that waste contaminated soils have relatively high organic matter content compared with that of non-waste contaminated soils (Shuman, 1991). The profiles of soil OM in this study are consistent with other studies (Dube *et al*., 2000 and Jobbagy and Jackson 2000). The antithetical relationships between pH and OM correspond to the results of other study (Dube *et al*., 2000 and Lawan *et al*., 2012).

CONCLUSION

The result of this study shows that there exists risk for the environment due to notable migration of heavy metals across depth profile. The migrations were also observed to be highly correlated with organic matter content than pH values. There where movement of heavy metals down the soil profile (leaching) to a depth of 15 cm due to application of sewage sludge and waste water from river Ngada were observed (Herk, 2012).

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Table 1: WHO Safe limits in PPM with Minimum and Maximum Acceptable limits for drinking Water and their adverse effects.

S/No.	Heavy Metals	Ground Water		Effect on lifting
		Maximum	Minimum	
1	Lead	0.05	NA	Toxic plumb solvency diseases, burning in mouth, several inflammations in gastro intestinal track, causes paralysis mental confusion, visual disturbance anemia etc.
2	Chromium	0.05	NA	Carcinogenic acuity (cancer), can produce coetaneous and nasal mucous membrane ulcer & Dermatitis, Hexavalent Cr causes lung tumors
3	Copper	1.5	0.05	Astringent taste but essential elements for metabolism, deficiency results is anemia in infants, excess may results in liver damage.
4	Mercury	0.001	NA	Causes minimata disease also causes blue baby disease in Infants the color of skin in baby is turn into blue. Paralysis.
5	Nickel	0.02	NA	May be carcinogenic, can react with DNA. Resulting in DNA damage.
6	Zinc	15	5	Causes Astringent taste & opalescence in water, Essential elements in human metabolism.
7	Iron	0.3	0.1	Promote Iron Bacteria in water, bad Taste, In trace is nutritional.
8	Manganese	0.5	0.05	Produces bad taste, essential as cofactor in enzyme system & metabolism process.
9	Selenium	0.01	NA	Toxic, leads to hair & finger loss, numbness in fingers or toes, causes circulatoryproblems.
10	Arsenic	0.05	NA	Beyond this limit water become toxic, causes skin damage circulatory problem increase risk of skin cancer, (found in ground water in Rajnandgaon district in M.P. also seen very much skin problems in slums area that are mainly depends on ground water source for drinking purpose.)

1 PPM = 1000 PPB, Source; (Akhilesh et al., 2009)

Table 2: Concentration of heavy metals across depth profiles in Maiduguri, Nigeria.

Parameters	Meri M. (cm)			Zajeri Z. (cm)			Bulunkutu B. (cm)		
($mgkg^{-1}$)	0-5	5-50	50-100	0-5	5-50	50-100	0-5	5-50	50-100
Cu	1.32	1.35	1.36	1.32	1.36	1.57	1.41	1.62	1.65
Pb	1.20	1.17	1.32	0.91	0.86	1.29	1.69	1.69	1.74
Mn	1.49	1.51	1.72	1.38	1.36	1.40	1.47	1.49	1.74
Zn	1.67	1.70	1.81	1.52	1.52	1.70	1.77	1.79	1.80

Source: Lawal et al., 2012

Table 3: Concentration of heavy metals across depth profiles in Allahabad, India

Parameters	Nianai N. (cm)			Buxi Badh B2 (cm)		
($mgkg^{-1}$)	0-15	15-30	30-45	0-15	15-30	30-45
Cd	6.86	5.45	3.65	4.24	3.24	2.20
Cr	3.20	2.80	1.40	3.00	2.60	1.20
Pb	45.2	33.24	20.45	24.42	20.12	16.24

Source: Dinesh Mani et al. 2015

Table 4: Concentration of heavy metals across depth profiles in Owerri, Nigeria

Parameters	Otomiri Valley O1 (cm)			Otomiri Hilltop O2 (cm)		
($mgkg^{-1}$)	0-20	20-40	40-60	0-20	20-40	40-60
Zn	0.03	0.12	0.09	0.01	0.26	0.40
Fe	0.30	1.80	0.70	1.30	0.30	1.20
Pb	0.22	0.23	1.12	0.46	0.32	0.93

Source: Enejo and lemoha., 2012

Table 5: Concentrations of heavy metals in Alaba International Market Lagos, Nigeria

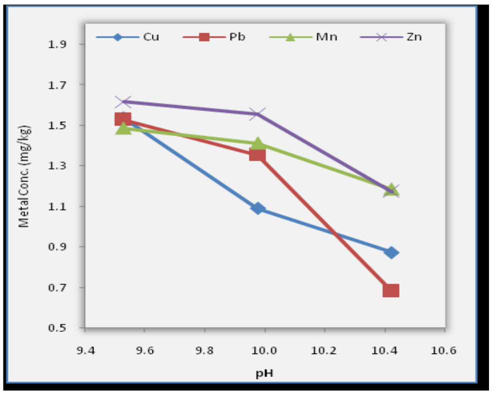
Parameters	(A)	(A)
($mgkg^{-1}$)	0-15 (cm)	15-30 (cm)
Cd	7.82	7.28
Zn	66.90	60.32
Pb	502.12	428.12
Cr	32.65	32.84

Source: Oladunni et al. 2013

Table 6: Mean pH and Organic Matter (% OM)

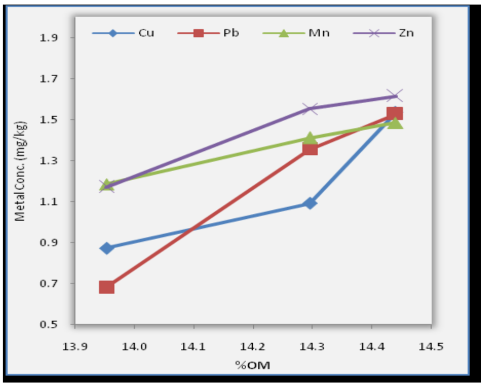
Dumpsites	DEPTH (cm)	pH	%OM
REF	0	11.05±1.09	4.15±0.76
	50	10.2±1.37	4.36±0.43
	100	9.96±0.83	4.42±0.92
B	0	10.34±1.33	21.68±4.88
	50	10.17±1.45	21.87±5.11
	100	10.02±1.59	21.88±4.82
M	0	9.9±1.22	15.93±3.14
	50	9.66±0.91	16.65±2.56
	100	9.42±1.33	17.04±5.22
Z	0	10.41±1.00	14.05±2.38
	50	9.87±1.21	14.3±1.78
	100	8.72±0.72	14.42±2.54

Source: Lawan et al., 2012



Source: Lawan et al., 2012

Figure. 1. Relationship of pH and Metal migration profile at dumpsites.



Source: Lawan et al., 2012

Figure 2. Relationship of % OM and Metal profile at migration dumpsites.

TILLAGE EFFECTS ON HYDRAULIC SOIL PROPERTIES IN A SANDY ENVIRONMENT

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ABSTRACT

Hydraulic soil properties can be used for the prediction of physical water flow processes in soils. The tillage practices adopted were disc ploughing (DP), disc harrowing (DH) and zero tillage (ZT). The three tillage practices were replicated thrice in a randomised complete block design. Hydraulic properties such as water content, infiltration rate, sorptivity, hydraulic conductivity, macroscopic capillary length, mean pore size and characteristic time in relation to gravity in the sandy environment were investigated for two years (2009 and 2010). Infiltration parameters and hydraulic properties were determined using the disc permeameter. Soil physical properties such as particle size distribution, bulk density, moisture content and porosity related to the tillage practices were also investigated. Mean bulk density were 1.54, 1.38 and 1.39 g cm^{-3} for DH, DP and ZT respectively. Saturated hydraulic conductivity ranged from 14.94 to 28.38 mm hr^{-1} for ZT, 17.77 to 19.35 mm hr^{-1} for DP and 11.44 to 46.24 mm hr^{-1} for DH. Mean sorptivity values for ZT, DP and DH under saturated flow condition were 10.05, 8.23 and 10.34 mm hr^{-1} respectively ($P<0.05$). It was observed that the tillage practices had no significant effect on the soil physical and hydraulic properties investigated.

Keywords: *Soil Hydraulic Properties, Soil physical properties, Soil tillage, Tillage*

INTRODUCTION

Tillage being a soil management practice involves the agricultural preparation of the soil by mechanical agitation of various types such as digging, stirring, and overturning (Dada *et al*., 2014). Tillage practices have the ability to influence hydraulic properties in soils due to the change in configuration and the soil fabric by physical manipulation. Reports have shown that tillage alters the structure or macroporosity of many topsoil layers and their hydrophysical properties thereby modifying the soil water movement or flow (Moret and Arrue, 2005). Hydraulic properties help in controlling water infiltration and surface runoff and it is dependent on soil structure and texture which can be aided by tillage practices (Fuentes *et al*., 2004). These hydraulic soil properties are important in revealing the physical processes in both saturated and unsaturated zones in the soil. McGarry *et al*., (2000) reported that saturated hydraulic conductivity was not consistent across locations and soils for instance high values of hydraulic conductivity were observed on an alluvial soil in the semi-arid zone under no tillage relative to tilled treatments and this was due to the sizes of the macropores while others reported low hydraulic conductivity values under no tillage (Evett *et al*., 1999). Some other studies revealed that reduced tillage when compared with mouldboard ploughing provided the highest hydraulic conductivity due to differences in pore size distribution (Moreno *et al*., 1997) and despite the fact that during tillage there is a destruction of macropores (Malone *et al*., 2003), hydraulic conductivity has been reported to increase in soils that have just been recently tilled and this can be attributed to the increase in number of active mesopores (Messing and Jarvis, 1993). Khan *et al*., (2001) reported that geometry of pore space, changes in continuity, size and extent of pores in soil depends on the type of tillage operation carried out and this affects the ability of such soil to retain and transmit water.

MATERIALS and METHODS

Experimental Site Description

The site for this project was situated in the Federal University of Agriculture Abeokuta (Latitude 7° 14' North and Longitude 3° 25' East), Nigeria. Common cropping practices in this area are disc ploughing, disc harrowing, ridging and zero tillage. The land was demarcated into nine (9) plots and the intended tillage practice (treatment) was established on each. The tillage practices were divided on the plots using a Randomized Complete Block Design (RCBD) which involved three replicates of three tillage practices. Each plot had a dimension of 10m by 8m, with 3m alley between plots and from the boundary which acted as a buffer (Figure 1) allowed for tractor passage and turning during the establishment of tillage practices. Hydraulic soil properties were determined using the disc permeameter (Figure 2).

Investigated parameters

Moisture content: This was determined on all the tillage plots. The soil samples were collected in cellophane bags, weighed moist and oven dried at 105°C until constant weight for about three days of ten hours daily power supply.

Moisture content was determined by the equation:

$$\theta g = \frac{Mt - Ms}{Ms} = \frac{Mw}{Ms} \qquad 1$$

where
θg is gravimetric moisture content (%)
Mt is total mass of wet soil (g)
Ms is mass of dry soil (g)
Mw is mass of water (g)

Bulk density: Bulk density samples were taken from each tillage plot to depth 10cm using cylindrical cores (Blake and Hartge, 1986) 7 cm diameter x 10 cm height. Each of the samples were transferred into a moisture can, weighed and oven dried at 105^{o}C until constant weight for about three days of ten hours daily power supply. The samples were reweighed to determine the mass of dry soil. Mathematically, bulk density was calculated using the relation:

$$Bd = \frac{Wdry}{Vol} \qquad 2$$

where:
Bd = dry bulk density (g cm^{-3})
Wdry = weight of the dried soil sample (g)
Vol = total volume of the soil core sampler (cm^3) = $\pi r^2 h$.
where r is radius of soil core and h is the height (cm)

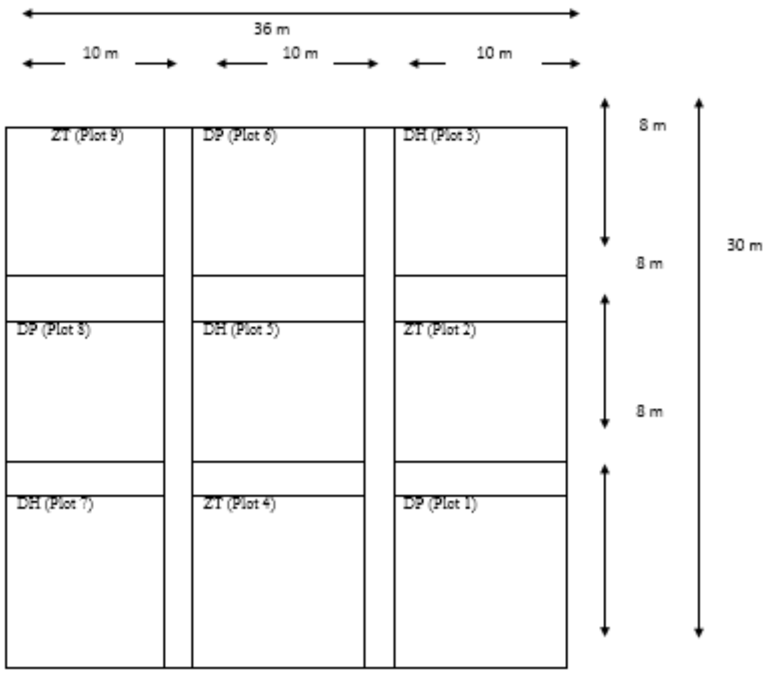

Figure 1: Plot layout in metres
Key: ZT- Zero Tillage
DP- Disc Ploughing
DH- Disc harrowing

Saturated Hydraulic Conductivity: Saturated hydraulic conductivity was determined using the disc permeameter (Perroux and White, 1988). It consists of two water towers over a circular base and water flows out through a nylon mesh. The smaller tower creates the tension that is applied to the soil (Figure 2). The Wooding's equation (1968) was used for the determination of the hydraulic conductivity (K_0) due to the three dimensional movement of water in the soil.

$$K_0 = \frac{q}{\pi r^2} - \frac{4bSo^2}{\pi ro(\theta o - \theta n)} \qquad 3$$

where
q is the steady state water flux,
r_o is the radius of the disc permeameter,
S_o is sorptivity in mm hr^{-1}
θo is the moisture content at the supply potential in %
θn is the initial moisture content in %.

The dimensionless constant, b (0.55) is usually used for field soils and it lies between ½ and $\frac{\pi}{4}$. (Warrick and Broadbridge, 1992).

Figure 2. Disc permeameter on a zero Tillage plot

Sorptivity: Cumulative infiltration as given by (Phillip, 1987) is represented thus:

$$\frac{Q}{\prod r2} = S_o t^{1/2} \qquad 3$$

where
Q is the total volume of water infiltrated.
t is the time from commencement of infiltration in hours
S_o is the slope of cumulative infiltration versus square root of time (t) which represents sorptivity
Steady State Flow: This was determined by plotting the cumulative infiltration with time during the last stage of the infiltration.

Macroscopic Capillary Length: The macroscopic capillary length was determined from the relation below:

$$\lambda c = bS_o^2/[(\theta o - \theta n) K_o] \qquad 4$$

where:
λc is the macroscopic capillary length (mm)
b is a parameter close to 0.55
S_o is Sorptivity (mm hr^{-1})
θo is final moisture content (%)

θo is initial moisture content(%)
K_o is hydraulic conductivity (mm hr^{-1})

Mean Pore Size: Soil structure index was defined by the frame-weighted mean pore size λ_m (White and Sully, 1987) which is inversely proportional to λc ; a K-weighted mean potential that is related to the characteristic pore dimension (λ_m) by the equation:

$$\lambda_m = \frac{\sigma}{\rho g \lambda c} \quad 5$$

where
λ_m is mean pore size (mm)
σ is the air/soil-water surface tension(0.073 N m^{-1})
ρ is the density of soil water (1000 kgm^{-3})
g is the acceleration due to gravity (9.8 m s^{-2}).

For pure water at 20°C and for the purpose of this study, the relationship between λ_m and λ_c using Laplace's capillary rise formula (Phillip, 1987) was:

$$\lambda_m = \frac{7.4}{\lambda c} \quad 6$$

Characteristic Time Related to gravity (Tgrav**):**

Philip (1969) defined the characteristic time related to gravity (*Tgrav*), as:

$$(Tgrav), = \left[\frac{So}{Ko}\right]^2 \quad 7$$

Where
Tgrav is the characteristic time in relation to gravity (hr)
So is Sorptivity in mm/$hr^{0.5}$
Ko is the hydraulic conductivity in mm/hr.

RESULTS and DISCUSSION

Soil Physical Properties

The particle size distribution as determined by the hydrometer method of Gee and Bauder, 1986) using sodium hexametaphosphate as dispersion agent revealed that the soil was sandy. There was prevalence of gravel in the study area as observed visually. Sand content was generally high in all the tillage plots with values ranging from 88.2 to 89.05 % during the two years of experiment. Bulk density was relatively consistent across the tillage treatments for the two years ranging between 1.52 to 1.55 g cm^{-1} though there was a slight increase in the second year which can be attributed to the natural settling of the sand particles. Porosity as determined from bulk density values using a particle density of 2.65 g cm^{-1} was high in all the plots with values ranging from 41.64 to 42.64%. pH values revealed that the soil was moderately acidic in all tillage plots. In all tillage treatments, there was no significant difference in the soil physical properties.

Table 1. Mean values of Physical properties as influenced by tillage

Year	Plot	pH	Particle size Distribution (%)			Bulk density (g cm^{-1})	Porosity (%)
			Sand	Clay	Silt		
2009	Disc Harrowed	6.3	88.2	3.4	8.4	1.43	41.64
	Disc Ploughed	6.4	89.3	4.2	6.3	1.31	42.64
	Zero Tillage	6.2	89.4	5.2	5.4	1.35	41.89
2010	Disc Harrowed	6.3	89.05	6.10	4.85	1.53	41.65
	Disc Ploughed	6.3	88.5	6.00	5.5	1.45	42.64
	Zero Tillage	6.2	88.8	6.12	5.08	1.42	41.89
LSDP≤0.05							
Year		NS	NS	NS	NS	0.14	NS
Tillage Practice		NS	NS	NS	NS	0.41	NS
Year x Tillage Practice		NS	NS	NS	NS	0.92	NS

Soil hydraulic properties as influenced by tillage

In the two years under consideration, all the tillage treatments had a final moisture content within the same range 20-22% which is an indication that the soil moisture regime within the study area is fairly consistent and there was no significant effect of year and tillage practice on moisture content P<0.05. Bulk density ranged from 1.31to 1.53 g/cm^{-3} and disc harrowed plots despite the level of pulverization had the highest value of 1.43 and 1.53 g/cm^{-3} for the two years respectively. The higher bulk density observed on disc harrowed plots in comparison to other tillage practices can be attributed to the compaction effect during tillage. Saturated hydraulic conductivity was relatively consistent in 2009 but increased in the following year on disc harrowed and zero tillage plots 11.44 to 46.24 mm hr^{-1} and 14.94 to 28.38 mm hr^{-1} respectively. There was no increase on disc ploughed plots in the two years considered which can be as a result of the presence of organic matter and less compaction on disc ploughed plots thereby reducing the rate of hydraulic conductivity in the sandy soil. In 2010, saturated hydraulic conductivity were generally high when compared to values obtained in 2009, with disc harrowed plots having the highest value of 46.24 mm/hr giving an indication that the soil with time had better water absorption potential and ability to hold more water (Table 2). This implies that under irrigation processes, disc ploughed plots will allow more water to sustain crop growth despite the fact that bulk density values were generally high compared to year 2009. The influence of tillage practices on sorptivity showed that disc ploughed plots had consistently low values for the two years (7.71 and 8.74 mm hr^{-1}) but the disc harrowed plot in 2009 had the lowest sorptivity value (6.67 mm hr^{-1}). High sorptivity values in soils are generally attributed to the effect of sand and large pore spaces. Mean pore sizes which revealed the sizes of pores that were hydraulically functioning was higher on disc ploughed plots in 2009 (0.66 mm) but reduced in 2010 (0.23 mm) but the effect of year and tillage did not have any significant effect on the pores. Macroscopic capillary length was highest on zero tillage plots with values as high as 163.22 mm in 2009, 86.61 mm and 22.74 mm for disc ploughed plots and disc harrowed plots respectively (Table 2). The high values of the macroscopic capillary length observed on the zero tillage plots gave an indication of the capillary flow dominating more than the gravitational flow and the fact that more continuous pores were involved in the transport process. The macroscopic capillary length was very high in 2009 on zero tillage plots (163.22 mm) but there was a major reduction in 2010 (38.26 mm) which can be attributed to the pores being hindered or blocked by smaller soil particles during splash erosion from intermittent rainfall. The characteristic time in relation to gravity which is an indicator of the time at which gravity and sorptivity were both contributing to the flow revealed that zero tillage plots had the highest times compared to other conventional tillage practices. In 2009, the characteristic time in relation to gravity under saturated soil condition was highest on zero tillage plots with value 1.216 hours (1 hour 13 minutes) while disc ploughed plots and disc harrowed plots had value 0.858 hours (51 minutes) and 0.362 hours (22 minutes) respectively. Similar result was observed in 2010 with values of the characteristic time in relation to gravity being high on zero tillage plots with values of 0.67 hours (40 minutes) while disc ploughed plots and disc harrowed plots had values 0.31 and 0.35 hours (18 minutes; 21 minutes) respectively (Table 2).

Table 2. Tillage effects on hydraulic soil properties

Year	Plot	Initial moisture content (%)	Final moisture content (%)	Bulk density (g cm^{-3})	Saturated Hydraulic Conductivity (mm hr^{-1})	Sorptivity (mmhr^{-1})	Steady state flow (mmhr^{-1})	Mean pore size (mm)	Macroscopic capillary length (mm)	Characteristic time in relation to gravity (Tgrav) (hr)
2009	Disc harrow	13.06	20.60	1.43	11.44	6.67	14.80	0.33	22.74	0.36
	Disc plough	12.77	23.84	1.31	19.35	7.71	26.47	0.66	86.61	0.86
	Zero Tillage	17.08	21.44	1.35	14.94	10.89	33.30	0.14	163.22	1.22
2010	Disc harrow	10.89	21.72	1.53	46.24	14.01	87.58	0.29	39.70	0.35
	Disc plough	14.37	21.55	1.45	17.77	8.74	26.70	0.23	43.85	0.31
	Zero Tillage	13.56	21.78	1.42	28.38	9.22	36.76	0.30	38.36	0.67
LSD≤0.05										
	Year	0.53	0.91	0.14	0.16	0.33	0.12	0.43	0.35	0.43
	Tillage practice	0.46	0.87	0.41	0.72	0.70	0.44	0.38	0.56	0.58
	Year X Tillage practice	0.60	0.84	0.92	0.39	0.27	0.14	0.20	0.54	0.86

CONCLUSION

The effect of conventional and conservation tillage practices on hydraulic and physical soil properties were studied for two years in a sandy soil. The study revealed that despite the level of tillage on the soil, there was no significant effect on the hydraulic properties of the soil which was a function of the soil sandy state. This study is similar to may researchers who stated that sorptivity was significantly affected by soil properties such as bulk density and soil texture (Lien, 1989) Based on this study it is recommended that farmers who practice disc harrowing as a form of tillage or agricultural lands that have high percentage of sand, can practice drip irrigation system to increase the water use efficiency of their crops and to avoid deep percolation and seepage of irrigation water and the use of liquid fertilizers can easily be applied through the drip system of irrigation on such soils.

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ASSESSMENT OF HEAVY METAL POLLUTION IN SOME NIGERIAN SOILS: A REVIEW

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ABSTRACT

Nigeria is one of the fast developing African Nation with a population of about 170 million. Over the years, industrialization, urbanization and agricultural activities have generated great amount of waste in the societies, about 0.57 kg/capital/day is generated in around Nigerian Cities. It has being noted that municipal waste contains heavy metals and their accumulation contaminates agricultural soil. This paper reviews the various sources of soil contamination, heavy metal concentration and its related health effects. A long term exposure and accumulation above the acceptable levels of this metals whether due to natural or human factors may leads to environmental and health problems. Residue of cadmium (Cd), nickel (Ni), copper (Cu), lead (Pb), arsenic (As), chromium (Cr), tin (Sn) and zinc (Zn) in soil above Standard level requirement are toxins in the environment, polluting the soil.

***Keywords**: Heavy metals, contamination, soil, health risk, environment.*

INTRODUCTION

Due to increasing population growth, agriculture, industries and urban infrastructures in Nigeria, considerable degradation of the environment is occurring. Heavy metals are being release into the soil as a result of human activities to meet the everyday demand for life. The occurrence of heavy metals in soil can be of natural or as a result of human activities. The human activities include mining, smelting, domestic waste and various Industrial activities and they are the major source of soil toxin. The direct activities of extraction, processing for industrial and consumer use contributes to the mobilization of heavy metals into the soil. According to Yahaya *et al*, (2009) and Edorh (2007) the situation of heavy metal pollution is more worrisome in the developing countries where research efforts towards monitoring the environment have not been given the desired attention by the stakeholder. Industrial scale mining activity is comparatively low in Nigeria, yet at this level of mining, the nation is increasingly becoming exposed to the unwanted ecological effects of heavy metals (Olatunji and Osibanjo, 2012).

Heavy Metals has being defined by several researchers, Amo- Asare (2012) defined heavy metals as any metallic chemical element that has a relatively high density (density higher than that of water) and is toxic or poisonous at low concentrations. as elements in the periodic table having atomic number more than 20 or densities more than 5g/cm3 (Morris, 1992; Lozet and Mathieu, 1991). Individual metals and metal compounds can impact human and aquatic health. Five common heavy metals are discussed in this review: arsenic, cadmium, chromium, lead, and mercury. These are all naturally occurring substances which are often present in the environment at low levels and if in larger amounts they are dangerous, health risk due to heavy metal contamination of soil has been widely reported (Eriyamremu et al, 2005; Muchuweti et al, 2006; Satarug et al, 2000).

The use of dumpsites as a farmland is a common practice in urban and sub-urban centre in Nigeria because of the decayed and composted wastes enhances soil fertility (Ogunyemi *et al*, 2003). When agricultural soils are contaminated, these toxins are taken up by plants and accumulate in their tissue. Animals that graze on such contaminated plants and drink from polluted waters as well as marine lives that breed in heavy metal polluted waters also accumulates such metals in their tissue and milk (Garbarino *et al*, 1995). Industrial, agricultural and municipal activities have all resulted in soil and groundwater pollution by a variety of contaminants (Sabri, *et al.*, 2013, Oguzie *et al.,* 2002, Lawson, 2011, Lee *et al*., 2001, Vidal, *et al*., 2000, Speir *et al.*, 2003, Remon, *et al*, 2005) such heavy metals as cadmium (Cd), nickel (Ni), copper (Cu), lead (Pb), arsenic (As), chromium (Cr), tin (Sn) and zinc (Zn) and so on which end up in the soil as the sink when the leached out from the dumpsites (Yahaya *et al*, 2009). This Contaminated soil can be a primary route of human exposure to (Nabulo, 2010) heavy metals which is viewed as an international problem because of the effects on ecosystem in most countries. (Egila, *et al*, 2014).

In Nigeria the situation is no better by the activities of most industries and populace towards waste disposal and management which usually lead to increasing levels of pollution of the environments. Many studies have shown municipal refuse may increase heavy metal contamination in soil and underground water (Okoronkwo *et al*, 2005, Okoronkwo *et al*, 2006) which may have effects on the host soils, crops and human health (Reyes-Gutiérrez et al., 2007). Thus the environmental impacts of municipal refuse are greatly influenced by their heavy metal contents. (Egila *et al*, 2014). However, while total heavy metal contents is a critical measures in assessing risk of refuse dumpsite, total metal content alone does not provide predictive insight on mobility and fate of the heavy metal contaminants (Uba *et al*, 2008), Thus it is the chemical or species of the heavy metal that is an important factor in assessing their impacts on the environment. This is because it is the chemical form of the heavy metal that controls its mobility (Norvell, 1984).

The strategy for minimisation of the effects of heavy metals in waste is partly to reduce today and future environmental and human exposure to the heavy metals in the waste, partly to reduce the content of heavy metals in products marketed.

SOURCE OF HEAVY METALS

In arable lands in most countries, the source of heavy metal include natural source, mining, smelting, agrochemicals and sewage sludge applications, and livestock manure uses. Heavy metal in waste is primarily a result of the intended use of heavy metals in domestic, agricultural and industrial products. At the end of their useful life all products will end up in waste to the extent, they are not attractive for recycling. These metals may also be lost to waste during production and use phases. Losses in the manufacturing process are often disposed of as manufacturing waste, while products may be exposed to wear and tear inclusive corrosion during the use phase (European Commission, 2002).

Municipal Waste

Municipal soils receive loads of noxious waste than the sub-urban or rural areas due to the concentration of anthropogenic activities of urban settlements (Komarnicki, 2005; Lee *et al*., 2006; Srivastava and Jain, 2007). According to Adelekan and Alawode (2011) research carried out on various municipal refuse dumps site in Ibadan Nigeria shows elevated values of Pb, Cd, and Cr in soils at the refuse dumps. Mustapha *et al* (2015) reported a high level of contamination of the soil in various dump site in Kano State, Nigeria, the concentration of most of these metals have exceeded the permissible level. Other researches have recognised the occurrence of some trace element in municipal and industrial effluents discharged into the municipal streams, and in the waters used for irrigation (Binns *et al*., 2003; Dawaki and Alassan, 2008). Maharazu (2010) evaluation in Kano, Northern Nigeria reported the concentration and accumulation of Cd to be seriously noticeable in both Domestic source pollution and Industrial source pollution where the values was close to the allowable limit of 3.00 mg/kg in the Industrial source pollution(2.94 mg/kg) and even above in the domestic source pollution (3.06 mg/kg).

Industrial Activities

Refinery and petrochemical plants generate solid waste and sludge composed of organic, inorganic compounds including heavy metals (Uzoekwe and and Oghosanine, 2011). Amadi *et al*, (2014) also reported the contamination of the soil and groundwater in parts of the surrounding environs' of the Kaduna refinery, the concentrations of the heavy metal were found to exceed the recommended maximum permissible limit. Their enrichment were similar in both soil and groundwater in the order of Fe>As>Cu>Zn>Pb>Cr>Cd>Mn. Due to the ineffectiveness of purification systems, waste water may become dangerous, leading to the accumulation of toxic products in the receiving water bodies with potentially serious consequences on the ecosystem. (Bay et al., 2003, Amadi *et al*, 2014). In Nigeria, Pb in petrol is banned, but with the recent importation of petroleum products into the country, the source may not be fully verified can also constitute a source of Pb introduction into the environment (Edori and Edori, 2012).

At Automobile Mechanic Villages in Ibadan, Adelekan and Abegunde (2011) research shows high level of soil contamination of various heavy metals in different soil and at different depth. According to Idugboe *et al*, (2014) research on an auto-mechanic villages in Benin City, Nigeria, heavy metal analysis of the soils in the three stations revealed the presence of Iron(Fe), Zinc(Zn), Manganese(Mn), Lead(Pb), Copper(Cu), Cadmium(Cd), Chromium(Cr), Nickel(Ni) in the order of decreasing concentration in the soils of the auto-mechanic villages. The concentrations of heavy metals in both soils were considerably higher than those of the control and were above the maximum allowable limits of NESREA, 2007 and WHO, 2007.

Olatunji and Osibanjo, (2012) researched the level of heavy metal concentration around the Itakpe Iron-ore Mining Field, Itakpe, Kogi State, Nigeria and reported that the concentration levels of Cd, Mn, Cr, Ni, Cu, Zn and Pb in soil around Itakpe iron-ore deposit and industrial area were low and within natural concentration levels. Thus the soil around Itakpe iron ore deposit and mining field are yet to be impacted negatively by heavy metals. There is a need to develop an environmental monitoring and management programme for heavy metals as small scale mining is on-going though the industry is not in full working capacity.

A study by Ezenwa *et al* (2014) on ESPRO Asphalt Plant and Quarry site in South-western Nigeria shows the concentration of heavy metals in soil at a depth of 0 – 15 cm varied with distances to the quarry site. The concentration of Cd and Cr decreased with increase in distance to the quarry site. The influence of the distance on Pb and Se concentrations in the soil did not follow a definite pattern. The concentration of Ni and Co also decreased with increasing distance from the quarry site. The effect of increasing distance on the concentration of Mn, Fe and Zn was rarely observed at 300m from the quarry, although the values of Fe and Zn at 300m were lower than the values at 1-250m. Yusuf *et al*

(2015) reported the pollution of Illela Garage in Sokoto State, Nigeria with Fe, Pb and Cr to have exceeded the permissible limit prescribed by World Health Organization WHO, 2007 and Federal Environmental Protection Agency.

Agricultural Practices

Research carried out by Hong *et al* (2014) on River Benue plot wastewater irrigation site (RBS) and Shinko municipal wastewater irrigation site (SHS) revealed that the concentration of heavy metals at RBS and SHS sites soil was highly elevated above the maximum permissible level for soils standard obtainable from European Union and the United Kingdom. Hong *et al* (2014) noted a case of lead poisoning in Zamfara State in the North Western part of Nigeria as reported by Nigerian Daily Trust in 2013 where over 2000 children and pregnant women were affected. An experiment performed by Chiroma *et al* (2012) indicated that the mean concentrations of heavy metals in treated and untreated Urban Sewage Waters used for Irrigation are above the maximum permissible levels set by the World Health Organization (WHO), analysis of the farm soil where the sewage water was used indicate high level contamination by heavy metals. The plant grown on the plot also show variations in concentrations of the heavy metals in different parts of the vegetables plants irrigated with treated and untreated sewage waters exceeding the maximum permissible level. Experiment carried out by Thomas *et al* (2012) shows high level of Zn and Ni in soil after the application of phosphate fertilizer. Poultry manure contains considerable amounts of nutrients and heavy metals which are introduced through feed (Steinfeld *et al*, in FAO, 2006). With increasing use of metals not only as growth promoters, but also as feed additives to combat diseases in intensive poultry production, the application of poultry manure has emerged as an important source of environmental contamination with some of these metals. This manure contains appreciable quantities of potentially toxic metals such as arsenic, cobalt, copper, iron, manganese, selenium and zinc which are added to feeds as a means to prevent disease, improve weight gain and feed conversion, and increase egg production (Bolan et al., 2004; Jackson et al., 2003). In excess, these elements become toxic to plants, can adversely affect animals that feed on these plants, and can enter the soil and water systems through surface run-off and leaching.

EFFECT OF HEAVY METALS ON HUMANS AND THE ENVIRONMENT

Lead (Pb)

Lead is a metal ion toxic to the human biosystem, and is among the common global pollutants arising from emergent industrialisation. The allowable permissible threshold in the European Union is 300mg/kg (CCME, 2003). The assimilation of relatively small amounts of lead over a long period of time in the human body can lead to the malfunctioning of the organs and chronic toxicity (Badmus *et al*, 2007) In general, Lead does not bioaccumulate and there is no increase in concentration of the metal in food chains (European Commission, 2002). Many urban soils are contaminated with high concentrations of lead and exposure to it disrupts the development of the nervous system, causing delays in growth and learning disabilities (Ilaria *et al* in 19th WCSS, 2010). The Queensland doctors Gibson (1904) and Turner (1909) first identified the problem of environmental lead exposure in children from paint and dust over a century ago (Mark *et al*, 2011). In addition, another potentially important exposure pathway for Pb into humans may be via ingestion of contaminated vegetables (Finster *et al*, 2004; Kachenko *et al*, 2004, 2006)

In humans, lead can result in a wide range of biological effects depending upon the level and duration of exposure. For infants and young children lead in dust and soil often constitutes a major exposure pathway and this exposure has been one of the main concerns as to the exposure of the general population ago (Mark *et al*, 2011). In adult approximately 10% of the dietary lead is absorbed. Effects may range from inhibition of enzymes to the production of marked morphological changes and death. Of particular concern for the general population is the effect of lead on the central nervous system. Epidemiological studies suggest that low level exposure of the foetus and developing child may lead to reprotoxic effects, i.e. damage to the learning capacity and the neuropsychological development (Howard, *et al.,* 2002, Mark, *et al*, 2011, World Health Organization, 2007). Studies of children indicate a correlation between higher lead contents in the blood and a lower IQ. Slowing of nerve conduction velocity has been found at low lead blood levels. Impairment of psychological and neurobehavioural functions has also been found after long-term lead exposure of workers (Schwartz, *et al.*, 2001).

Lead has been shown to have effects on haemoglobin synthesis and anaemia has been observed in children at lead blood levels above 40 µg/dl (Howard, *et al.,* 2002, Ogwuegbu, and Muhanga, 2005). Lead exposure is associated with a small increase in blood pressure (World Health Organization, 2007). Lead is known to cause kidney damage. Some of the effects are reversible, whereas chronic exposure to high lead levels may result in continued decreased kidney function and possible renal failure (Ogwuegbu and Muhanga, 2005). Renal effects have been seen among the general population when more sensitive indicators of function were measured (European Commission, 2002, Howard, *et al.,* 2002, Kim, *et al.,* 1996). It also said to affects the male sperm morphology and count (Ogwuegbu and Muhanga, 2005).

Mercury

Mercury is a peculiar metal. Most notable is its fluidity at room temperature, but two other properties are more important for the possible exposure of man and the environment to mercury (European Commission, 2002) which is the volatility and its chemically or biologically transformation to organic mercury. The main human exposure to mercury is via inhalation of the vapour of elemental mercury and ingestion of mercury and methylmercury compounds in food. Mercury and its compounds are toxic to humans. The toxicity varies among the different types of mercury. Generally, organic forms are much more toxic than the inorganic forms (European Commission, 2002).

Methylmercury represents the most important toxic impact of mercury to humans. It is present worldwide and the general population is primarily exposed to methylmercury through their diet, in particular through the consumption of fish and fish products (European Commission, 2002, Mark, 2004). Most of the total mercury in fish is in the form of methylmercury (may be close to 100% for older fish, especially in predatory species). This implies that population groups particularly dependent on or accustomed to marine diets, for instance the Inuit's of the Arctic, as well as populations depending on fishing and marine hunting anywhere else on the globe, are particularly at risk. (AMAP, 1998).

Several researchers have identified that Methylmercury has been found to have adverse effects on several organ systems in the human body as well as in animals. These include the central nervous system (Mark, 2004, European Commission, 2002, Sabine *et al*., 2009) i.e. mental retardation, deafness, blindness, impairment of speech, changes in vision or hearing, and memory problems and the cardiovascular system (blood pressure, heart-rate variety and heart diseases) also Renal toxicity includes proteinuria, renal syndrome, and acute renal failure (Mark, 2004). Research on animals has given evidence of effects on the immune system and the reproduction system. Recently, an extensive evaluation of the toxicological effects of methylmercury was performed under the U.S. National Research Council (NRC, 2000). Here, it was concluded that the effects on the developing nervous system in unborn and newborn children are the most sensitive.

Methylmercury in our food is rapidly absorbed in the gastrointestinal tract (stomach and intestine), readily crosses the placental barrier and enters the brain. A series of large epidemiological studies have recently provided evidence that methylmercury in pregnant women's marine diets appears to have subtle, persistent effects on the children's mental development (cognitive deficits) as observed at about the age of school start (NRC, 2000).

Cadmium (Cd)

Cadmium and cadmium compounds are relatively water soluble, compared to other heavy metals. Making them more mobile in soil and generally more bioavailable and tends to bioaccumulate. The allowable permissible threshold in the European Union is 3.0 mg/kg (CCME, 2003). The major route of exposure to cadmium for the non-smoking general population is via food; the contribution from other pathways to total uptake is small. Tobacco is an important source of cadmium uptake in smokers (i.e. about 50% absorption of intake), as tobacco plants like other plants accumulate cadmium from the soil (European Commission, 2002).

It has been reported that increases in soil Cd content will result in an increased uptake by vegetables (Al-Chaarani *et al*, 2009). The Cd uptake by vegetables from soil is also higher at a low pH of soil (Akinola *et al*, 2008, Al-Chaarani *et al*, 2009).

Occupational exposure is linked to lung cancer and prostate cancer. According to a recent review, the epidemiological data linking cadmium and lung cancer are much stronger than for prostatic cancer, whereas links between cadmium and cancer in liver, kidney and stomach is considered equivocal (Waalkes, 2000). Cd contaminated vegetables are known to result in bone fracture, bone diseases, kidney and lung problems, anaemia, diarrhea, stomach pains and severe vomiting, reproductive failure, damage of central nervous system and DNA, in addition to cancer development (Oti *et al*, 2013, Hardy *et al*., 2008, Adelekan and Abegunde, 2011, Asio, 2009).

European Commission, (2002) reported that cadmium is toxic to a wide range of microorganisms as it affect the growth and replication of some soil microorganisms like fungi, some species are eliminated after exposure to cadmium in soil.

Chromium

Chromium occurs in a number of oxidation states, but Cr(III) (trivalent chromium) and Cr(IV) (hexavalent chromium) are of main biological relevance. There is a great difference between Cr(III) and Cr(VI) with respect to toxicological and environmental properties (Assem and Zhu 2007), and they must always be considered separately. Chromium is in general not bioaccumulated and there is no increase in concentration of the metal in food chains (European Commission, 2002). The allowable permissible threshold for soil in the European Union is 180 mg/kg (CCME, 2003). Cr(III) is considerably less toxic than Cr(VI). Cr(VI) has been demonstrated to have a number of adverse effects ranging from causing irritation to cancer.

Contrary to the three other mentioned heavy metals, Cr(III) is an essential nutrient for man. Chromium is necessary for the metabolism of insulin (European Commission, 2002, Krejpcio, 2001). Most of the daily chromium intake is ingested with food and is in the trivalent form about 0.5-3% of the total intake of trivalent chromium is absorbed in the body (European Commission, 2002, Krejpcio, 2001). The gastrointestinal absorption of Cr(VI) is 3-5 times greater than that of trivalent forms; however, some of it is reduced by gastric juice.

Skin exposure of the general public to chromium can occur from contact with products containing chromium e.g. leather or preserved wood or chromium containing soil. Airborne chromium may contribute significantly to occupational exposure. High level exposed of chromium or its compounds, primarily Cr(VI) by inhalation, may lead to irritating respiratory effects, possible circulatory effects (Krejpcio, 2001, Sabine *et al*., 2009)), effects on stomach and blood , liver and kidney effects, can lead to dermal ulcers, effects on the renal, haematological and cardiovascular system (Assem and Zhu, 2007), Reyes-Gutiérrez *et al.,* 2007) and increased risk of death from lung cancer (RTI. 2000).

Arsenic

Aside from occurring naturally in the environment, arsenic can be released in larger quantities through volcanic activity, erosion of rocks, forest fires, and human activity. The wood preserving industry uses about 90% of the industrial arsenic in the U.S. Arsenic is also found in paints, dyes, metals, drugs, soaps and semi-conductors. Animal feeding operations and certain fertilizers and pesticides can release high amounts of arsenic to the environment, as industrial practices such as copper or lead smelting, mining, and coal burning (Sabine *et al*., 2009)

Inorganic arsenic is a known carcinogen and can cause cancer of the skin, lungs, liver and bladder. Lower level exposure can cause nausea and vomiting, decreased production of red and white blood cells, abnormal heart rhythm, damage to blood vessels, and a sensation of "pins and needles" in hands and feet. Ingestion of very high levels can possibly result in death.

Arsenic exposure occurs from inhalation, absorption through the skin and ingestion of contaminated drinking water or food. Seafood, fish, and algae are the richest organic sources. These organic arsenic compounds cause raised arsenic levels in blood but it may be excreted in urine. Arsenic intake is higher from solid foods than from liquids including drinking water. Organic and inorganic arsenic compounds may enter food chain from soil irrigated with arsenic contaminated water (Ratnaike, 2003). Long-term low-level exposure can cause a darkening of the skin and the appearance of small "corns" or "warts" on the palms, soles, and torso (Sabine *et al*., 2009).

CONCLUSION

Soil is a great reservoir for contaminant as well as a natural buffer for transportation of chemical materials and elements in the environment. The contamination of the soil poses serious danger to the overall quality of human life. The most adverse effect of heavy metals is that they can be introduced into the food chain and threaten human health. Agricultural products growing on soils with high metal concentrations are source of metal accumulations at levels harmful to human and animal health as well as to the bio-environment, this metals may have been mixed with groundwater by leaching.

To control soil contamination, legislative measures must be taken, legally binding the individual and industries, proper waste management system must be established, forbidding discharge of unsorted and untreated or poorly treated waste into the environment.

Appropriate remediation measures should be taking promptly to remove excess metal contamination in the soil. Regular monitoring of toxic metals in the agricultural soil is needed to ensure safe environmental.

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LOW-COST LEACHATE TREATMENT TECHNOLOGY USING ELECTROLYSIS AND ACTIVATED CARBON

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ABSTRACT

Leachate poses serious danger to the neighbouring environment whereby it contaminates groundwater by deep percolation and causes greenhouse effect by releasing methane gas. Combined processes of electrolysis (iron electrodes) and adsorption by activated carbon, AC (palm shell) were used in this study to treat raw leachate obtained from Jeram Sanitary Landfill, Malaysia. Combinations of voltage and hydraulic retention time (RT) were used thereby selecting 24 Volts (V) and 50 minutes (min) respectively in respect of the electrolysis process. Adsorption process was conducted immediately after the electrolysis process. Highest efficiencies were recorded on the parameters checked (pH, Salinity, BOD_5 and COD) using the best combination of the voltages and the RTs (i.e. 24 V and 50 min) chosen. The results obtained shown that the BOD_5 and COD removal efficiency were 84.32% and 85.94% respectively. Salinity removal efficiency of 71.43% was obtained and the pH values yielded from 8.00 to 9.37 meaning that, it was classified as alkaline. The study focuses on a simple technology that could lead to environmental sustainability. Therefore, more broadly research regarding to technological concept of making a mini-model is recommended in the area of leachate treatment by oxidation process using different set of electrodes. Also, other parameters such as ammonia nitrogen, colour and some heavy metals could also be checked to establish their relationship with this method.

Keywords: *Activated carbon, Electrolysis, Raw leachate, Solid waste decomposition, Jeram Sanitary Landfill.*

INTRODUCTION

Concern about environmental conservation protection has increased over the years from a global viewpoint. Over several decades, the exponential growth of population and social civilization expansion, changes in the production and consumption habits, increasingly well-to-do lifestyles and resources use, and systematic development of the industrial and technology has been accompanied by the rapid generation of municipal and industrial solid wastes, which create the most uncompromising challenge around the world (Foo and Hameed, 2009). Moreover, poorly designed or inadequately managed landfills can create a number of unfavourable environmental impacts such as wind-blown litter, attraction of pests, and generation of liquid leachate. Another ordinary product of landfills is gas (like methane and carbon dioxide), which is generated from anaerobic breakdown of organic waste. The methane gas produced causes odour problems, destroy surface vegetation and leads to greenhouse gas (João, 2010). Interestingly, sanitary land filling is recognized as the most common and satisfying solid waste management strategy for sustainable disposal and elimination of residue wastes from separation, reuse and incineration in both developed and developing countries (Baldasano *et al.*, 2003). In terms of its simplicity, low exploitation and capital costs, sanitary landfill accounted roughly 95% of the total municipal solid waste collected worldwide (Foo and Hameed, 2009). Generation of leachate come about when moisture gets contact with refuse in a landfill by dissolving the contaminants into liquid phase and producing moisture content adequate to initiate liquid flow. The leachate is a high-strength and rich in toxic chemicals wastewater that has a key impact and influence on landfill design, operation and its management. According to Keenan *et al.,* (1984) reported that, fluctuations in strength of leachate is dependent on short and long term periods taken by the leachate to be formed which is also dependent on variations in type of waste composition, hydrogeology and variations in climate of the landfill area. Current practices in landfill design and disposal make it a consistent, well established means of disposing both municipal and industrial waste. A landfill is a special engineering project, involving multiple stages of strong and critical survey of the area to be sited, proper planning and design before installation (Wisiterakul, 2006). The factors to be considered prior to construction of landfill are waste sources, transportation access, distance from human receptors, availability of cover material, waste characteristics and volume, cost of land and site, and groundwater level need to be considered prior to construction of landfill (The Midwest Hazardous Substance Research Center, 2014). Figure 1 shows a cross-section of a modern sanitary landfill with groundwater monitoring wells and a gas monitoring probe. The protective cap, clay cap, foundation venting layer, gas vent, leachate collection system (series of pipes), drainage protection layer, synthetic liner, clay liner, as well as re-compacted sub-soil were also among the features shown.

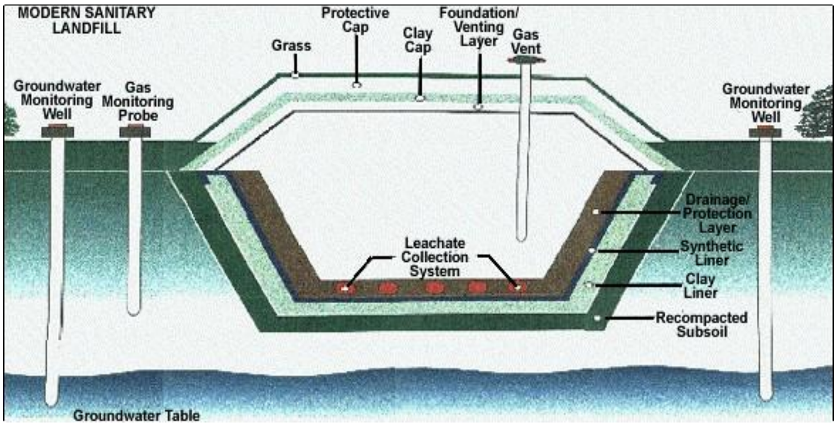

Figure 1: Modern sanitary landfill

Source: (The Midwest Hazardous Substance Research Center, 2014)

Typically, leachate possesses high dosages of ammonia and organic pollutants (usually measured in terms COD and BOD), halogenated hydrocarbons and heavy metals. Additionally, leachate contains high dosages of inorganic salts (mainly sodium chloride, sulphate and carbonate) and is depends on the composition of land-filled waste (Visvanathan *et al.*, 2004). High moisture content in the solid waste of young landfills (typically <1–2 year-old) helps acid fermentation of the organic matters that leads to the discharge of large quantities of free volatile fatty acids and causing pH to decrease, which will in turn accelerates heavy metal dissolution. Therefore, young landfill leachate is characterized by its high dosages of COD and BOD, a high ratio of BOD/COD, high NH_3-N and alkalinity, as well as a low oxidation–reduction potential (Wang *et al.*, 2003). Efficiency of biological treatment can simply be improved by addition of Powdered Activated Carbon (PAC), this is due to its ability to remove refractory organic compounds and to boost nitrification (Environmental Protection Agency, 1995; Kang *et al*., 1990). Furthermore, sludge dewater-ability can be improved by addition of PAC to activated sludge which leads to an increase in the removal efficiency by adsorbing non-biodegradable components, toxic elements and also some metals. There was a synergy between micro-organisms present in leachate and activated carbon. Hence, the Powdered Activated Carbon Treatment (PACT) system could do away with organic compounds more efficiently than would likely be removed from either biodegradation or adsorption alone. An attachment surface provided by activated carbon causes micro-organisms to attach themselves to the surface thereby bio-regenerating the activated carbon (Aghamohammadi *et al.*, 2007). Corporation (1992) reported that, a high surface area to volume ratio of Granular Activated Carbon (GAC) made it a good adsorbent medium, whereby one gram (1g) of a typical commercial activated carbon will have a surface area equivalent to 1,000 m^2. This high surface area advantage, allows accumulation of a large number of contaminant molecule. Additionally, rainfall serves as a medium of transportation for contaminants from within and outside the landfill. It also provides the essential moisture needed for methane production and biological decay (Visvanathan *et al.*, 2004).

MATERIALS and METHODS

The raw leachate used in the experiment was obtained from Jeram Sanitary Landfill, Malaysia. The study area is located 20 km North/West of Kuala Lumpur and it is on the latitude 3°11'20"N and longitude 101°21'50"E. Jeram Sanitary Landfill receives waste (predominantly domestic and garden waste) from different areas, mostly from Kuala Lumpur and Selangor Municipality. The Jeram Sanitary Landfill has a capacity of 1,500 ton/day with a total capacity of 6 million tons and occupies an area of 65 hectares (i.e. about 160 acres). Standard laboratory methods of analysis were employed during the experimental exercises to evaluate and ascertain levels of BOD and COD while salinity and pH were measured using a pocket tester meter called 'TRACER POCKETESTER' (Code: 1766, LaMotte, Taiwan). Table 2 shows the characteristics of the raw leachate samples collected from Jeram Sanitary Landfill between the months of June to August, 2014. In the Table 2, minimum and maximum values of the four (4) pollutant parameter were measured and recorded thereby comparing the recorded values with the Malaysian Standard B as well as the WHO standard.

Table 2: Characteristics of the raw leachate samples collected from Jeram Sanitary Landfill

Pollutant Parameters (Unit)	Value		Malaysian Standard B	WHO Standard
	Min.	Max.		
pH	8.00	8.29	5.5 – 9.0	6.5 – 8.5
BOD_5 (mg/L)	9,000	9,500	50	50
COD (mg/L)	12,800	12,800	100	250
Salinity (mg/L)	13,000	17,000	-	-

Experimental set-up and operation conditions (Electrolysis)
Simple electrolysis bath using a cylindrical glass container was used, whereby iron electrodes (mild steel) were used as both cathode and anode. The electrodes were in form of a metallic bar with each having 60 cm^2 as effective area of electrolysis and placed 4 cm apart. Different electrical voltages of 3 V, 6 V, 12 V, 18 V and 24 V were applied during the electrolysis process whereby each of the voltages, was allowed to pass through the electrolyte (leachate sample) for 5 min, 10 min, 15 min, 20 min, 30 min, 40 min and 50 min so as to determine the best combination of voltage and retention time (RT) to give optimum result. Figure 2 shows the electrolysis set-up while Figure 3 shows the colour changes indicated by the samples following the separation of the effluent from the sludge after electrolysis.

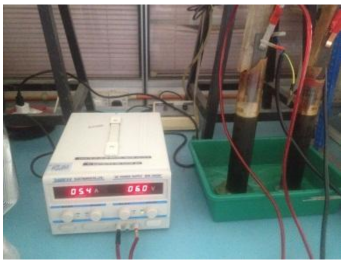

Figure 2: Electrolysis set-up

Figure 3: Samples after electrolysis process

pH measurement
A level indicator for acidity or alkalinity is known as the pH value. A pH value of 7 means a substance is neutral. The lower value indicates acidity, and a higher value is a sign of alkalinity. Spellman (2009) suggested that the pH values should approximately range from 5.5 to 9.0 to ensure the quality of water for recreational use and aquatic life. A pocket tester (Code: 1766, LaMotte, Taiwan) was used while measuring the pH values for the raw leachate sample and the electrolysed sample by dipping the tracer into a beaker containing the sample to be tested. At least three (3) different readings were taken in order to ensure precision in the measurement.

Salinity measurement
Theoretically, salinity is the amount of dissolved salt content of water. Salinity is an ecological feature of significant value as it influences the types of organisms that are living in an aquatic environment. A pocket tester (Code: 1766, LaMotte, Taiwan) was used while taking the measurements for salinity in both the raw leachate sample and the electrolysed sample by dipping the tracer into a beaker containing a well mixed sample. The device is being rinsed between every two successive testing of different samples. At least three (3) different readings were taken in order to ensure precision in the measurement.

Biochemical Oxygen Demand (BOD) measurement
BOD is a measure of the amount of oxygen used by micro-organisms (aerobic bacteria) in the oxidation of organic matter present in water bodies. Plant decay and leaf fall are among the natural sources of the organic matter. However, both plant growth and decay may abnormally speed up when sunlight and nutrients required by the plants are too much due to human activities (Systems, 2014). Standard laboratory procedure was employed in measuring the BOD_5.

Chemical Oxygen Demand (COD) measurement
The COD value indicates the oxygen dosage needed to oxidise all carbon compounds in the sample. Standard laboratory procedure was employed in measuring the COD.

Activated Carbon – Adsorption process

Activated Carbon (AC) is a strong carbonaceous material in its purely crystal form. The pore structure of activated carbon is well developed as it has a very large surface area and pore volume (EnviroCarbon, 2014). In this study, a palm shell type of AC was used on the electrolysed samples after finally obtaining the best combinations of RT and voltage which are 50 min and 24 V respectively.

RESULTS AND DISCUSSION

Characteristics of raw leachate

According to literature and conventional parameters, the leachate collected from the Jeram Sanitary Landfill and used in this study can be classified as intermediate as it doesn't yet reach 10 years from the year it was constructed.

Electrolysis process

The results obtained after the electrolysis made the choice of 24 V and 50 min to be used as the best combination in this study. However, while trying to get the best combination of voltage and RT, it was noted that salinity (Figure 4) results deviated a bit from the RT chosen (50 min) as it indicated preference for 30 min. However, the 24 V was found to be maintained as the best for all the parameters. Meanwhile, BOD_5, COD, pH, (Figure 5, 6 and 7 respectively) results indicated a preference for 50 min. Therefore, 24 V and 50 min were chosen as the best combination and used throughout this study as it gives more promising results. The higher voltage selected (i.e. 24 V) is an indication that an optimal electrical potential plays a role in quickening the removal rate of pollutants during the electrolysis process as more sludge is formed in a shorter time compared to lower voltages other than 24V. Still, the use of 24 V made the replacement of the electrodes necessary after every three (3) successful experiments especially the anode**,** hence the high voltage used has proved itself to be directly proportional to the rate of oxidation and reduction processes occurring at the anode and cathode respectively which made the anode getting thinner as it erodes its part into the solution while the cathode becoming thicker due to deposition of sludge on its surrounding surface. At the end of every process, the electrodes are removed and allowed to cool then get washed with normal water and emery paper to remove deposits and clear rough surfaces formed during the electrolysis process on the cathode and the anode respectively.

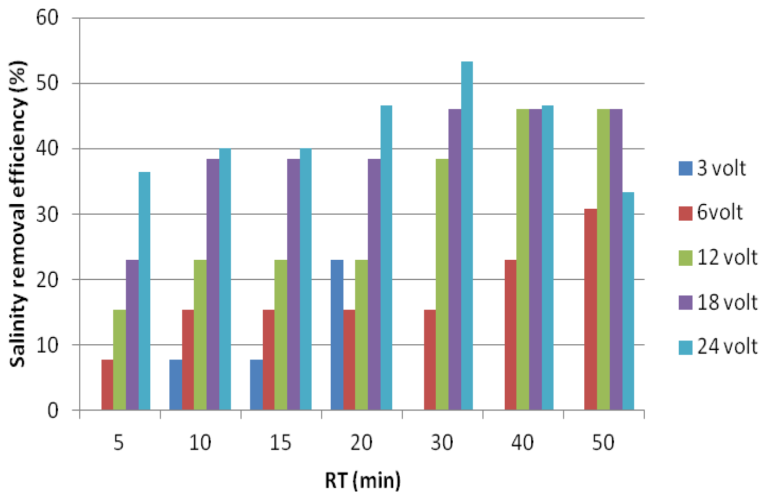

Figure 4: Performance of Salinity removal by electrolysis

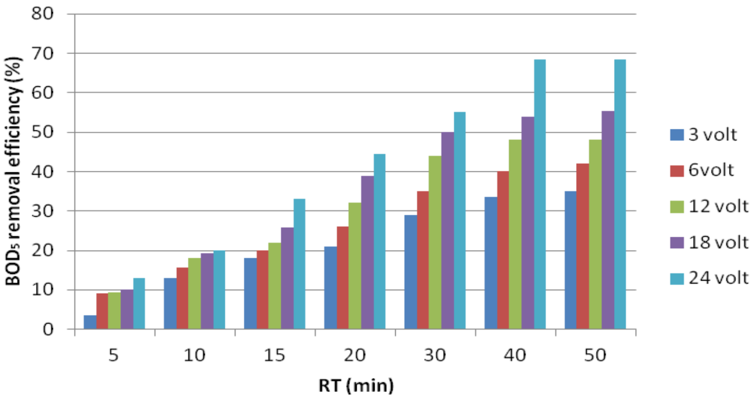

Figure 5: Performance of BOD_5 removal by electrolysis

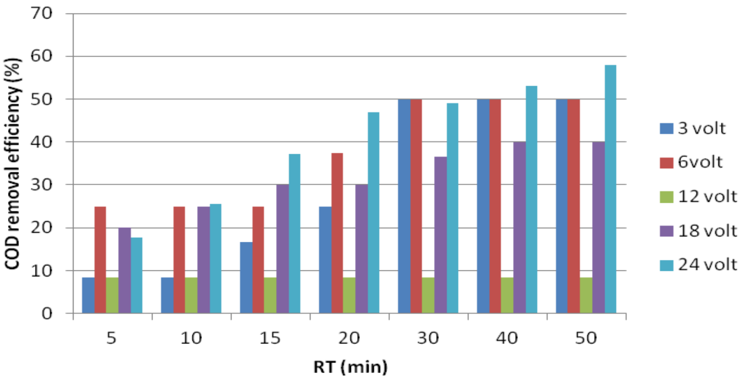

Figure 6: Performance of COD removal by electrolysis

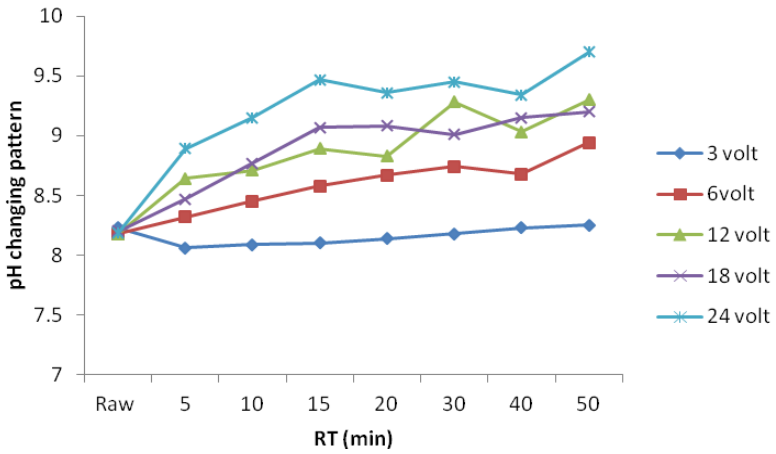

Figure 7: pH changing pattern after electrolysis

Electrolysis using 24 V and 50 min followed by adsorption process

For every raw sample of the leachate to be analysed, a combination of voltage and RT (24 V and 50 min respectively) selected was used to obtain the rate of reduction regarding all the parameters with the exception of pH, as it is expected to rise. Figure 8 to Figure 11 shows the resulted variations between the raw leachate and the electrolysed leachate samples after addition of AC at varying dosages of 2 g/L, 4 g/L, 6 g/L, 8 g/L and 10 g/L, under varying concentration time (CT) of 1 hr, 2 hr, 3 hr, 4 hr, 5 hr and 6 hr on each of the dosage level. For example, at 2 g/L AC dosage and CT of 1 hr, 2 hr, 3 hr, 4 hr, 5 hr and 6 hr, the changes that occurred were observed and recorded accordingly.

Treatment effect on BOD

The decay of organic matter in water or wastewater is measured as biochemical or chemical oxygen demand. Determination of BOD being a primary parameter in ascertaining the level of pollution in wastewater would be helpful in knowing the level of pollution in water so as to take the needed measure. BOD removal to a low level from wastewater would yield a safe circumstance to environment before disposing the wastewater into water bodies. Figure 8 shows various levels of BOD removal efficiencies achieved at varying CT for each dosage of AC used. Using AC dosage of 10 g/L at 6 hr CT yielded a removal efficiency of 84.32%. This is an indication that the rate of removal of BOD is directly proportional to the dosage of AC used and CT taken.

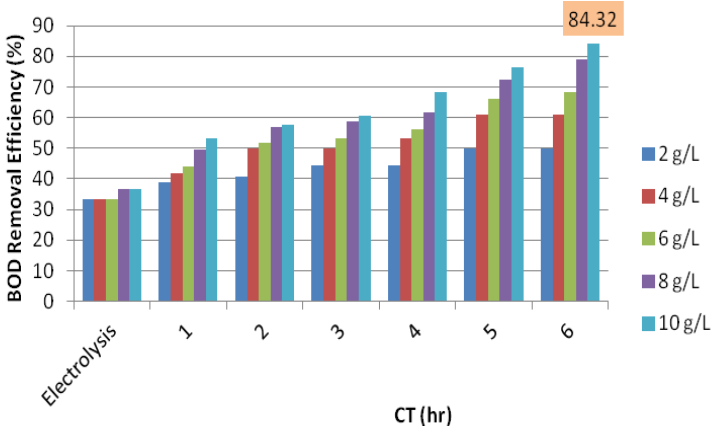

Figure 8: Performance of BOD removal by electrolysis and adsorption for different AC dosage and CT

Treatment effect on COD

Chemical oxygen demand (COD) is the total quantity of oxygen required by all chemicals (i.e. both organic and inorganic) in the water or wastewater as it always have higher amount when compared to the BOD of same water, since BOD refers to that amount needed by bacteria to degrade only organic matter present in the water. A removal efficiency of 85.94% was achieved regarding to COD as shown in Figure 9. This was obtained using AC dosage of 10 g/L at 6 hr CT just as recorded for BOD. This result also confirms that, the higher the current density or in other word the voltage level, the better and efficient removal of COD would result.

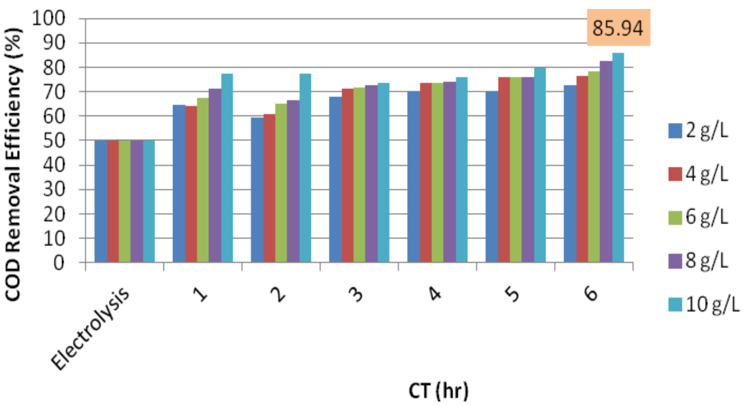

Figure 9: Performance of COD removal by electrolysis and adsorption for different AC dosage and CT

Treatment effect on Salinity

Basically, salinity is a measure of dissolved salt content in water. The results of the experiments conducted regarding to salinity revealed a drastic decrease in the salinity level of the effluent tested. A common value of 71.43% obtained twice as the removal efficiency after adsorption process having dosage of 10 g/L at CT of 5 hr and 6 hr as shown in Figure 10.

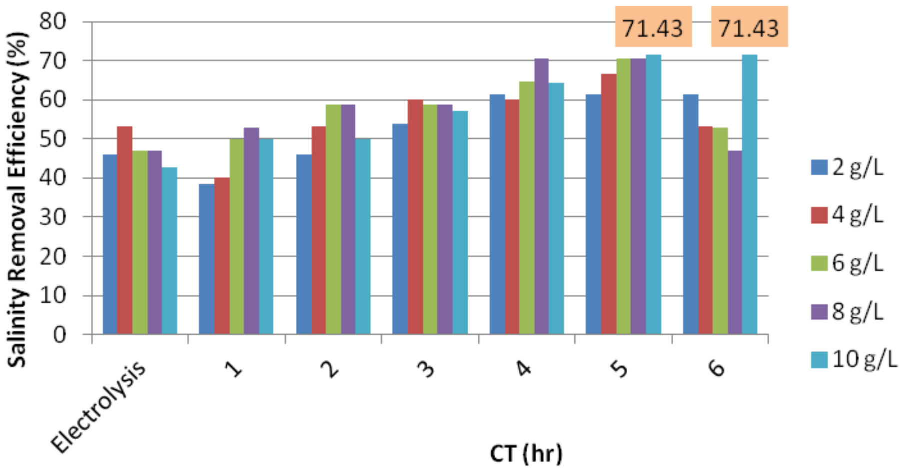

Figure 10: Performance of salinity removal by electrolysis and adsorption for different AC dosage and CT

Treatment effect on pH

Generally, pH can be described as a measure of acidity or alkalinity of sample content. A solution of pH less than 7 is said to be acidic, while greater than 7 is termed basic. Neutral solution is the one having a pH value of 7. In this experiment, it was revealed that increases in pH were obtained after the electrolysis process thereby making the samples to become more alkaline than the initial pH values of the treated samples, which happened as a result of loosing hydrogen ions during the electrolysis process. Figure 11 shows the pH changing pattern. The adsorption process as a subsequent treatment after the electrolysis using AC dosage of 8 g/L differ when compared to treatment using 10 g/L as it gave 17.13% increase (from pH 8.00 to 9.37).

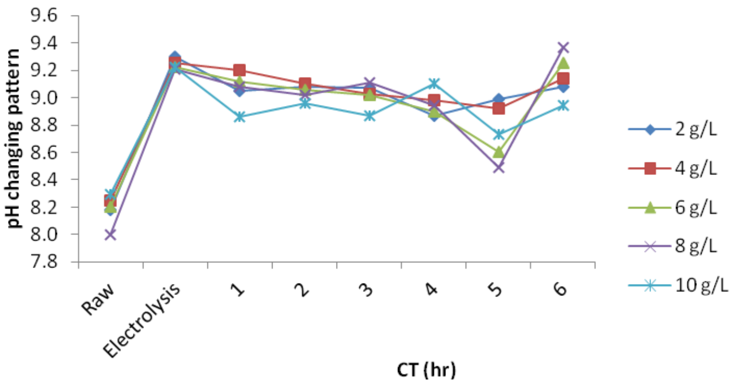

Figure 11: pH changing pattern for different dosage of AC and CT

CONCLUSION

The study concluded that the combined processes of electrolysis using iron electrodes and adsorption by palm shell type of AC make it possible to treat raw leachate. The result obtained shows that BOD_5, COD and salinity removal efficiencies were 84.32%, 85.94% and 71.43% respectively. While for the pH value, the result shows an increases from 8.00 to 9.37. Therefore, the study can conclude based on the implication of BOD_5, COD, salinity and pH values that, leachate treatment with high efficiencies can be achieved. It can also be seen that; it is feasible to have an integrated process as alternative treatment technique by combining electrolysis with AC adsorption to treat landfill leachate. It is also noted that, the method used can be regarded as an environmentally friendly technology which would not result in the creation of more hazardous by-products as it does with other treatment methods as a result of using in organic chemical. Hence, detailed research regarding leachate treatment using the combined processes used in this research is recommended such as using different set of electrodes and looking for other parameters such as ammonia nitrogen, colour, heavy metals and so on.

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LOW COST WEIGHING LYSIMETER FOR CROP WATER USE DETERMINATION FOR VEGETABLES IN SOUTHWESTERN NIGERIA

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ABSTRACT

This study described the design and construction of low cost weighing lysimeter and also investigates the performance evaluation of the lysimeter by determining the crop water requirement of Jute mallow (Corchorus olitorius), Lagos spinach (Celosia argentea) and Leafy amaranth (Amarathus cruentus) vegetables production. This lysimeter was constructed by readily available materials like plastic container which serve as lysimeter tank and inner tyre tubes filled with water connected to a glass U- tube manometer for the weighing system. The daily displacement of water in the glass U- tube manometer due to change in weight of lysimeter as were translated to crop water use. The results showed that the average daily water use of the Lagos Spinach increased from 0.16 mm/day at the early crop growth stages to 5.23 mm/day at mid-season and declined to 1.08 mm/day at the late season of the crop. The leafy Amaranths shows that the average daily water use increase from 0.13mm/day at the early growth stage of the crop to 4.96 mm/day during the mid-season and declined to about 1.60 mm/day at the late season. While Jute mallow shows that average daily water use increased from 0.11mm/day at the early growth stage of the crop to 4.44 mm/day during the mid-season and declined to 1.67 mm/day at the late season. The potential crop water use estimated for all the vegetables showed that the weighing lysimeter is effective and results obtained can be used as a guide by farmers for selecting the amount and frequency of water to be used for the vegetables

Keyword: *Cost, Season, Weighing Lysimeter, Crop water Use, Vegetable*

INTRODUCTION

Vegetable production can be adopted as a strategy for improving livelihood and alleviating the nutritional status of the people. It offers a significant opportunity for the poor people in southwestern Nigeria to earn a living because vegetables production can be done with little capital investment. It is also the answer to the perpetual problems of hunger and malnutrition in the country. Adebooye *et al.* (2003) reported an expanded list of twenty-four indigenous leaf vegetables that are eaten in southwest Nigeria only. There is only scattered information concerning water management of indigenous leafy vegetables. For proper irrigation scheduling and high level agricultural production, a precise knowledge of crop water use under field conditions is required. Since the micro-climate during the wet season differs from that of the dry season, it is most expected that crop water requirements for irrigation should differ from that under rain-fed condition (Igbadun, 2012). All measurement of crop water use depends on knowledge of the soil water balance from which crop evapotranspiration (ET_c) is calculated:

$$ET_c = P + I - R - F - \Delta S \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where P is precipitation depth, I is irrigation depth, R is the depth of runoff, F is the depth of water lost to deep percolation below the root zone or gained by upward flow from a shallow aquifer or deeper soil horizons and ΔS is the change in the depth of water stored in the soil due to crop water use, irrigation, precipitation, runoff and /or deep percolation with all terms (often mm) per unit time.

However measurements of rainfall and irrigation depths are possible with rain gauges and water metres, it is difficult to measure the change in storages of soil water or loss of water to deep percolation. These two measurements can be made very accurately with a weighing lysimeter because the soil container prevents loss of water to deep percolation and gain of water from a shallow aquifer or lateral water movement because most runoff is prevented by the edge of the box, which is higher than the surrounding soil surface. Weighing lysimeters are potentially the most accurate way to determine crop water use; and many different designs and weighing mechanisms have been used (Howell *et al.*, 1991). The evaluation of lysimeter data allows a much more reliable calculation of the solute load carried towards the groundwater than any other method. If the lysimeters weight is recorded in certain time steps, precipitation and seepage water amount is measured separately, actual evapotranspiration can be deduced from their weight change (Young *et al.,* 1997). The crop water use is calculated from the changes in weight of the lysimeter tank, and adjusted to account for weight changes caused by factors other than crop water use such as drainage or runoff and water input (Malone *et al*., 2000). Water need of plants in lysimetric experiments is supplied by natural rain, irrigation or by an artificially maintained water table. Therefore, this study described the design and construction of low cost weighing lysimeter and was used to determine the crop water use of vegetables. However, the lysimeter create less disturbance to the environment of inters during installation and easy to install with minimal technical and financial effort.

MATERIALS AND METHODS

Description of Study location

The field experiment was carried out during rainy and dry season in the experimental field of Department of Agricultural and Environmental Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria. The experimental plot was located on longitude 4.50^{0}E and latitude 7.50^{0}N, it has elevation of about 281 meters above the mean sea level using. The study area experiences bimodal rainfall, the peak of the rainfall occurs in August to September, and the dry season is at the peak between March to April each year with slight irregularity in the rainfall distribution yearly. Ile –Ife is described as humid tropical environment with mean annual rainfall of about 1400mm while the mean temperature ranges between 28^{0}C to 34^{0}C. Relative humidity is about 75.8% to 86% for dry and wet seasons respectively (Orimoogunje, 2005).

Lysimeter construction

The design criteria for the weighing type lysimeter developed in this research are that they can be able to continuously monitor evapotranspiration at the resolution of 12 hours and they can be easily and rapidly deployed, redeployable (i.e. portable), economical to construct and install with a modification to Igbadun; (2012). In order to minimize surface disturbance during operation owing to the lysimeter hardware, circular containers with minimum wall thickness for holding the soil are desired. Nine (9) sets of weighing lysimeter were constructed for the purpose of this research. Each lysimeter consist of lysimeter tank, the weighing system and the runoff system as shown in Fig 1. The plastic container that serves as lysimeter tank is circular in shape and has dimension of 21-cm depth with top and bottom diameter of 44-cm and 25.5-cm respectively. The 21-cm depth was considered adequate to grow vegetables without significantly restricting normal root development and soil water extraction. Monitoring of the mass of the lysimeter tank is done by placing the lysimeter tank on inflated tyre tube filled with that is connected to U - tube manometer which serves as weighing system. The weighing system has dimension of 5-cm tall and 30-cm diameter. Rubber hose of 0.8-cm diameter was connected to the inflated tyre tube with 0.6-cm diameter valve at one end and the other end of rubber hose connected to a U-tube glass manometer of 1.5-cm long. The U – tube glass manometer was fixed to a graduated pole of 71.5-cm length , the pole was attached with the wooden platform that have stand , the pressure exerted on the inflated tyre tube forced the water in it to rise to a height in the U- tube glass manometer. The change in the water level in the manometer glass tube was related to changes in weight of the lysimeter tank. The weighing system measure the weight lost resulting from vegetables ET and weight gain resulting from precipitation and irrigation. The difference in the water level in the manometer glass tube before and after the evapotranspiration a seen shows the amount of water been used by each vegetables. At the height of 16-cm in the lysimeter tank, an outlet fitting was made and 2-cm diameter rubber hose connect the lysimeter tank to the plastic bucket which serve as runoff collector as shown Fig 1. The runoff system consisted of a plastic bucket of 29-cm diameter and 27-cm deep which serves as the runoff collector. The collector was placed at a lower elevation so that the runoff water from the lysimeter tank flows by gravity into the collector. For this application the bottoms of the low cost lysimeter constructed were sealed forcing drainage to zero i.e. that is no drainage system.

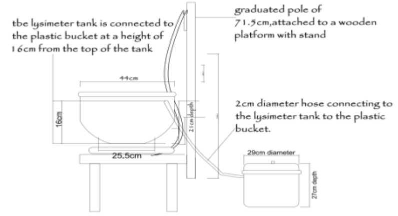

Figure 1: Typical Side View of Lysimeter

Calibration and Testing

The weighing system of the weighing lysimeter constructed was calibrated for its range, stability, repeatability and sensitivity according to Marek *et al.* (1988). Figure 3 shows the relationship between the weight of the lysimeter tank and corresponding water height in the manometer U-tube. The minimal range of mass used in the calibration was determined from the expected maximal mass change during the irrigation or precipitation season with assumption that farmer would not allow the soil in the root zone to dry by more than 50% of available water holding capacity. There was a strong linear relationship between the weight of the lysimeter tank and the corresponding value of water in the U – tube manometer. The coefficient of determination (R^2) between added weight of the lysimeter tank and corresponding value of the height of water in the manometer in the calibration result was very high (≥ 0.98). This indicates that the setup is reliable.

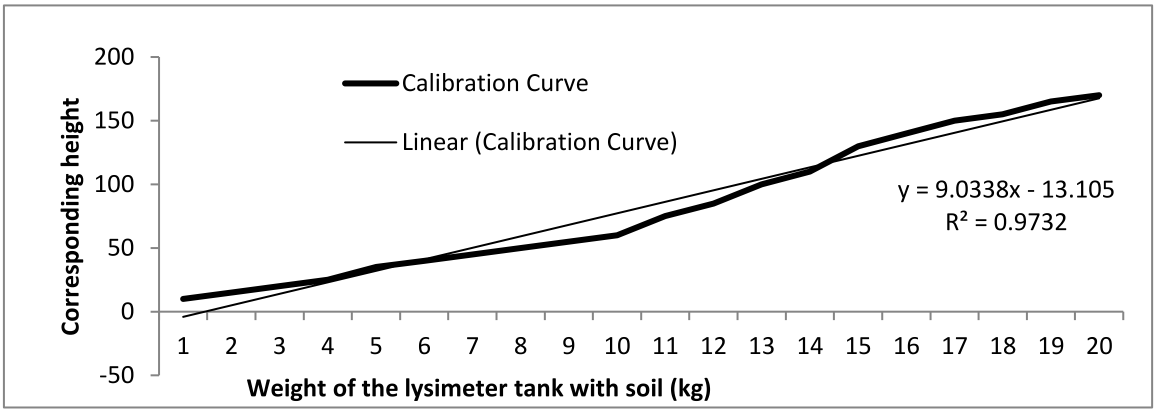

Figure 2: Calibration curve of the experimental setup

Field Experimental Procedures

Nine (9) sets of weighing lysimeter constructed which serve as three (3) replications for each experimental setup for each vegetable were assembled at experimental field. The lysimeters were assembled in 50 m x 10 m field and maintained vertically in a free floating position and separated by a space of 4 m distance between each lysimeter set as shown in Plate 1. The assembled lysimeters caused no disturbance to the environment and the soil structure inside the lysimeter is same to that of the surrounding area. Also, rain gauge was also installed at the study site to measure the amount of rainfall everyday throughout the planting period. The following vegetables were planted in the lysimeter: Jute mallow (*Corchorus olitorius*), Lagos spinach (*Celosia argentea*) and Leafy amaranth (*Amarathus cruentus*) based on their economic and nutritional roles.

Plate 1: Typical Setup of the Weighing Type Lysimeter.

Each lysimeter consist of a plastic container of 44 cm surface diameter and 21 cm depth which serve as lysimeter tank where the vegetables were planted, the weighing system and the runoff system. The levels of water in the manometer glass tubes were monitored every 12 hours throughout the crop growing season. Excess water that cannot infiltrate into the soil inside the lysimeter tank during the rainy season will go into the runoff collector. The selected vegetables were planted inside the lysimeter tank on the same day during rainy season and also during dry season and no manure or fertilizers were added.

Determination of Crop Water Use from the Lysimeter

Three (3) weighing type lysimeter set for each vegetables as shown in Plates 2, 3 and 4 for Lagos spinach (*Celosia argentea*), Leafy amaranth (*Amarathus cruentus*) and Jute mallow (*Corchorus olitorius*) respectively were used. All the vegetables were planted on the same day (11/8/2013 – 17/9/2013 and 04/03/2014 – 24/04/2014) and they were all exposed to the same environmental conditions, there was no fertilizer application. The weight of the lysimeter tank on any given day was determined by the level of water in the manometer tube using a relationship early determined from calibration curve between the height of water in the manometer glass tube and known weight soil packed into the lysimeter tank.

The relationship was obtained as:

$$W = 0.111 * H + 1.450 \quad (R^2 = 0.973) \ldots\ldots\ldots\ldots 2$$

Where; W = Weight of lysimeter (kg) H = Corresponding height of water in the manometer glass tube.

Plate 2: Lysimeter Setup for Lagos Spinach (Celosia argentea) Amaranth (Amarathus cruentus)

Plate 3: Lysimeter Setup for Leafy

Plate 4: Lysimeter Setup for Jute Mallow (Corchorus olitorius)

As water was added to each lysimeter tank through rain or irrigation, the pressure exerted on the tyre tubes due to increase in weight of the lysimeter tank causes a rise in the water level in the manometer glass tube. Excess water beyond that could not infiltrate into the soil in the lysimeter tank will go into the runoff collector. As evaporation took place and the crop used water for its metabolic activity on daily basis, the weight of the lysimeter tank reduced and consequently the level of water in the manometer glass tube decreased. The weight of the lysimeter tank on any given day will be determined from the level of water in the manometer glass tube using a relationship between height of water in the manometer glass and known weight packed into the lysimeter tank. Weight changes, in kilogram, were converted to an equivalent depth of water, in millimeter, by dividing the weight change by the density of water (g/cm^3) and the surface area of the inner tank (m^2). The weight of the lysimeter tank obtained using Equation (2) and their difference was translated to the depth of water in mm/day using a factor of 2.89 which was based on the surface area of the lysimeter tank and the density of water. Equation 3 was used for the computation of daily crop water use:

$$CU_i = P_i - Rf_i - ((W_{i+1} - W_i) * cf \ldots\ldots\ldots\ldots 3$$

Where;

P_i = Irrigation amount (mm) of day i collected in the rain gauge
Rf_i = Runoff (mm) of day i.

W_i = Weight of the lysimeter soil on day i.
W_i+1 = Weight of the lysimeter soil the next day at an interval of 24 hours.
CU_i = Crop water use of day i
cf = A factor converting weight to equivalent depth of water

RESULTS AND DISCUSSION

Rainfall and Runoff Depth

The precipitation which is mainly in form of rainfall ranged between 3.4 mm and 24.5 mm as shown in Figure 3 during the planting period (11th Aug – 17th Sept), it is not only the total amount of rainfall that matters; but how effective the rain is in terms of its time of occurrence, spread, intensity, frequency, and availability as soil moisture (Adefolalu, 1988). A total of 13 rainfall events were recorded for all the selected vegetables planted and the peak rainfall occurred on August 29th. There is no difference in depth of rainfall experience at the site where all the selected vegetables were planted because all the vegetables were planted at the same location and on the same day. The depths of rainfall and runoff from the leafy amaranth (*Amaranth cruentus*), Lagos Spinach (*Celosia argentea)* and Jute mallow (*Corchorus olitorius*) lysimeter setup are shown in Figure 3. The runoff depth varied from 0.6 to 7.2 mm for leafy amaranth (*Amaranth cruentus*), 0.6 to 6.6 mm for Lagos Spinach (*Celosia argentea)* and 0.6 to 5.7 mm for Jute mallow (*Corchorus olitorius*) lysimeters setup respectively. Lagos Spinach (*Celosia argentea)* and Jute mallow (*Corchorus olitorius*) lysimeters setup were 14.2%, 12.6% and 14.4% respectively of the total rainfall recorded.

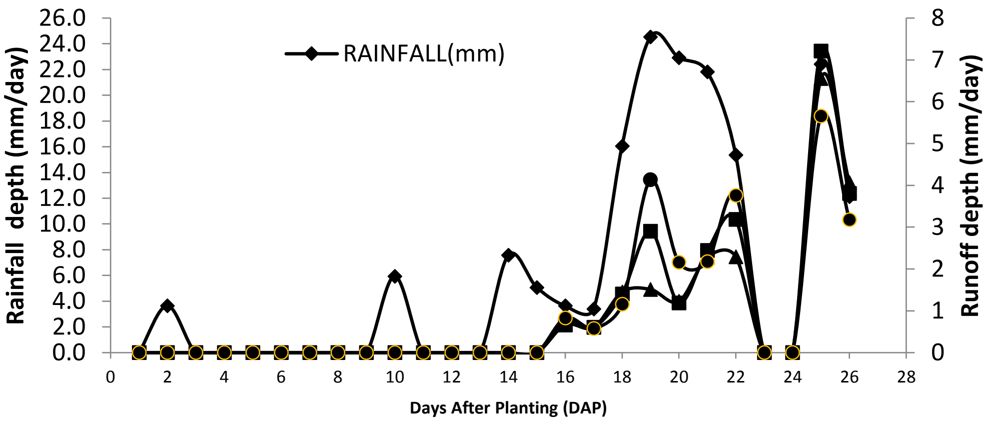

Figure 3: Rainfall and Runoff Depths from all the Vegetables Lysimeter Setup

Daily Crop Water Use during Rainy Season

Figure 4 shows the trend of daily crop water use of leafy amaranth (*Amaranth cruentus*), Lagos Spinach (*Celosia argentea*) and Jute mallow (*Corchorus olitorius*) respectively. The daily crops water use for Leafy Amaranth (Amarathus cruentus) lysimeter setup varied from 0.64 to 9.60 mm/day, Lagos Spinach (*Celosia argentea*) also varied from 0.75 to 9.22 mm/day and daily water use for Jute mallow (*Corchorus olitorius*) varied from 0.51 to 8.57 mm/day. It was observed that there was definite pattern for the daily crop water use with respect to crop age as the values kept risen from the initial season period and falling towards the end of season. This is typical daily evaporation during the rainy season as higher evaporation does happen on very sunny and cloudless days and lower evaporation on cloudy and rainy days. This is typical daily evaporation during the rainy season according to FAO (2005).

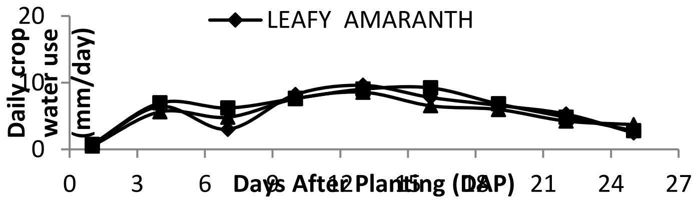

Figure 4: Daily Crop Water Use of Leafy Amaranth, Lagos Spinach and Jute Mallow during Rainy season

Daily Crop Water Use during Dry Season

The trend of daily crop water use of leafy amaranth (*Amaranth cruentus*), Lagos Spinach (*Celosia argentea*) and Jute mallow (*Corchorus olitorius*) respectively during dry season were shown on Figure 5. The daily crops water use for Leafy

Amaranth (Amarathus cruentus) lysimeter setup varied from 0.78 to 9.28 mm/day, Lagos Spinach (*Celosia argentea*) also varied from 0.9 to 9.79 mm day and daily water use for Jute mallow (*Corchorus olitorius*) varied from 0.07 to 9.78 mm/day. It was observed that there was definite pattern for the daily crop water use with respect to crop age as the values kept risen from the initial season period and falling towards the end of season.

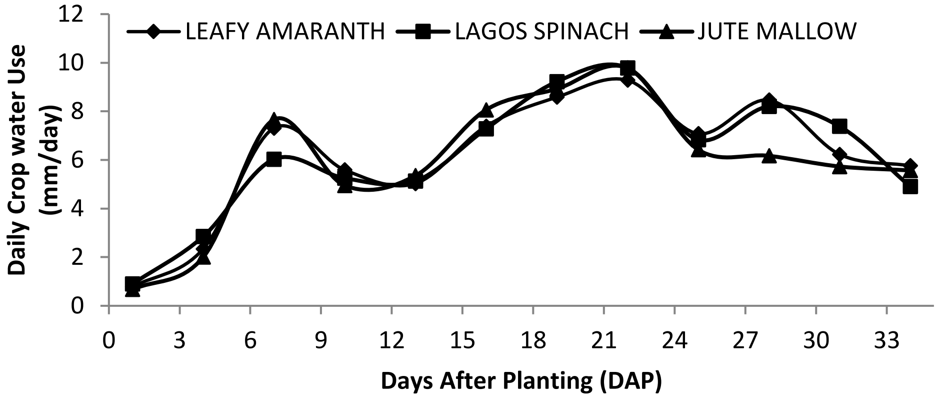

Figure 5: Daily Crop Water Use of Leafy Amaranth, Lagos Spinach and Jute Mallow during Dry season

Comparison of Estimated and Potential Crop Water Use (Dry Season)

Table 2, 3 and 4 show weekly potential crop water use (ET_C) and estimated crop water use using lysimeter for Jute Mallow, Lagos spinach and Leafy Amaranth respectively during Dry season. The CU compared closely with ET_C for all vegetables with mean difference of 0.25 and 2.82 mm/week for the Jute Mallow, Lagos spinach and Leafy Amaranth respectively. The mean difference were not statistically significantly different at the 0.05 level of significance, which implies that the weighing lysimeters is effectively estimated the crop water use of the vegetables.

Table 2**:** Estimation of Potential and Lysimeter Based Water Use for Jute Mallow during Dry Season

DAP	**ET_O**	**ET_C**	**CU**
1 -7	16.38	9.1	**10.33**
8 - 14	23.57	18.11	**18.36**
15 - 21	28.42	25.41	**25.12**
22 - 28	20.65	15.96	**17.47**

Table 3**:** Estimation of Potential and Lysimeter Based Water Use for Lagos Spinach during Dry Season

DAP	**ET_O**	**ET_C**	**CU**
1 -7	16.38	9.1	**9.78**
8 - 14	25.85	17.27	**17.66**
15 - 21	28.58	23.02	**25.84**
22 - 28	29.17	22.32	**2048**

Table 4: Estimation of Potential and Lysimeter Based Water Use for Amaranth during Dry Season

DAP	**ET_O**	**ET_C**	**CU**
1 -7	16.38	9.1	**10.43**

8 - 14	26.69	18.11	**18.01**
15 - 21	30.76	25.41	**24.94**
22 - 28	20.22	24.24	**20.45**

Comparison of Estimated and Potential Crop Water Use (Dry Season)

Table 5, 6 and 7 show weekly potential crop water use (ET_C) and estimated crop water use using lysimeter for Jute Mallow, Lagos spinach and Leafy Amaranth respectively during Rainy season. The CU compared closely with ET_C for all vegetables with mean difference of 0.88and 2.13 mm/week for the Jute Mallow, Lagos spinach and Leafy Amaranth respectively. The mean difference were not statistically significantly different at the 0.05 level of significance, which implies that the weighing lysimeters is effectively estimated the crop water use of the vegetables

Table 5: Estimation of Potential and Lysimeter Based Water Use for Jute Mallow during Rainy Season

DAP	**ET_O**	**ET_C**	**CU**
1 -7	11.13	11.13	**10.94**
8 - 14	19.25	16.59	**12.51**
15 - 21	23.31	11.27	**12.51**
22 - 28	11.83	8.45	**7.76**

Table 6**:** Estimation of Potential and Lysimeter Based Water Use for Lagos Spinach during Rainy Season

DAP	**ET_O**	**ET_C**	**CU**
1 -7	13.02	13.02	**13.9**
8 - 14	15.54	14.53	**16.66**
15 - 21	16.59	14.92	**16.05**
22 - 28	16.52	8.35	**7.63**

Table 7**:** Estimation of Potential and Lysimeter Based Water Use for Leafy Amaranth during Rainy Season

DAP	**ET_O mm/day**	**ET_C**	**CU**
1 -7	13.09	13.09	**10.43**
8 - 14	15.96	16.72	**18.01**
15 - 21	17.99	25.95	**24.94**
22 - 28	17.29	18.45	**20.45**

CONCLUSION

The study has demonstrated the use of weighing lysimeter that are economically constructed with readily available materials to estimate the crop water use for Jute mallow (*Corchorus olitorius*), Lagos Spinach (*Celosia argentea*) and Leafy Amaranths (*Amaranthus cruentus*). The lysimeter performance is close to expected resolution and accuracy and is entirely adequate for the intended crop water use research. The growth pattern within the lysimeter tank was observed to be similar to those within the field. Potential crop water use estimated compared with daily water use for all selected vegetables implies that the weighing lysimeter setup for the study were quite effective and the system will grants easy opportunity to estimate crop water use.

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ASSESSMENT OF HEAVY METALS IN AGRICULTURAL SOILS IN SELECTED LOCAL GOVERNMENT AREAS OF KWARA STATE

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ABSTRACT

Assessment of agricultural soils for heavy metal contents is of great concern due to potential health implications and safety issues involved in the uptake of the metals by crops on agricultural soils. This study is aimed at assessing the concentration of heavy metals in agricultural soils of some selected farms in Kwara state. Soil samples were collected from four location (Idofian, Oro, Omu-Aran and Ogbondoroko) and analysed for pH, textural classification and some heavy metals metal contents (Cd, Cr, Pb, Zn, Co, Cu, and Mn) using standard pH meter, hydrometer method and atomic absorption spectrometer (AAS) method respectively. The results of the analysis showed that the pH of the soil ranges from slightly acidic to slightly alkaline (5.40 to 7.50). The textural classification of the soils showed that aside of Oro which can be classified as sandy loam other locations have loamy soil. The mean concentrations of the heavy metals ranged from (0 to 7.67 mg/kg) for Cd, Cr, Pb, Zn, Co, Cu, and Mn. The obtained values for respective metal are below the established limit of FAO and WHO. This implies that the heavy metals considered are not of grave concern at present. The correlation analysis showed a strong correlation between the heavy metals and soil pH.

Keywords: *Agricultural Soils, Heavy Metals, Kwara State, Pearson‘s correlation analysis*

INTRODUCTION

Soil is an important component of the ecosystem that supports the growth of plants. This vital resource is a subject to short term fluctuations, such as variation in moisture content and pH, and it as well undergoes gradual alterations in response to changes in management and environmental factors (Abubakar et al, 2002). Aside the agricultural function; it is also an important reservoir receiving a significant amount of pollutants from different sources. It does not only serve as sink for the chemical pollutants but also acts as a natural buffer by controlling the transport of chemical elements and substances in the environment (Kabata-Pendias et al., 2011). The chemical reaction between chemical pollutant and soils are usually irreversible leading to undesirable changes in our environment and leaving the soil contaminated (Odoi et al., 2011). Once the soil is contaminated it poses health risk to soils, most biomaterials cultivated on it and to man who ultimately consumed them (Stavrianou, 2007). Soil gets expose to these metals through a number of way which include natural sources, fossil fuel combustion, phosphate fertilizers, wastewater and municipal solid waste incineration (Michael, 2010).
Recently, different groups have produced reports addressing the state of the soils and recommendations have been made for soil protection policy (Qishlaqi and Moore, 2007). Van-Camp et al. (2004) for instance identified the need to measure soil heavy metal concentrations and contamination processes. The excessive use of agrochemicals in agriculture in order to boost production is also noted for the introduction of heavy metals as well as other pollutants into the soil (Facchinelli et al., 2001). The analysis of heavy metal concentrations in agricultural soils is therefore, critical for policy making orientated toward reducing heavy metal inputs to soil and guaranteeing the maintenance or even the improvement of soil quality (Mico et al., 2006). Thus, this study is aimed at assessing the heavy metal content of agricultural soil in Kwara state.

MATERIALS AND METHODS

Description of the Study Area

This study was carried out in some Local Government Areas of Kwara state. Soil samples were collected from four (4) sites. The sites are Idofian in Ifelodun Local Government (Lat 8^{0}23’24”N; Long 4^{0} 39’53”E), Ogbondoroko in Asa Local Government (Lat 8^{0} 23’45’’N; Long 4^{0} 35’13’’E), Oro (Lat 8^{0} 13’52”N; Long 4^{0} 54’3”E) and Omu Aran (Lat

8^0 8" 35"N; Long $5^0$6'48"E) both in Irepodun Local Government. The choice of the sampling points was informed by the types of activities done close to the farm areas and based on the sizes and types of agricultural practice (Fig. 1).

Fig. 1: Map showing the study areas

Soil Sampling

A total of twelve (12) samples were taken from the study areas. Each farm site was divided into three and from each; eight (8) subsamples were taken at a depth of 0-30cm of cultivated farmland with a soil auger. The subsamples were mixed thoroughly in a container to get an accurate representation of the farm, after which a sample was taken from each making a total of three (3) samples from each sites as adopted by Syed *et al.* (2012). Each sampling point on each location has a difference in distance of not less than 10 m (Syed *et al.,* 2012). Some 250 to 300g of soil samples were taken from each site and placed in a pre-cleaned polyethylene container and labelled accordingly before being taken to laboratory for analysis. The collected soil samples were air dried at room temperature for three (3) days. Large debris, stones, and pebbles were removed before being passed through a polyethylene sieve of 2mm size.

Physicochemical Analysis of the Soil Samples

Soil texture and pH

The soil texture was determined using the USDA textural triangle as described by Gee and Or (2002). The pH meter was standardized using buffer 7 and buffer 10 solutions before carrying out the test. A 40 g of the collected soil sample was poured into a plastic cup after which 40 mL of distilled water was added using a pipette, stirred using a glass rod and left for an hour. The sample was then stirred continuously and the soil pH was measured and recorded (Abollino *et al*., 2002)

Heavy Metals Determination

Some 1g of the air dried and well pulverized soil was weighed using digital weighing balance into a conical flask of 100ml. Distilled water of 10ml was used to moisten the soil and 10ml of aqua rega (1:3 HNO_3 and HCl) was also added. The soil solution was boiled for about 30 minute after which another 10ml of distilled water was added. The boiling was continued for another 10 minutes after which the soil solution was filtered and the filtrate was made up to 100ml with distilled water and then transported to laboratory for analysis using Atomic Absorption spectrometer (AAS) (Brigden *et al*., 2008).

Statistical Analysis

The results obtained were statistically analyzed using Descriptive Analysis (DA) and Correlation Analysis (CA). CA was used to reveal the relationship between pH and heavy metal concentrations, DA helps in showing the mean and standard deviation of the heavy metals and CA was used to determine the degree of relationship among the parameters considered. The analysis was performed with Palaeontological Statistics (PAST) software.

RESULTS AND DISCUSSIONS

Particle Size Distribution and pH values

The result of the particle size distribution indicates that using the mean value of each site Idofian (83.1±0.8.1 % Sand, 13.81±7.09 % Silt, 2.85± 0.99 % Clay), Omu-Aran (88.7±1.02 % Sand, 11.3±**1.**02 % Silt, 0.0± 0.0 % Clay) and Ogbondoroko (86.47±4.15 % Sand, 11.93±3.07 % Silt, 1.75±1.28 0. % Clay) have the same textural class (Loamy sand), while Oro (87.88±3.59 % Sand, 7.8±2.11 % Silt, 4.33±1.48 % Clay) has Sandy loam (Table 1). The textural classifications obtained for these locations are in line with what was observed by Affinnih *et al.* (2014) for agricultural soils in Kwara as many of the sites are loamy sand.

Table 1: pH and soil particle size distribution value of the study sites

Sites	Parameters			Textural Class		
		pH	% Sand	% Silt	% Clay	
Idofian	Range	6.80-7.50	73.17-93.02	4.65-21.95	2.07-4.16	Loamy sand
	Mean	7.07	83.1	13.81	2.85	
	SD	0.306	8.104	7.099	0.989	
Oro	Range	5.40-6.90	83.33-92.11	5.26-10.42	2.65-6.25	Sandy loam
	Mean	6.14	87.88	7.8	4.33	
	SD	0.612	3.592	2.107	1.48	
OmuAran	Range	6.00-6.20	87.50-90.00	10.00-12.50	0	Loamy sand
	Mean	6.1	88.7	11.3	0	
	SD	0.1	1.023	1.023	0	
Ogbondoroko	Range	6.20-7.10	81.81-91.89	8.11-15.63	0-3.03	Loamy sand
	Mean	6.5	86.47	11.93	1.75	
	SD	0.391	4.15	3.071	1.282	

pH is an important soil parameter which is responsible for the regulation of chemical and biological activities in soil (Brady and Weil, 2002). Nutrient and heavy metal availabilities are functions of pH level in soil (Solomon, 2008). Thus, soil pH has the tendency for providing a useful index for the potential soil holding capacity for heavy metals, nutrients and fertility of soils (Aheneku and sadiq 2014). In this study, Idofian soil has a mean pH value of 7.07 indicating a neutral state of soil which is tending towards alkalinity. Oro, Omu-Aran, and Ogbondoroko soils are slightly acidic with a mean pH value of 6.14, 6.1 and 6.5 respectively. The obtained pH value in this study is though higher than the value (4.00-6.30) reported by Affinnih *et al.* (2014), it is in line with the value (5.58 -7.16) reported by Ibiremo *et al.* (2010) for agricultural soil in kwara state. This implies that the state of the soil assessed is good for agricultural activities as acidic soil (with pH < 5.5) hinder microbial activities (Animashaun *et al.,* 2015).

Heavy Metal Contents of the assessed agricultural soils

Presence of heavy metals at measurable concentration was observed in all the agricultural farmlands assessed. The mean concentration of Ni in Idofian soil sample was 0.3±0.025 mg/kg which is lower than the soil maximum allowable value of 75 mg/kg by FAO. The observed value (0.01±0.00) for Cd was also below the established limit of 73 mg/kg by FAO (2006). Cr content of the soil was 0.17±0.060, while the respective Pb, Zn, Co, Cu and Mn contents of the soil were 0.37±0.208, 0.32±0.085, 0.16±0.015, 0.25±0.01, 5.54±0.53 mg/kg (Fig. 2). Though Mn was relatively high, all the parameters assessed had values that were lower than the established limit by FAO (Cu= 135, Zn= 300, Ni= 75, Pb= 300) in agricultural soils as reported by Abrahim and Parker (2008)

At Oro, the mean concentration of Mn (5.54±0.53 mg/kg) was also the highest, while Cd had the least value of 0.01±0.00 mg/kg. The mean concentrations for Ni, Cr, Pb, Zn, Co, and Cu were 0.08±0.026 mg/kg, 0.23±0.068 mg/kg, 0.30±0.1 mg/kg, 0.54±0.267 mg/kg, 0.08±0.006 mg/kg, and 0.18±0.044 mg/kg respectively. The observed values for the metals were all within the permissible limits by FAO in agricultural soils. The mean concentration of the assessed metals in Omu-Aran soil sample ranged from 0.01 to 3.10 mg/kg. The order of concentration in this location was also similar with the first two locations. Mn recorded the highest mean concentration of 3.10±0.65 mg/kg while Cd has the least (0.01±0.01 mg/kg). Ni, Cr, Pb, Zn, Co, and Cu have respective mean concentrations of 0.12±0.01 mg/kg, 0.24±0.025 mg/kg, 0.20±0.100 mg/kg, 0.60±0.113 mg/kg, 0.17±0.081 mg/kg and 0.16±0.006 mg/kg. At Ogbondoroko a similar trend was also observed in terms of the metals with the highest and lowest concentration. Mn has the highest mean concentration of all the heavy metals assessed (7.67±1.33 mg/kg) while Cd has the least concentration. The mean concentrations of Ni, Cr, Pb, Zn, Co, and Cu were 0.07±0.02 mg/kg, 0.13±0.015 mg/kg, 0.10±0.0 mg/kg, 0.33±0.090 mg/kg, 0.10±0.025 mg/kg, and 0.14±0.015 mg/kg respectively.

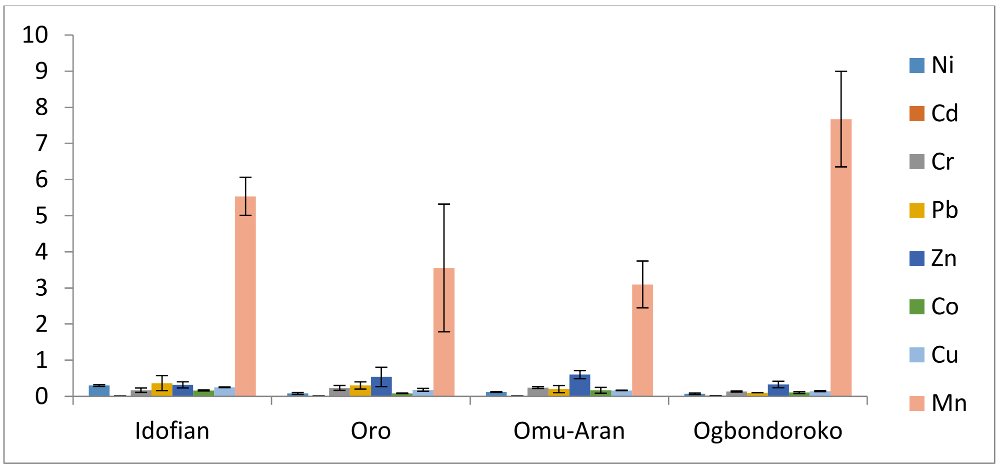

Fig. 2: Mean Concentration of Heavy Metals in Idofian Soils (mg/kg)

All the heavy metals considered in this study can be associated with environment hazard and human health problems especially in areas with high anthropogenic pressure (Singh and Angrawal, 2010; Islam *et al.,* 2007). However, some (such as Zn, Mn, Cu) are essentially needed by the body for growth and development, (Skudi, 2011). Their presence in soil, even in traces can cause serious problems to all organisms as heavy metal bioaccumulation in the body through the food chain can be highly dangerous (Lone *et al.,* 2008).This is because ingestion is the main route of exposure of man to these metals in contemporary period (Singh and Taneja, 2010).

The concentration Ni in the four assessed farmlands ranged from 0.05 to 0.33 mg/L, while that of Cd, Cr, Pb, Zn, Co, Cu and Mn ranged from 0.05-0.33 mg/kg, 0.01-0.03 mg/L, 0.11-0.31 mg/L, 0.1-0.6 mg/L, 0.4-0.84 mg/L, 0.09-0.24 mg/L, 0.13-0.26 mg/L and 2.07-9.1 mg/L respectively. The results obtained (especially for Pb, Zn and Cu) in this study are lesser than the values reported by Ahaneku and Sadiq (2014). This is not unexpected as relatively high pH values recorded on the study areas do not favour heavy metal concentration (Rieuwerts *et al.*, 1998).

Though, Pb concentration is low, it needs to be monitored regularly as it is considered a highly poisonous metal, affecting almost every organ and system (especially nervous system) in the body (Jagadish, 2010). Long-term exposure to it can result in nephropathy, severe brain damage, colic-like abdominal pains and deficiency in the production of blood cells (Needleman *et al*., 1990; Counter *et al*., 1998). Zn at a considerate level oversees the efficient flow of body processes, maintenance of enzyme systems and cells (Kipkemboi, 2009) but at a high level it causes vomiting and diarrhea and leads to liver or kidney damage (Bothwell, 2003). Cu also has a tendency to accumulate in the blood and deplete the brain zinc supplies.

The mean content of Ni in the areas under study followed the order Idofian>Omu-Aran>Oro>Ogbondoroko while Mn followed as Ogbondoroko>Idofian>Oro>Omu-Aran. Mean contents of Ni, Cd, Cr, Zn and Co in Omu-Aran were the highest among all sites. Omu-Aran soils contain higher levels of heavy metals compared to other areas assessed. This may be due to the usage of dam water for irrigation. Tahmiscioğlu *et al*. (2011) claimed that soil pollution can be one of the negative consequences of dam.

Correlation Analysis

Pearson‘s correlation analysis was done to determine the degree of relationship between the soil pH and heavy metal concentrations of the soil. The results of the analysis showed that there is a strong relationship between pH content and heavy metals contents of the soil (Table 2-5). In Idofian soil for instance, pH was negatively correlated Ni (r = 0.888), Pb (r = 0.799), Co (r = 0.851), Cu (0.935) and Mn (r = 0.996) while it has a strong positive correlation with Cr (r = 0.897) and Zn (r = 0.922) (Table 2). This implies that while Ni, Pb, Co, Cu and Mn increase with decrease in pH, Cr and Zn increase with increase in pH. The results also indicated that almost all the heavy metals were significantly correlated ($p<0.05$) with one another in each of the location. Ni was positively correlated with Pb (r = 0.986), Co (r = 0.997), Cu (r = 0.993) and Mn (r = 0.846), while it has strong negative correlation with Cr (r = 0.999) and Zn (r = 0.997)

Table 2: Correlation coefficients (r) between measured parameters in Idofian Soils

	pH	Ni	Cr	Pb	Zn	Co	Cu	Mn
pH	1.000							
Ni	-0.888**	1.000						
Cr	0.897**	-0.999**	1.000					
Pb	-0.799*	0.986**	-0.983**	1.000				
Zn	0.922**	-0.997**	0.998**	-0.970**	1.000			
Co	-0.851**	0.997**	-0.996**	0.996**	-0.988**	1.000		
Cu	-0.935**	0.993**	-0.995**	0.961**	-0.999**	0.982**	1.000	
Mn	-0.996**	0.846**	-0.856**	0.746*	-0.886**	0.804**	0.902**	1.000

In Oro, Ni (r = 0.940), Cr (r = 0.959), Zn (r = 0.943) where positively correlated with pH while Co (r = 0.858), Cu (r = 0.924), Mn (r = 0.996) were negatively correlated (Table 3). Cd (r = 0.866), Co (r = 0.619) and Cu (r= 0.866) were positively correlated with pH in Omu-Aran (Table 4) while all the assessed heavy metal had strong negative correlation with pH in Ogbondoroko soils (Table 5). Strong positive and negative correlation among the heavy metals observed in this study is in line with the findings of Mustapha and Aris (2012) and Ahaneku and Sadiq (2013).

Table 3: Correlation coefficients (r) between measured parameters in Oro Soils

	pH	Ni	Cr	Pb	Zn	Co	Cu	Mn
pH	1.000							
Ni	0.940**	1.000						
Cr	0.959**	0.805**	1.000					
Pb	-0.487**	-0.756*	-0.220	1.000				
Zn	0.943**	0.773*	0.999**	-0.169	1.000			
Co	-0.858**	-0.982**	-0.679*	0.866**	-0.639*	1.000		
Cu	-0.924**	-0.737*	-0.994**	0.115	-0.999**	0.596*	1.000	
Mn	-0.969**	-0.995*	-0.860**	0.687*	-0.832**	0.958**	0.801*	1.000

Table 4: Correlation coefficients (r) between measured parameters in Omu-Aran soils

	pH	Ni	Cd	Cr	Pb	Zn	Co	Cu	Mn
pH	1.000								
Ni	0.500	1.000							
Cd	0.866**	0.866**	1.000						
Cr	-0.397	0.596*	0.115	1.000					
Pb	0.500	0.990**	0.866**	0.596*	1.000				
Zn	0.044	0.887**	0.538*	0.899**	0.887**	1.000			
Co	0.619*	0.989**	0.929**	0.475	0.989**	0.812*	1.000		
Cu	0.866**	0.000	0.500	-0.803*	0.000	-0.461	0.143	1.000	
Mn	0.116	0.918**	0.597*	0.866**	0.918**	0.997**	0.852**	-0.396	1.000

Table 5: Correlation coefficients (r) between measured parameters in Ogbondoroko soils

	pH	Ni	Cd	Cr	Zn	Co	Cu	Mn
pH	1.000							
Ni	-0.952**	1.000						
Cd	-0.877**	0.982**	1.000					
Cr	-0.877**	0.982**	0.998**	1.000				
Zn	-0.931**	0.998**	0.992**	0.992**	1.000			
Co	-0.911**	0.993**	0.997**	0.997**	0.999**	1.000		
Cu	-0.877**	0.982**	0.999**	0.998**	0.992**	0.997**	1.000	
Mn	-0.893**	0.988**	0.999**	0.999**	0.996**	0.999**	0.999**	1.000

** Correlation is significant at the 0.05 level*

*** Correlation is significant at the 0.01 level*

CONCLUSION

The agricultural soils in Idofian, Oro, Omu-Aran and Ogbondoroko were assessed for heavy metals concentration. The result showed that the most dominant among the assessed metals was Mn and the metal with the least concentration value was Cd. Though there is variation in the concentration of the metals across the location, the values are within the permissible limit for agricultural soils. This showed that the concentration of the heavy metals in all the areas are not of high risk for now and the soils are still good for agricultural purposes. The results of correlation analysis indicated strong relationship among the heavy metals and soil pH. Considerable high value of some of the metals indicated probable anthropogenic sources of pollution.

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EFFECT OF TILLAGE DEPTH ON SOME SOIL PHYSICAL PROPERTIES IN GIDAN KWANO

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ABSTRACT

Soil tillage management influences soil, as a result of altering physical, chemical and biological properties statement not clear. This study was conducted to evaluate the effect of tillage depth on some soil physical properties in Gidan Kwano of the Federal University of Technology, Minna using the school farm. Twelve (12) soil samples were analyzed to check the effect on the physical properties at varied tillage depths; 0-10 cm, 10-20 cm and 20-30 cm. These physical properties include soil moisture content, bulk density, porosity, soil volume disturbed, soil temperature and soil particle distribution. The soil particle size analysis reveals that the soil textural class majorly falls on loamy sand with 80.8-85.1 % sand, 5.56-10.85 % silt and 7.40-12.9 % clay. Results showed significant ($p<0.05$) difference in soil physical properties due to the imposed variation in tillage depth. Soil temperature was only significant at tillage depth of 0-10cm, while no significant difference was observed for No-Tillage (NT) and tillage depth range from 10 to 30 cm. It was observed that bulk density increased with corresponding depth, tillage depth 20-30 cm recorded the highest value for bulk density. Also moisture content showed significant difference as the highest moisture content value was recorded at 20-30 cm tillage depth. It was discovered that soil volume disturbed increased with tillage depth. Soil porosity was observed to show little significant difference ($p\leq0.05$) against variation in tillage depth.

KEYWORDS: *Tillage depth, soil physical properties, moisture content, soil, no tillage.*

INTRODUCTION

Tillage is the manipulation of the soil in order to provide conditions necessary for crop growth. In general, the objectives of tillage include; providing a good soil tilt which will be suitable for the operation of subsequent machinery and growth of the crop, to prepare land for irrigation and drainage operation and also to mix fertilizers, crop residue and other soil amendments into the soil (Onwualu *et al*., 2006).

Tillage is used to manipulate the soil to create conducive environment (soil loosening) for crop growth. In the process, the soil physical properties can be impacted either positively or negatively depending on the management technique. Soil tillage may be defined as the mechanical manipulation of the soil aimed at improving soil conditions for crop production. It represents the most costly single item in the budget of a farmer. Tillage provides good weed control with low herbicide cost; allows the control of disease and insect pests by destroying them through burying of crop residue. Three things are involved in soil tillage which includes: the power source, the soil and the implements (Olatunji, 2007). Tillage implements or tools vary in terms of both width and depth of ploughing and in terms of the intensity in soil overturn administered by the implement (plough, harrow, etc.). Furthermore, interactions between natural factors (e.g., soil-type, geology, topography, and climate and weather patterns) and crop selection in part, determine the intensity, depth, frequency, and timing of tillage, which highlights the need for a mechanistic understanding of tillage effects on soil physical properties. Even incidental effects of tillage, such as wheel traffic, can lead to complicated and stochastic soil response. Some soil physical properties especially the hydraulic properties significantly vary even in a short time period, such as during crop cycle, especially immediately after tillage. Similarly, other researchers (Strudley *et al*., 2008; Alletto and Coquet, 2009) related the dynamics of temporal and spatial variability in soil physical properties and processes to tillage management practices. Tillage is used to manipulate the soil to create a conductive environment (soil loosening) for crop growth. In the process, the soil physical properties can be impacted either positively or negatively depending on the management technique.

However, tillage may have negative impacts on soil and crop production, when excessive or inappropriate. Among the disadvantages are land degradation, compaction of soil below the depth of tillage, increased susceptibility to water and wind erosion, accelerated decomposition of soil organic matter, high energy cost of tillage operations, and labour and temporal obligations (Mitchel *et al*., 2007). The impact of tillage depends on the combination of tillage operations and their timing which is the tillage system, to provide specific functions in given situations. The ways in which these operations are implemented affect the physical and chemical properties of the soil, which in turn affect plant growth and crop yield potential. Therefore, the first step in making sustainable production management decisions is to understand the practices associated with each tillage system (Aina, 2011). Soil bulk density, penetration resistance (PR), and water movement in the soil, all indices of soil compactness and porosity, depend on depth and method of tillage (Hamza and Anderson 2002, 2003, 2005). Therefore, assessing the effect of tillage depth and method on these soil physical properties may explain variability in crop growth, crop development, yield, and quality (Hamza and Anderson, 2002, 2003, 2005). Generally speaking, all tillage methods reduced soil bulk density and penetration resistance to the depth of tillage (Erbach *et al*., 1992). It is needful to state that soil tillage is among the important factors affecting soil physical properties. Tillage method affects the sustainable use of soil resources through its influence on soil properties (Schwartz *et al.*, 2010). The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrient (Aina, 2011). Use of excessive and unnecessary tillage operations is often harmful to soil. Therefore, currently there is a significance interest and emphasis on the shift to the conservation and no-tillage methods for the purpose of controlling erosion process (Iqbal *et al.,* 2005).

It therefore becomes needful to test the commonly practiced tillage depths in Nigeria by plough implement in order to ascertain the efficacy of each in relation to what is desirable.

The Objectives of this study are;

- To carryout ploughing operation at different tillage depth.
- To determine the soil physical properties after ploughing operation.

MATERIALS AND METHODS

Site Description

The study was carried out at the Federal University of Technology, Gidan Kwano Campus, Minna (latitude 9° 41 ' N and longitude 6° 31 ' E; 258.5 m above sea level), in the southern Guinea savanna zone of Nigeria. Climate of Minna is sub humid with mean annual rainfall of about 1284 mm and a distinct dry season of about 5 months duration occurring from November to March. The mean maximum temperature remains high throughout the year, about 33.5 oC particularly in March and June (Ojanuga, 2006). The town has a mean annual precipitation of 1300mm taken from an exceptionally long record of 50 years. The highest mean monthly temperature is in September with almost 300mm. the raining season starts on average between the 11th and 20th April, and last between 190 and 200 days. Temperature rarely falls below 22 ºc .The peaks are 40ºc (February-March) and (November-December). The experiment was conducted during the first peak of rainy season.

Equipment Description

A 70 hp (50.2 kW) 275 Massey Ferguson tractor was used to pull the implement during the field operations. Standard disk plough (SDP) was used for the experiment, the plough consist of three (3) plane concave discs with a spacing of 680 mm.

Experimental Design

The single-factor experiment was laid out in a randomized complete block design (RCBD) with three (3) treatments and three (3) replicates and a control experiment in each block. Three blocks were used with area coverage of 150 m² per block. Three tillage depths were compared. The description of the tillage treatment in RCBD is presented in Table 3.1. The size of each block was 15.0m long and 10.0m wide, also each block was composed of four (4) plots with 1m spacing so that each plot in a block . A buffer zone of 1.0m spacing was provided between blocks. The field experiment was done on the 8th June, 2016.

Measurements

Four (4) soil samples were taken from each block with the aid of locally made Soil Auger commonly used for obtaining soil samples near the surface and for boring depths where samples may be obtained. Total of twelve (12) soil samples were taken on the 8th June, 2016 after the field operation was conducted. The distance apart from one sampling point to another was approximately 3 m at each location.

Soil Moisture Content

For each sampling occasion, total of twelve (12) soil samples were taken randomly four (4) samples from each block at 10 cm depth increment to 30 cm as designated. A no-tillage plot was reserved in each block. Soil samples were weighed, oven-dried at 105˚c for 24 hours, and weighed again to determine the gravimetric moisture content.

Bulk Density

Soil samples from three replicates for each plots randomly collected, at 10cm depth increment to 30cm were taken to the laboratory to determine the soil bulk density. Soil samples were oven dried at 105ºc for 24 hours. Soil bulk density was calculated by using the following equation:

$$BD = \frac{W}{V} \quad (1)$$

Where, BD = bulk density, (g/cm^3); W = weight of dried soil sample, (g); V= total volume of the soil sample, (cm^3), (Osman *et al.*, 2011).

Soil Porosity

Soil porosity was obtained from the relationship between bulk density and particle density. Usually, particle density is expressed in units of grams per cubic centimeter (g/cm^3). An average value of 2.65 g/cm^3 is assumed for soil sample (Ahaneku and Dada, 2013).

$$\text{Soil Porosity} = (1 - \frac{\text{Bulk density}}{\text{Paticle density}}) \quad (2)$$

Soil Volume Disturbed

The total soil volume disturbed was calculated in cubic meters per hour by multiplying the effective field capacity with the depth of cut as below. It was assumed that the implement disturbed the soil up to its recorded depth and no undisturbed patch of land was left (Osman *et al*., 2011).

$$V = 10000CD \quad (3)$$

Where, V= Soil Volume disturbed, m^3/h; C= Field capacity, ha/h; D= Depth of cut, m.

Soil Temperature

Soil temperature is simply the measurement of the warmth in the soil. Soil temperature samples were measured with the use of soil thermometer by putting the silver sensor of the thermometer 2-2.5cm into each soil sample.

Analysis of Soil Particle Distribution (using hydrometer method)

Fifty (50) grams of soil sample was weighed of 2mm sieve; 100ml of distilled water was added to the sample in a bottle of and 5% sodium hexametaphosphate solution (Calgon (NaPO3)6, which served as dispensing agent. The mixer was placed in a shaker and shacked content was transferred quantitatively without losing any particle into the sedimentation cylinder, up to the liter marked with distilled water. The soil suspension was stirred with glass rod for 2mins. The hydrometer was inserted and reading taken at 40 seconds, also the temperature was measured by use of thermometer. Sample was placed on a surface undisturbed for 2 hours at which the hydrometer and thermometer were inserted respectively to take readings.

The 40 seconds reading was taken to measure the percentage of silt and clay in suspension. A blank sample was prepared without soil and the readings were also obtained. For every 1 ºc above 20 ºc, 0.36 was added to the hydrometer reading and for every 1ºc below 20 ºc, 0.36 was subtracted from the hydrometer reading (Anderson and Ingram, 1993)

$$\% \, Silt + clay = \frac{(S_1 - B_1) + ((ST_1 - 20^0 c) \times 0.36)}{50} \times \frac{100}{1} \quad (4)$$

$$\% \, Clay = \frac{(S_1 - B_2) + ((ST_2 - 20^\circ c) \times 0.36)}{50} \times \frac{100}{1} \quad (5)$$

$$\% \, Sand = 100 - \% \, silt + Clay \quad (6)$$

$$\% \, Silt = \% \, Silt + Clay - \% \, Clay \quad (7)$$

Where,

S_1= Sample Hydrometer reading at 40 sec; ST_1= Sample Thermometer reading at 40 sec;
S_2= Sample Hydrometer reading at 2 hrs; ST_2= Sample Thermometer reading at 2 hrs;
B_1= Blank Hydrometer reading at 40 sec; BT_1= Blank Thermometer reading at 40 sec;
B_2= Blank Hydrometer reading at 2 hrs; BT_2= Blank Thermometer reading at 2 hrs.

Tillage Depth

Tillage depth was achieved by releasing the hydraulic lever at various level to allow the disc plough penetrate the soil. Immediately following the tillage operations, tillage depth was measured on each plot to suit the stated depth. A steel rule was inserted into the tilled soil until a characteristic hard pan was encountered. The tillage depth was measured from the corresponding reading on the steel rule.

Data Analysis

Analysis of variance (ANOVA) in statistical package for social sciences (SPSS) version 20 was used to evaluate the significance of each treatment on all parameter under this study in a randomized complete block design with three replications. Mean between treatments were compared with Duncan's multiple range test. The statistical inference was made at 0.05 (5 %) level of significance.

RESULTS AND DISCUSSION

Effect of Tillage Depth on Soil Temperature

Soil temperature was significantly ($p<0.05$) affected by the tillage depth as shown in Table 3.1. Tillage depth at 0-10cm yielded higher value of soil temperature for the period of the study when compared with other tillage depth as the range of soil temperature (30.8-31.0ºc). At NT there was no significant difference in soil temperature as observed from Table 1. This may be attributed to short term of the period during which tillage operation was established in this study. There was no general trend in soil temperature difference with respect to tillage depth, as fluctuation in temperature value was noticed. This fact is supported by the study of Nofziger (2005) that soil temperature fluctuates annually and daily affected mainly by variations in air temperature and solar radiation. The annual variation of daily average soil temperature can be estimated using a sinusoidal function. (Hillel, 1982; Marshall and Holmes, 1988; Wu and Nofziger, 1999). Factors also likely to affect the surface soil temperature are radiation from the sun, slope of the land, water content, vegetation cover and albedo. Other factors that may be responsible for uniform subsurface soil temperature are heat flux from surface, moisture content, bulk density and heat capacity of soil.

Table 1 Average Temperature at Different Tillage Depth

Tillage depth (cm)	Soil Temperature (ºc) Block 1	Block 2	Block 3
0-10	$30.80^a \pm 0.100$	$31.00^a \pm 0.100$	$30.9^b \pm 0.000$
10-20	$28.50^{ab} \pm 0.200$	$28.30^a \pm 0.000$	$28.20^a \pm 0.100$
20-30	$27.60^a \pm 0.200$	$27.80^a \pm 0.000$	$28.00^b \pm 0.800$
NT	$28.40^a \pm 0.100$	$28.30^a \pm 0.000$	$28.20^a \pm 0.100$

NT-No Tillage. Values are means of three replicates in all Treatment. Results presented are mean values of each determination ± standard error mean (SEM). Values on the same row for each parameter with different superscript are significantly different (P$\leq$ 0.05) while those with the same superscript are not significantly different (P$\geq$ 0.05).

Effect of Tillage Depth on Soil Bulk Density

Bulk density was significantly (p<0.05) affected by tillage depth as shown in Table 2. Bulk density reflects the soil condition disturbed. Table 4.2 shows slight increase in mean values of bulk density of the soils along rows of different tillage depth under consideration. This is consistent with similar studies (Osman *et al*., 2011; Doa, 1996). All the recorded bulk density values were between 0.910 to 1.123 g/cm³, which is the range described by Chi *et al*. (1993) for usual agricultural soils. Highest bulk density was noticed at tillage depth (20-30 cm), and that is probably referred to the variation in the structural conditions of the soil as described by Chen *et al*. (1998). It was also noticed from the Table 4.2 that closely followed with higher value of bulk density was no till. Some studies have found that bulk density increased under no-till in relation to conventional tillage (Disc plough) as reported (Terbrugge and During, 1999) or reduced tillage (Mc Vay *et al*., 2006). Bulk density may generally increase with depth but did not follow any consistent trend with time among tillage depth (Table 2). Tillage depth may be responsible for the significant difference on soil bulk density at depth 0-10 cm, 10-20cm and 20-30 cm (Table 3.2).

Table 2 Average Bulk Density at Different Tillage Depth

	Bulk Density (g/cm³)		
Tillage Depth (cm)	Block 1	Block 2	Block 3
0-10	0.953^{a}±0.029	1.049^{b}±0.067	0.944^{a}±0.042
10-20	0.910^{a}±0.073	0.916^{a}±0.084	1.123^{b}±0.140
20-30	1.034^{a}±0.0277	0.953^{b}±0.980	1.032^{a}±0.0257
NT	0.988^{a}±0.021	0.994^{a}±0.973	1.045^{b}±0.036

NT- No Tillage. Values are means of three replicates in all Treatment. Results presented are mean values of each determination ± standard error mean (SEM). Values on the same row for each parameter with different superscript are significantly different (P$\leq$ 0.05) *while those with the same superscript are not significantly different (P*$\geq$ 0.05).

Effect of Tillage Depth on Soil Moisture Content

Different tillage depth significantly affected soil moisture content during the study. The highest soil moisture content (15.68 %) was obtained for tillage depth 20-30cm and the lowest (9.02%) for NT as shown in Table 3.3. Result show that NT obtained the lowest soil moisture content compared to other tillage depth. The low value of moisture content associated with NT is due to the decreased pore space, increased shear strength and stable aggregates (Mitchell *et al*., 2007) associated with conservation tillage (NT). Another reason attributed to low moisture content with NT soil is the level of compaction known with conserved soils (Garnet *et al*., 1984; Ried, 1978; Cambell *et al*., 1974; Raper *et al*., 1994). The general trend of variation amongst the tillage depths with regards to moisture content shows 20-30cm>0-10cm>10-20cm>NT respectively.

Effect of Tillage Depth on Soil Porosity

Soil porosity and organic matter content play a critical role in the biological productivity and hydrology of agricultural soils. The effect of different tillage depths on soil porosity is presented in Table 3.4. However, the significant is quite slim if not non-significant. Soil porosity across tillage depth are closely related as Pagliai and Vignozzi (2002) state that soil porosity characteristics are closely related to soil physical behavior, root penetration and water movement. The Table 3 also shows a thin line difference across tillage depth. Highest soil porosity was recorded at 0-10cm tillage depth for the period of the study as compared to other tillage depth; this is consistent with the report of Ahaneku and Dada (2013). This may be attributed to less pulverization of the soil provided by later tillage depths. Porosity can be said to decrease with increase in soil depth due to the natural increase in packing density with depth. Overall, in both 0-10cm and 10-20cm tillage depth produced the highest total porosity, while the NT treatment gave the lowest porosity, this result is in agreement with that recorded by Aikins and Afuakwa (2012) which state that overall, in both the 0-10 cm and 10-20 cm soil layers, the disc ploughing followed by disc harrowing treatment produced the highest total porosity while the No Tillage treatment gave lowest total porosity.

Table 3: Average Moisture Content at different Tillage Depth

	Moisture Content (%)		
Tillage Depth (cm)	Block 1	Block 2	Block 3
0-10	9.96^{a}±1.423	11.66^{b}±0.277	12.53^{c}±1.147
10-20	11.52^{b}±0.213	10.53^{a}±0.776	11.87^{c}±0.563
20-30	12.07^{b}±0.320	15.68^{c}±3.29	9.42^{a}±2.97
NT	9.02^{a}±0.820	10.03^{b}±0.46	10.47^{c}±0.630

NT- No Tillage. Values are means of three replicates in all Treatment. Results presented are mean values of each determination ± standard error mean (SEM). Values on the same row for each parameter with different superscript are significantly different (P< 0.05) *while those with the same superscript are not significantly different (P*> 0.05).

Table 4: Average Porosity at Different Tillage Depth

	Soil Porosity		
Tillage Depth (cm)	Block 1	Block 2	Block 3
0-10	0.640^{b}±0.011	0.604^{ab}±0.015	0.644^{c}±0.0147
10-20	0.657^{b}±0.028	0.654^{b}±0.089	0.576^{a}±0.053
20-30	0.606^{a}±0.013	0.640^{b}±0.021	0.611^{a}±0.008
NT	0.627^{a}±0.007	0.625^{a}±0.006	0.606^{b}±0.013

NT- No Tillage. Values are means of three replicates in all Treatment. Results presented are mean values of each determination ± standard error mean (SEM). Values on the same row for each parameter with different superscript are significantly different (P≤ 0.05) *while those with the same superscript are not significantly different (P*≥ 0.05).

Effect of Tillage Depth on Particle Size Distribution

The result Loamy sand was the dominant textural class across various tillage depth (0-10, 10-20, and 20-30 cm); sand ranges from 80.80-85.10 %, silt ranges from 5.56-10.85 % while clay ranges from 7.40-12.90 %. These results are similar to the Loamy sand textural class having 82.63% sand, 9.14 % silt and 8.23 % clay as reported by Sadik (2014). The result also show that tillage depth 0-10cm and NT have similar textural class (sand loamy); with ranges of sand 74.80-77.58 %, Silt 10.19-12.14 % and clay 12.80-12.23 % respectively, which are similar in comparison with those reported by Afolabi *et al.* (2014) (76.50 % of sand, 10.20 % of silt and 13.30 % of clay). This also correspond to the study of Odoh and Adebayo (2011) having 71.77% of sand, 12.27% 0f silt and 15.97 % of clay.

Effect of Tillage Depth on Soil Volume Disturbed

The soil volume disturbed was influenced by bulk density and soil water content at tillage (Cholaky *et al*., 2010). Fig. 1 shows the result of the average soil volume disturbed at 0-10cm, 10-20cm and 20-30cm tillage depth respectively. The highest soil volume disturbed as seen in Fig. 1 was at 20-30 cm depth, while the lowest at 0-10cm tillage depth. Soil volume disturbed increases with increase in tillage depth, thus establishing a direct proportionality. There is a significant difference on soil volume disturbed with respect to tillage depth. This result is reverse to the study by Osman et al. (2011,) that recorded soil volume disturbed decreases with increase in tilt angle of the of the disk plough, thus an indirect proportionality.

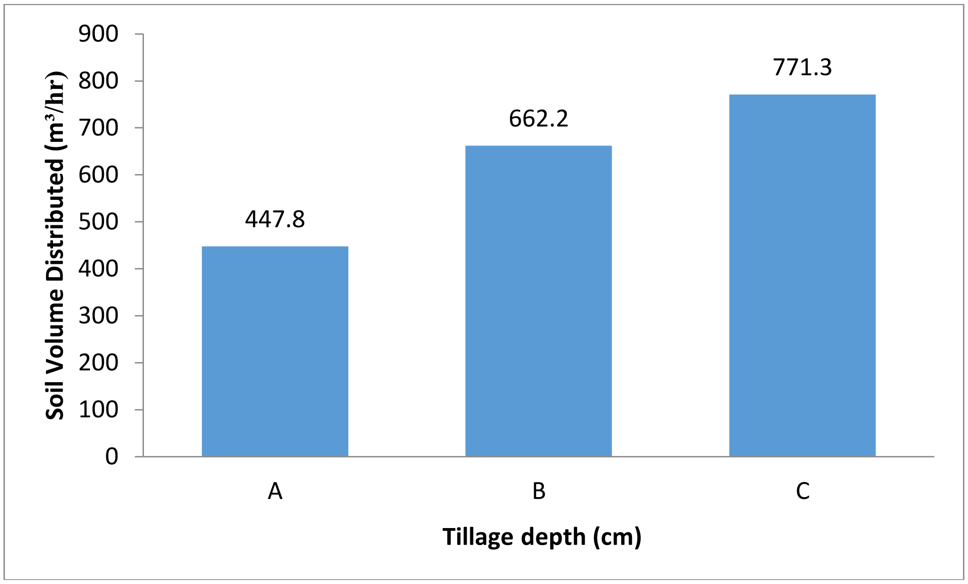

Fig. 3.1 Average Soil Volume Disturbed at Different Tillage Depth.

For Fig. 1

A- Tillage Depth at 0-10cm; B-Tillage Depth at 10-20cm; C-Tillage Depth at 20-30cm

4.0 CONCLUSION

Extracts from this study established a data base that can aid the predictions of the effect of conservation tillage depths on the soil physical properties. Results from the study indicate that:

- Soil temperature was only significant at tillage depth of 0-10 cm, while no significant difference was observed for NT and tillage depths 10-30 cm.
- Bulk density increases with tillage depth, highest bulk density was observed at the deepest tillage depth recorded (20-30cm).
- Decreased pore space account for low moisture content which was observed in NT. However, 20-30cm tillage depth exhibited highest moisture content. It therefore depicts that if high soil moisture content is required for crop cultivation, then deep tillage operation should be employed.
- Soil moisture content, particle size distribution and bulk density are more reliable indices for assessing soil tilth than soil temperature and soil porosity under different tillage depth.
- The study reveals that with increase in tillage depth during operation soil volume disturbed increased uniformly.

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EMERGING TECHNOLOGIES IN AGRICULTURE

THE IMPACT OF CLIMATE CHANGE ON NIGERIAN AGRICULTURAL SECTOR AND ECONOMY

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ABSTRACT

Nigeria economy already battered by the fall in oil price in the international market, with-0.37% GDP in first quarter of 2016(Q1/16) has been marked 'hot spot' for climate change by IPCC. The effects of Climate change which vary widely between the Northern and southern parts also vary slightly within the regions. The paper reviewed these effects as it relate to crop and animal productions, storage systems and farm machinery operation. It identified the causes and recommended ways of effective mitigation; especially via agriculture, which contribution to National GDP was up by 0.309% larger than manufacturing and oil sector in Q1/16and provides job to about 70% of the 173 million populations.

Keywords: *climate change, economy, agriculture, global warming, and oil price.*

INTRODUCTION

The term Global Warming was defined by Mastrandrea *et al.,* (2008) as the measurable increase in the average temperature of Earth's atmosphere, oceans, and landmasses. This increase in average global temperature is traced to the amount of greenhouse gas (GHG) emission into the atmosphere from both natural and human activities. The International Panel on Climate Change (IPCC) had already projected increase in average global temperature from 1.8 to 4.0°C by the end of 21st century (Encyclopaedia Britannica, 2014). Across Nigeria, daily temperature average which differs by location and period of the year from 25^0C in the southern coast to 40^0C in the north is projected to an average temperature rise of 1–2°C by 2050 (Ngene, 2012).Also, Nigeria has been identify by IPCC (2007b) as a climate change "*hot spot*" likely to see major shifts in weather mainly temperature, rainfall, storms, and sea levels throughout in the 21st century (Aaron, 2011). Meanwhile, the Simon *et al.,* (2016) model on effect of climate change on financial assets revealed that the expected 'climate value at risk' (VaR) of global financial assets today is 1.8% along a business-as-usual (BAU) emissions path, translating to $2.5 trillion. That implies, climate change will wipe about $2.5 trillion or 1.8% of world's financial assets if global mean surface temperature rises above its pre-industrial level of 2^0C by 2100, and Nigerian is not isolated. Figure 1of the impact of climate change on discounted cash flow shows that along (BAU)discounted global cash flow is higher when modulated to pre-industrial level of 2^0C by 2100 (Appendix A).This paper therefore draws attention to effects of climate change to Nigeria agricultural sector, the economic and proffered methods of mitigation.

THE STATE OF NIGERIA ECONOMY

The April 2014 statistical "rebasing" exercise indicated Nigeria as the Africa's largest economy going by 2013 GDP estimated at$ 502 billion (Nduka and Ikpefan, 2016).However, since the fall of oil prices in the global market, Eleni (2016) observed the GDP declined since 2013, the GDP of other 'giant' nations in Africa, South Africa and Egypt, confirms that Nigeria GDP nosedived sharply between 2013 and 2016 to -0.36% in the first quarter of 2016 (appendix A). Also, the Nigeria Economic Forecasts of 2016to 2020 (Table 1) predicted further decline to -2.92% by Q1 of 2017(appendix A). Today, Nigeria borrows to fund her 2016 budget. With unemployment rate of about 27.9%and inflation rate of 13.7% as at May 2016, and about ₦ 5.2 trillion annually lost to oil pipe line vandalism; over 62% of it has about 173 million populations live in extreme poverty (CIA-WFB, 2016).

EFFECTS OF CLIMATE CHANGE ON AGRICULTURE ACROSS NORTHERN REGION

As a result of climate change, the arid-north area is already faced with severe heat and less rainfall, while the Sahel area gets less than 10 inches rainfall a year which is a 25 percent less than that of thirty years ago (Aaron, 2011). Going by the IPCC prediction, the situation may get worse by 2100 when global rainfall would have dropped below 10%. An insight by Eleni (2016) holds that even the available arable lands in some of these areas are already experiencing up to 20% loss in farming period. Consequently, a change in temperature and precipitation patterns distort farming activities, damage non drought-tolerant or heat-tolerant varieties of input crops, and disrupts ancient agricultural practises well known to local farmers for favourable crop production. Some experts already linked mounting crop failures and declining yields in the Northeast to higher temperatures and drought (Ebele and Amodi, 2016). Nduka and Ikefan (2016) also observed that the higher temperatures and more erratic rainfall could contribute to a long-term 20 - 30 percent reduction in crop yields in the region.

Similarly, hot temperature is also a challenge in crop storage systems if not properly managed, because temperature is an important factor in minimising insect activity. When it is moderately higher than the control temperature, insects infestation and spread of pest diseases are generally high leading to crop storage losses. In addition, ventilation systems of storage structures developed elsewhere may require modifications like resizing of fans to accommodate challenges in heat and mass transfer occasioned by hot ambient temperatures. Also, temperature gradient between ambient and of storage may be large and cause moisture migration; a phenomena of moisture condensation at the surface region of stored product, leading to crop deterioration.

Climate change affects crop irrigation by shrinking water bodies; a case is Lake Chad, the world's sixth largest lake and the North's biggest irrigation resource, which less rainfall and higher temperatures have shrunk to one-tenth its size a half century ago**(**Coe and Foley, 2001). A study of over twenty years by a government agency observed a 400% increase in sand dunes in some Northern states occasioned by climate change (Aaron, 2011). Consequently, lands that would have been used for crop production are over taken by sand dunes. Again, hot temperature can cause overheating of engines and affect machine effectiveness. This entails more operational cost for the tractor operator like more oil and water for cooling systems. It can constitute health challenge to farmers, reduce productivity and time loss infield operations. It should be noted that any square meter of arable land lost to climate change, there is a resultant short fall in crop productivity, GDP and economic output.

Both heat and lack of water resource affect animal production. Animal production requires adequate water. It suffers tremendous set back when water is not readily available. The statement by Rick (2012) corroborates with the confirmation of the Dairy Australia that water requirements for beef cattle which depends on weight (surface area) and stage of production (metabolism) in cold weather are however, doubled during hot weather: it is 1 gallon of water per 100 pounds of body weight during cold weather to nearly 2 gallons in hot weather. Also lactating cows which require nearly twice as much water when compared to the dry ones per day, double the demand in hot weather. Therefore, to sustain animal production and diary business in hot weather may cost twice as much as in cold weather. Also, the need for water and grazing site have occasioned the migration of cattle and the herdsmen from the North to the South so as to keep the business afloat. The recurrent conflict between farmers and herdsmen in many parts of the country is a clear indication of devastation of climate change like the recent destruction of lives and property in Agatu and Nimbo communities of Benue and Enugu States respectively over grazing site and water source. Generally, climate change creates harsh business environment for animal production consequently reduces massive participation. Ebele and Amodi (2016) observed that there is already more than 20% reduction per annum investment profits in livestock production system due to climate change.

EFFECTS OF CLIMATE CHANGE ON AGRICULTURE ACROSS THESOUTHERN REGION

In the Southern States of Nigeria the effects of climate change vary between irregular and unpredictable seasonal rainfall to more torrential rains, harsher wind storms, and flooding in the coastal areas. Odjugo (2005**) observed that** over the past forty year's volumes of torrential rains increased by 20 percent across the various Southern States. Ojo(2011) reported that due to climate change, floods, droughts and storms are now both more severe and more frequent in some Southern areas where they were previously either unknown or rare.

In the South-Eastern States, late rainfall has reduced planting time and results in late harvesting of crops. The usual first batch of maize (early harvest) by the end of May which road-side corn rosters take advantage of to make quick business has been grossly irregular. Also, erosion menace which Aaron (2011) **noted to be severe due to frequent rainfall contributes to loss of arable land for crop production**. There is loss of crop inputs as a result of enzymatic activities, and biological deterioration due to late farming. Crops decay or spoilage force farmers to either sale off or consume their seed input before the planting season.

Another effect of climate change in the coastal area is flooding occasioned by sea rise. Statistics show that between 1992 and 2007, wind- and rainstorms alone destroyed at least $720 million in economically productive assets including crop produce and rendered at least 80,000 including farmers homeless at the end of 2009 across twelve of Nigeria's thirty-six States (Aaron, 2011).**One flood disaster that** wiped out agricultural produce in 23 states of the country according to National Emergency Management Authority (NEMA), and forced the government to divert scarce resources to disaster management was t**he** 2012 **flooding. Meanwhile,** Ebele and Amodi (2016) observed that owing to the rise in sea level and heavy rainfall, fishing activities in the various ecological zones of the coastal area has drastically reduced resulting in a great decline in the fish production business. Also the viability of inland fisheries is threatened by increased salinity from sea rise even as some coastal states of the South-South and the South -West already witness up to 160 inches of rainfall a year, with wet seasons lasting eight to ten months **(**BNRCC, 2011).It should be noted that a**reas with prolonged wet season have high relative humidity and less sunshine hours which adversely affect photosynthesis**.

CONCLUSION

PACJA (2009) noted that climate change has the potential to affect African agriculture in a range of ways leading to an overall reduction in productivity and loss in GDP between 2 % to 7 % in 2100 in the Sahara and about 2 to 4% in Western Africa, of which Nigeria is marked as 'hot spot' by IPCC. It is been estimated that Nigeria stands to lose between 6 – 30% of its GDP by 2050 which worth between $100billion and $460 billion to climate change (Ebele and Amodi 2016). Having observed that crop production alone occupies nearly 94% of the agricultural lands, and about 85 percent of crop production is rain-fed; more so, many of its locally grown crops are sensitive to even tiny shifts in rainfall and temperature; then the effects of climate change cannot be trivialized or treated with reckless abandon (Coe and Foley, 2001).

The initial step to effective mitigation of climate change is to first identify the causes in Nigeria. Although the causes of climate change are obvious: human activities and natural disaster; some identified causes in Nigeria include:

i. Unabated gas flaring. Nigeria is the world's second largest flarer of gas. It warms and pollutes the atmosphere, and results in acid rain.
ii. Mono-economy or over dependence on oil export resulting in extensive oil exploration, soil degradation and water pollution in the Niger Delta.
iii. Lack of adequate institutional, legislative and fiscal capacity for effective management of natural resources and stability of the ecosystem (Stanley, 2015).
iv. Poor adaptive responses to growing shifts in temperature, rainfall, storms, and sea levels and lack of planning or brigade approach.
v. Laissez-faire attitude to the warnings from National and State Meteorological Agencies for reliable climate data.
vi. Indiscriminate felling of trees for fire wood and construction purposes without elaborate replacement via tree plantation.
vii. Non development of renewable energy resources: solar, nuclear, wind, hydropower and biomass to replace fossil fuel.

RECOMMENDATION

According to Jekwu (2001), it is imperative that full attention is given to ways through which the Nigerian economy can be diversified and steered away from fossil fuels both in terms of production and consumption, which is incidentally one of the cardinal agenda of the present administration of President Muhammadu Buhari. Some of the recommendations for the Federal and State governments are:

i. Government active participation in the crusade to save the environment by policies formulation and affirmative action by government at all levels.
ii. Support agencies like Nigeria Meteorological Agencies, NEMA, and National Orientation agency in their drive for safer environment.
iii. Timely sensitization on issues of climate change using all Media outfits.
iv. Incorporation of climate change-related subjects into primary and post-primary schools curriculum.
v. A sustainable land management practices such as agroforestry—where trees are integrated with crops, animals, or both to provide shade and natural fertilization and conservation agricultural methods such as low or no tillage operations, which reduce soil depletion (WBG, 2013).
vi. Diversification of the economy especially away from oil production to solid mineral, and agriculture to reduce over-dependence on fossil fuel.
vii. Enforce acceptable limit of exhaust gas emission for automobiles.
viii. Develop renewable energy resources like solar, wind, hydropower and nuclear for effective use in electricity generation.
ix. Develop the agricultural sector of the economy.

Amongst all proffered remedies, the agricultural sector provides ultimate way out the menace of climate change and economic rupture. Agriculture accounts for 40 percent of the country's GDP and employs 70 percent of Nigeria's people. Even the Governor of the Central Bank of Nigeria during the 2016 Nigeria Agric.- Finance Conference in Abuja, stated that the Agricultural sector which grew from 6.28% to 9.50% per annum (pre-rebasing) contributed to Nigerian GDP an increased from 23.86% to 24.18% in the last quarter of 2014, while in the first quarter of 2016,the contribution to National GDP is up by 0.309% larger than manufacturing and oil sector (Nduka and Ikefan, 2016). It therefore, appears that the era of oil boom is over and Nigeria has the potential to grow its Agricultural sector, her arable land and large population. It is time to match words of economic diversification with actions given the fact that climate change is already here with us, and the effect ravaging from North to South.

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Appendix A

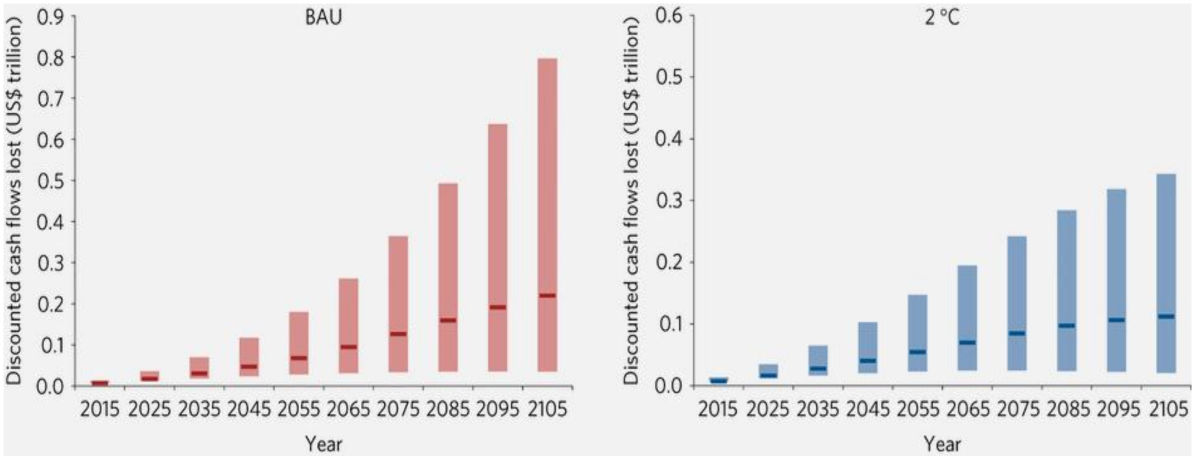

Figure 1: The impact of climate change on discounted cash flows from the stock of global financial assets. Source: Simon et al., 2016

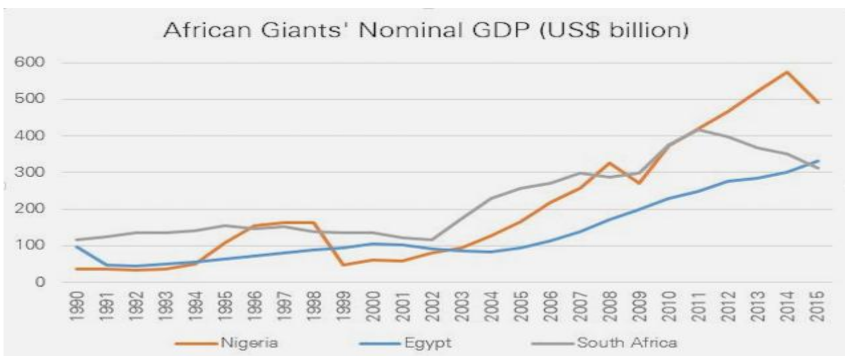

Figure 2: African Giants' Norminal GDP of South Africa, Egypt and Nigeria (*Source: Shapshak. 2016*)

Table 1. NIGERIA ECONOMIC FORECAST 2016-2020 0UTLOOK (Modified)						
Overview	**Actual**	**Q2/16**	**Q3/16**	**Q4/16**	**Q1/17**	**2020**
GDP Growth rate	3.10	2.3	8.8	3	-2.92	0.92
Development rate %)	10.40	10.8	10.3	10.7	10.7	12
Inflation Rate (%)	12.80	12.7	11.9	11.9	12.1	10.6
Interest Rate (%)	12.00	12	12	12	11.5	10.5
Balance trade NGN Millions	26385.50	77167	180170	172110	110791	324023
Government debt of GDP	10.50	12.5	12.04	12.04	12.41	11.91

Source: Trading Economics, 2016.

CHALLENGES OF RENEWABLE ENERGY RESOURCES DEVELOPMENT: CASE OF KIRI DAM HYDROPOWER PROJECT IN ADAMAWA STATE-NIGERIA

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ABSTRACT

Kiri hydropower project is one of the larger-scale projects presently under construction in Adamawa State. The project has been surrounded by controversies and strong oppositions. This study sought to examine these controversial issues, the causes and consequences of these challenges. Local people's perceptions within the project were also explored. The study employs interviews, focus group discussion and informed conversations, as well as secondary data sources. It was found that participation of stake-holders particularly during the process of the environmental and social impact assessment and the coordination between the project owner and pertinent government institution was limited. Its inconsistency with regulation set by the World Bank, African Development Bank made these financiers annul their financial support for Kiri Dam construction. On the other hand, the general perception of the local communities on the new project was generally positive expecting that this development will supply them electric light, facilitate school, health service and transparency of decision makers involving a greater participation of local communities and pertinent development partners.

***Keywords:** Consequences, Power, Hydroelectricity, Kiri Dam, Renewable*

INTRODUCTION

In the technologically advanced world of the 21st century, the development imperative of renewable energy resources and hydroelectric power in particular, in developing countries is attributed to the role it plays in economic advancement and in everyday activities: production, consumption, health, education e.t.c (Nnaji *et. al.,* 2010). Although electric energy is one of the major propellers of economic growth, one of the biggest challenges facing both developed and developing countries currently is the guarantee of a sufficient supply of environmentally friendly energy (El Bassam, 2004).

Renewable energy resources in general and hydropower in particular have been characterized as favourable sources of electrical energy that can have a positive contribution for climate change mitigation (IHA, 2003). Research on replenishing electrical energy resources has established an empirical ground to argue why renewable resources should constitute an essential part of the electrical energy system. Major reasons include that they are clean alternative to greenhouse gas producing fossil fuels; they can supply the demand from rapid population increase in the developing countries, the rise in the price of fossil fuels, and for the fact that the future depletion of fossil fuel reserves makes renewable fuel possible options for developing economies (El Bassam 2004, Sternberg, 2008). These key justifications may provide decision makers in developing countries a ground to consider renewable energy resources as an alternative source of energy or at least as part of the energy mix. And quite a large number of developing countries, of which Nigeria is not an exception, have framed an alternative policy that could facilitate the exploitation of locally available renewable electric energy sources such as hydropower resources.

Hydropower has a recorded history of electric production providing substantial energy services in many parts of the world such as the U.S.A., China, Canada, and Norway (Gilpin, 1995).

Hydropower is a renewable, economic, non-polluting and environmentally favourable source of energy. Hydropower stations helps in improving the reliability of the power system. Some hydroelectric projects have long life spans extending over 50 years and overall help in conserving scarce fossil fuels (IHA, 2003).

These nations are epistemological features, most of which are inherent characteristics of hydropower energy resources. However, rarely mentioned in these policy documents are the inherent characteristics reflected on the other side of the coin: the social and environmental costs of hydropower development projects (Briscoe, 1999).

The perception of large dams as a developing imperative is challenged by a paradigmatic shift in water resources development from a supply-based and control-based approach to increased concern for environmental and ecological impacts and the economic and social costs of the construction of a large dam (Alhassan, 2009). Consequently the negative impacts of large dams on both society and nature have generated the perception of larger dams as failed development technologies (Alhassan, 2009).

The critics of large dams is 'based on the concerns about how they dismember rivers, dislocate entire communities, fracture social cohesion, and damage the dignity and mental psyche of those affected , leading to untold and irreparable hardships, yet without any corresponding benefits' (Oyedepo, 2012). As a result some people who resettled due to the construction of dams feel short-changed. And if they at all are compensated or relocated, the relocated are left usually without post-compensation management.

The disapproval of large dams as a failed technology due to the social and environmental costs has coincided with a surge in non-governmental activism (ICOLD, 1998). The strong opposition against large-scale hydropower dams in contemporary Africa has then hinged the support of such large infrastructure developments in the continent, leading to a significant decline in the developments in continent, leading to a significant decline in the development of large dams in the late 1980s (Alhassan 2009).

This paper aims to examine the main challenges of hydropower development in Adamawa State with particular focus on the case of the Kiri dam hydropower project. Like many other larger scale hydropower projects, the Kiri Dam hydropower project involves a number of actors namely the project owner, the financing agencies, environmental NGO and local peoples affected by the project in general. These actors have different perceptions, values, purpose and expectations and thus differing roles regards project planning and implementation. The government of Nigeria envisages the project from the point of view of development imperatives with ambitious expectation of high electric production for extensive economic development. Local people view the project with a blend of fears and hopes. Their fear stems from the impacts the dam will have on their livelihoods, social relations, and the impoundment of the river banks on which large groups are dependents for alternative means of income including grazing land for semi-pastoralist tribes. Thus, these papers examine how this hydroelectric development projects affects the local environment and people's socio-economic condition and whether the project planning competently addresses these issues.

The general aim of the research is the Challenges of Renewable Energy Resources Development: Case of Kiri Dam Hydropower Project in Adamawa State-Nigeria

Kiri dam was constructed with the aim of boosting food production. A cursory look at the dam area however, tends to reveal that the dam is underutilized, while the nation is yearning for renewable energy. As such, implementing the proposed hydroelectric power project will put the dam to efficient utilization, thereby catering for the energy needs of the host community and our teeming population.

This study was conceived for the purpose of regional planning. This is because it will reveal the potential benefits and challenges to be derived from the implementation of the project, such as; Clean, renewable and low-cost alternative to other energy sources, Host communities are given employment opportunity for different activities of division of work in hydroelectricity generation and Support for various kinds of aesthetic and recreational activities, adding to the state income.

METHODOLOGY

Study Area

Kiri-dam is located in Shelleng Local Government Area of Adamawa state and situated on latitude 09^0 39'00" N – 09^0 54' 00"N and longitude 11^0 57' 00" E – 12^0 06' 00" E as shown in Fig. 1 below.

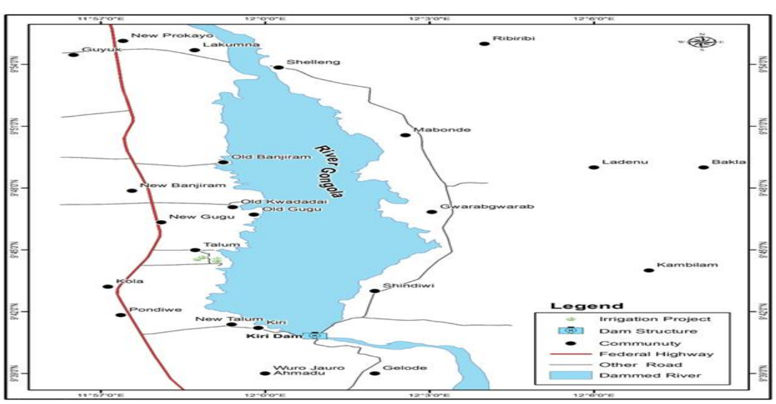

Figure 1: Kiri Dam
Source: Adapted and Modified From Google Maps, 2015

Research Method
In this study, the choice of qualitative as a main approach to explore the controversial issues pertinent to the Kiri dam hydropower project, since these are most appropriate to examine the research questions.
We examined the controversies surrounding projects with particular reference to the Kiri dam hydropower project located in Adamawa State. The study area is purposively selected as a case study with the intention of studying the Kiri dam hydropower project in the context of the local people to convey the controversies to decision makers, so these local complexities can be taken into account in due process of the project development.
The data for the study were generated from both primary and secondary sources. The techniques employed were in–depth interviews with expect from the project officer, the Environmental Protection Authority (EPA) experts at the project site, and the local project adjacent to the dam area. A focus group discussion was also conducted with the community that were affected by the project. Informal discussions were also important parts of the fieldwork. The study also made use of secondary data sources obtained from different institutions.

RESULTS AND DISCUSSION

Institutional Challenges

Under the host country, government agencies like the Power Holding Company of Nigeria (PHCN) are the functional actors within the domain of the country's national energy policy. Its role on the Kiri dam hydropower project and in the electric energy sector in general involves the production, transformation, distribution and commercialization of hydroelectric power. The construction of all hydropower projects in the country is controlled by this institute.
Among other requirements, PHCN must possess a well-organized and skilled staff, have a clear mandate and well organised and transparent information system. Moreover, PHCN must develop regular relationship with line government offices that can have positive contribution to the project efficacy. The sector has lack of skilled man-power, and lack of transparency and more bureaucratic structure to get access for information.

Transparency of stakeholders

Transparency is widely regarded as an important precondition for implementing development planning. The idea is that, if any institution is transparent, the major factors affecting the development process becomes perceptible. Failure to acknowledge the main hindrances challenging the implement ability of the projects under PHCN mandate can possibly make the institution accountable.
According to one of the experts in PHCN, in early 2012, a group of journalists from the BBC were visiting the project and had a discussion with the local people at the downstream areas. The BBC later reported on the convictions of the people regarding the impact of the project on their future living conditions. The teams report has two implications. First, PHCN became less transparent and more reluctant in revealing information about the project. For Kiri dam hydroelectric project, one has to get permission from the general manager to get access for information. Secondly, according to the experts, the BBC's report about the project had deterred decision makers from being passive about the project and its impact on the local people.

PHCN's Relations with Pertinent Institutions

One of the central challenges facing PHCN is to function as a responsible public institute and become structurally and functionally interrelated with other government institutions during the planning and implementation of the hydropower projects. It can generally be said that PHCN relationship with government institution such as the Environmental Protection Authority (EPA), Ministry of Health (MOH) and Forest and Wildlife Authorities etc. can positively or negatively affect the quality of the project planning. As a large-scale hydropower project, the Kiri dam hydropower is a complex affair that should involve participation of a cross-section of interest groups in the project planning process. The planning process should not be considered as a mere responsibility of the project owner alone. It must be underscored that responsible institutions at federal, regional, zonal and local levels have to be involved in the decision making process.

The International Organizations

The other actors in the cluster include the international organizations such as the World Bank, African Development Bank, international NGO's etc. These organizations each possess certain regulations designed to address the major environment and social issues surrounding hydropower development projects. A number of studies suggest that these principles were developed following the failure of several large-scale hydropower projects to address the problems associated with the local environment and local communities (Barrow, 2000, WCD, 2000, and Holder, 2004). As a result, a number of NGO's, commissions and departments were established and have campaigned against big power dam constructions in developing countries.

CONCLUSION

The research has examined in detail the controversies that emerged among actors and the problems encountered during the planning and implementation of the Kiri Dam hydropower project in Adamawa State-Nigeria.

It is assumed that hydropower is a renewable, locally available, and economically viable source of energy, To exploit this resource, it requires high financial investment, competent institutional capacity, accommodative regulatory frameworks, and participation of pertinent stakeholders during planning and implementation of hydropower projects, The controversies characterising hydropower project in developing countries can partly be lack of one or more of these factors.

It has been establish that hydropower development projects complex processes that often encounter a member of challenges which in turns demand that such projects have a participatory planning and implementation process.

The major issue of controversy surrounding Kiri dam hydropower project was the method employed by the project owner to conduct the environmental and social impact assessments (ESIA).

It was concluded that the more the project is delayed due to financial constraints the more will be its economic, environmental and social costs. In general, from the development imperative the Kiri dam hydroelectric project is perceived as one of the renewable electric energy resources that will increase the country's electric generating capacity by half upon its full operation, and thus will play a key role for the social and economic development of the country. From the environmental NGO's perceptive, the project is perceived as one of the destructive projects disrupting the local environment and ethnicities living in the area. From the local people's perspective, Kiri dam is perceived with a blend of hopefulness and fear.

They are hopeful because they expect that the project will supply them electric light, introduce modern transport infrastructure. They are suspicious of the project because the reservoir will interrupt the prevailing social-economic and cultural relations between people inhabiting on both sides of the river and the project owner, was unable to conduct an overall social impact assessment of the communities affected by the project and failed to consider the compensation for some members of the community. This can be one of the main causes of controversies of large-scale hydropower projects. It was also concluded that the project owners has to be transparent and inclusive in planning and decision making and to accommodate all other stakeholders and particularly those affected by the project at the initiation, planning, execution, implementation and closure levels.

ACKNOWLEDGEMENT

We will like to use this medium to acknowledge Prof. Charles Amen Okuofu of the Department of Water Resources and Environmental Engineering, Amadu Bello University, Zaria-Nigeria, whose advice and direction was invaluable throughout the period of this research. It is also pertinent to appreciate the staffs of Department of Soil Science and Land Resources Management, Federal University, Wukari, Taraba State

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ARDUINO BASED SMART INDOOR GARDENING CONTROL

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ABSTRACT

Indoor gardening is concerned with the growing of houseplants within a residence or building, in a conservatory, or in a greenhouse. In the urban area, the people are living in house like apartment, condominium and flat as the land property is very expensive and the land space is limited. Smart Indoor Gardening (SIG) system provides smart garden devices for indoor gardening systems, where the system is capable to grow indoor plant similar to outdoors. This project is developed to offer low cost and limited space concept of smart indoor gardening. This system consists of; source of light to replace the sunlight for photosynthesis and source of water, which are the most important factors for plant growth. Light Emitted Diodes (LED) was used as source of light energy for photosynthesis to occur; and an in built water pump would start immediately to supply the plants with water whenever the soils dry. The sensors connected to a microcontroller (Arduino) are soil moisture, temperature and light intensity sensor. The information send by the sensors are then analyzed by the microcontroller to control healthy grow environment for the plants. LCD screen is used to display the condition of soil, light and temperature. One of the advantages of this system is that it can create the greenhouse concept. In conclusion, the SIG system was successfully implemented using Arduino Software to control the growth of healthy plants in closed building.

***Key Words**: Arduino, control, garden, indoor, plant*

INTRODUCTION

Gardening is the practice of growing and cultivating plants as part of horticulture while indoor gardening is concerned with the growing of houseplants within a residence or enclosed building in a conservatory or in a greenhouse (Dilrukshi *et al.,* 2013). In gardening, people can grow herbs, vegetables or flowers. However, in some tourism places, gardens are decorative for joy to spend of leisure time. In addition, it is easy to protect as long as using right equipment and tools besides following the right criteria that the plants needed to grow up. The main requirements for plant growth include water, light, space, temperature and mineral.

Indoor garden has lots of advantages and benefits. Some plants are grown up in a garden to change the atmospheric condition of the environment. Besides that, indoor gardening can prove helpful to persons who have physical disability but love gardening. They can easily take care of the garden from the comforts of their wheel chairs and enjoy all the funs which are associated with outdoor gardening. Moreover, for the new starter in gardening the indoor garden is the best option to start. It is recommended by professional gardeners that a beginner must start off with indoor gardening and on a limited scale as well (Cathey and Campbell, 1978). Starting with small scale (indoor) garden, will pave a way to beginners and give them more clues on how to handle outdoor garden.

Requirement for Plant Growth

In order to produce healthy and quality plants, some factors affecting plant growth such as water, light, temperature, humidity, space and minerals need to be taken into account.

Water

Watering frequency will depend on the conditions under which the plants are growing (Ho and Myung, 2013). Water will only be given to plants when they are thirsty. But, excessive water to plants causes excessive alkalinity and salt content affects nutrient imbalance and poor plant growth. Softened water may contain harmful amounts of sodium. Water that tests high in total salts should not be used.

Light

Plants need sunlight for their photosynthesis process. Besides, artificial lighting can be used to start seedlings and replace sunlight. The main aspects to consider when providing light for indoor plants are the quality, quantity, and duration of the light. Plant with insufficient leads to smaller, lighter green leaves while plants with sufficient light have dark green leaves, short internodes and rapidly produce new leaves (Ho and Myung, 2013).

Beside natural light, artificial light like incandescent and fluorescent can also be used as light source, depend on the amount of natural light the plants normally received. For flowers buds, basically they need to be exposed to about 14 or more hours of light per day. Available incandescent light are of the range of about 100 to 150 W bulb. Medium plants needs to be kept at a distance of at least 4 feet and above from light, while for tall flower the distance should be between 8 to 10 feet (Yamori *et al.,* 2014).

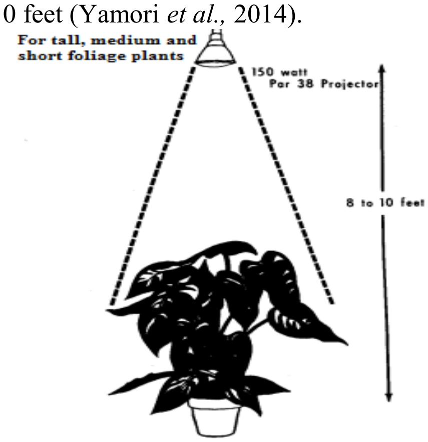

Figure 1: Distance Fluorescent with Small plant Lamp with Tall Plant (Teacher guide, 2013)

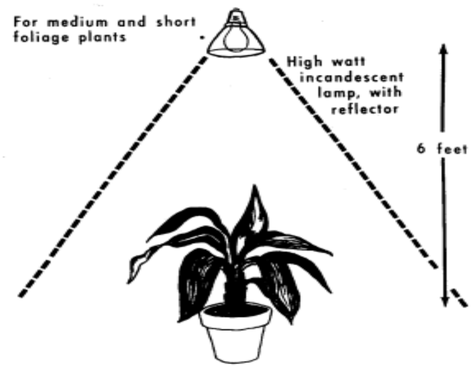

Figure 2: Distance Incandescent Lamp (Teacher guide, 2013)

Another type of artificial light is fluorescent light, which has 2 and half times much light per watt than incandescent bulb (Aravind *et al.,* 2012). It produces heat output, but only small area is cover with the light while, most part of the plan is out of light. There are two types of fluorescent light, cool and daylight tube types. The distance from the light to plants is in the range of 6-7 inches and the light would remain on for at least 12 hours per day for efficient photosynthesis. The latest technology by using LED bulb is easier, low cost and better quality (Ramazan and Kubilay, 2014).

Temperature
Temperature is one of the most import requirements needed by the plant. The height of the lamp from plant should be considered in all cases of lamps for proper plant growth. In fact, temperature and light can be thought as 'yin and yang' (Correll *et al.,* 2010). For indoor gardening, the normal temperature required by plants is between 20℃ to 28℃ and at night in range 15℃ to 20℃.

Space
Plant needs adequate space to ensure reception of sufficient light in photosynthesis process. An example tomato plants should be allowed 4 square feet per plant (Correll *et al.,* 2010).

Oxygen
Plants require oxygen for respiration to carry out their functions of water and nutrient uptake. In soil, adequate oxygen is usually available, in contrast, plants that grow in water are faced with on timely exhaust of the dissolved oxygen if no additional air is provided (Correll *et al.,* 2010).

Sensor
Sensor is a device which detects or measures a physical quantity (Yamori *et al.,* 2014). It measures a physical quantity and converts it into signal through transducer. A good sensor is sensitive to the measured property and does not influence the measured property. Sensor is designed to be linear to mathematical function of the measurement. The output of the sensor can be analog or digital. Analog sensors needs to have analog-to-digital (ADC) converter to enable the microcontroller understand its data. These properties act as the stimulus to the sensor, and the sensor output is conditioned and processed to provide the corresponding measurement of the physical property.

MATERIAL AND METHODS
Material used in the research paper are: Arduino Uno board, Real Time Clock (RTC) DS1307, light sensor, soil moisture sensor, DHT11 humidity sensor, temperature sensor, water pump, LED bulb, relay, Liquid Crystal Display

(LCD) 16x2 and LM393 driver. Source codes were written for Arduino and various components are arranged to form the required hard ware system.

Hardware Implementation

The hardware implementation consist Arduino UNO Board, light bulb, Submersible Water Head and Pump with SRD-05VDC-SL-C relay, RTC DS1307 module, DHT11 humidity and temperature sensor, light sensor module and soil moisture sensor with LM393 Driver, buzzer and LED indications.

Arduino Uno

The microcontroller in Arduino Uno board is ATmega328 is used as the brain of this system. Without it, the data from the sensor cannot be generated and the output would be null. Therefore, DHT11, light and soil moisture sensor would be attached with analog pin at Arduino Uno Board to transmit the data while ATmega328 would process the data and display the result on LCD screen. The analog data received by the sensor would be converted by ADC to enable the Arduino to interpret and activate the relay (switch) for either water pump and/or LED bulb based on the plant requirements at that period. Table 1 provides the function of each of the Arduino Uno pins.

Table 1 Function of Arduino Uno Pins

PIN	DESCRIPTIONS
Serial : 0 (Rx) and 1 (Tx)	Rx and Tx TTL serial data is used to receive or transmit respectively.
External Interrupts: 2 and 3	These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
PWM: 3, 5, 6, 9, 10, 11	Provide analog Write (function with 8-bit PWM output)
SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK)	Pin 13: Digital LED. When the pin is HIGH value, the LED is ON, when the pin is LOW value, the LED is OFF.

There are 6 analog inputs Pin named A0 to A5, each Pin provides 10 bits of resolution (i.e. 1024 different values) this is sufficiently enough to perform the required task comfortably. The programs written for Arduino are called sketches. There are two hardware related to Arduino Uno, there settings need to make in the Arduino IDE which is Board and Serial Port.

This is the basic structure of the Arduino:

```
void setup()
{
//statements;
}
void loop()
{
//statements;
}
```

Where setup() is the preparation, loop() is the execution. Both functions are required for the program to work. Variables need to be declared in the source code to enable the program sequentially follow routine check on the plant needs from beginning to an end of the program respectively in a loop.

Liquid Crystal Display

LCD 16 column by 2 rows characters was used to display the condition of the sensors.

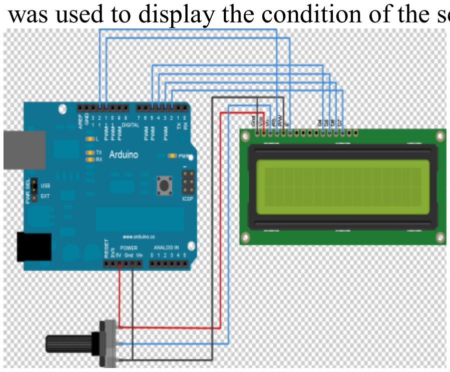

Figure 3: LCD pin Connection of the Arduino Uno Board

Figure 3 shows LCD pin connection to the Arduino Uno Board. 10 pins of Arduino Uno Board is used which is digital pin2, pin3, pin4, pin5, pin11 and pin 12.

Soil Moisture Sensor

The Soil Moisture Sensor is used to measure the volumetric water content based on the dielectric constant of soil. The sensor is inserted in the soil to sense the existence of water. An electric current can easily pass through if there is moisture and due to the fact that the level of moisture is hard to determine and to make sure that the moisture sensor is very accurate and efficient.

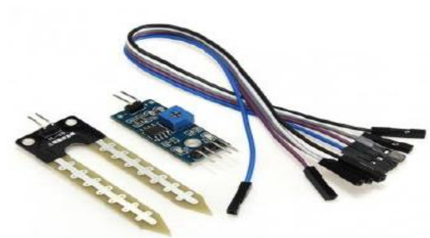

Figure 4: Soil Moisture Sensor YL-69

Figure 4 shows Soil Moisture Sensor YL-69 used, which is connected at pin analog A3 of Arduino Uno. One the characteristics of this soil moisture sensor YL-69 is, it has blue digital potentiometer adjustment as sensitivity adjustable. It operates at 3.3-5V.

Humidity and Temperature Sensor

DHT11 digital temperature and humidity sensor is used to check the temperature of surroundings. It is a composite sensor that contains a calibrated digital signal output of the temperature and humidity. The sensor is connected to the Arduino board at pin analog A0. Figure 5 shows DHT11 temperature and humidity sensor and pin connection with Arduino UNO board.

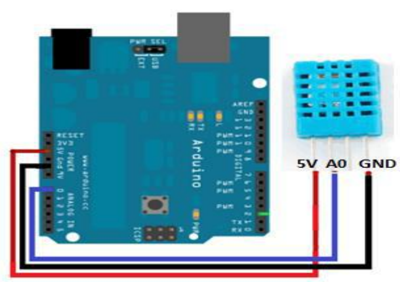

Figure 5: DHT11 Temperature and Humidity Sensor

Light Sensor

The Light sensor module used comes with basic components for light detection. The light sensor module is used to detect the light brightness in the environment. It comes with 2 outputs, digital and analog. The threshold (sensitivity) of digital output may be adjusted by tuning the on board variable resistor (potentiometer). On board it provides a Light Depended Resistor (LDR), high sensitivity and commonly being employed for light sensing. The module comes with power LED and status LED as an indicator.

In this paper, light sensor module is used to read light intensity for the surrounding of the smart indoor gardening system. The data from the sensor is sent to microcontroller to process and thus give signal to LED bulb whether to ON or OFF according to the data received from the soil condition in favor of the plants. LDR works with respect to the resistance of the photocell, the total resistance of the photocell and the pull-down resistor decreases as the intensity of light increases. Table 2 shows approximate analog voltage based on the light/resistance supply and $10K\Omega$ pull-down resistor.

Table 2 Approximate Analog Voltage Based on the Sensor Light/Resistance

Ambient Light	Photocell Resistance (Ω)	LDR+R (Ω)	Current through LDR+R (mA)	Voltage across R (V)
Moon light night	70k	71	0.07	0.1

Dark room	10k	11	0.45	0.5
Bright room	1.5k	2.5	2	2.0
Overcast day	300	1.3	3.8	3.8
Full day light	100	1.1	4.5	4.5

Real Time Clock (RTC DS1307)

DS1307 is a real time clock and was used as RTC module that keeps perfect time and has a battery backup to prevent reset if the Arduino loses. Figure 6 shows the RTC Ds1307 module and pin connection to Arduino UNO board.

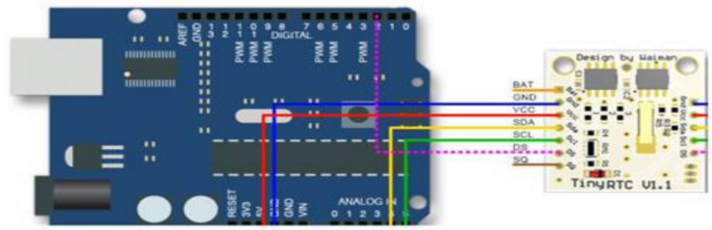

Figure 6: Connection between Arduino Uno Pin and DS1307

The relay is one of the switch types, which are electrically controlled. Relay uses an electromagnet to move swing terminal between two contacts (NO and NC). When there is no power applied to the inductor coil (Relay is OFF), hence no switch activated.
In this paper, two relay type SRD-05V dc-sl-c module was used to control high voltage in the LED bulb and water pump unit, while keeping them isolated from the microcontroller. It was chosen because is safe to use, with simple three line structure while it can be connected directly to the input/output port of microcontroller.

The water pump in Figure 7 was used as source of water supply to the plant. It used for irrigation system to generate water from reservoir or water tank to the plant through irrigation tubing. The water pump is interfaced with the microcontroller through a relay since the microcontroller output ports does not provide enough power to drive the pump. The pump works on mains supply of 220V/50Hz.

Figure 7: Local Car Glass Wiper Water Pump

LED Bulb
LED bulb is the most essential item in lighting part of SIG system, where it provided supplemental light to the plant. In this paper, 3-38W LED E14 (Non Standard) base bulb was used.

Software Development
In this paper, the software has been developed using Arduino Software by using C programming language. Arduino software 1.0.5 version was used to program the microcontroller. Arduino programs are written in C or C++. The advantages of this version, firstly, it has new library import functionality to install libraries directly from a.zip file in the IDE. Secondly, it already has signed driver of window. This means Window 8 will no longer prevent it from installing Arduino drivers.

RESULTS AND DISCUSSIONS

Figure 8 shows the overall system of the smart indoor gardening. Sensors would always send signals related to the soil state to microcontroller, in which the microcontroller would process the data received. The microcontroller would again manipulate the information and decide whether the pump would start operating or not. When the value obtained from the sensor is below the moisture level needed by the plant, the plant would start operating and the water would be supplied from the outlet of the pump to the plant. The floater inside the tank will control the level of water inside the tank. The systems keep running and the process continuous until the user cut the power source.

Figure 8, 9 and 10 shows the results obtained using spectral of the T5 fluorescent, white and yellow LED bulb. This experiment was run at room temperature and the same distance between a device and the bulb for all Figures (8-10). In conclusion, due to similarity of sunlight and LED bulb used, the LED bulb was choose as supplemental light to replace sunlight as seen from the experimental results.

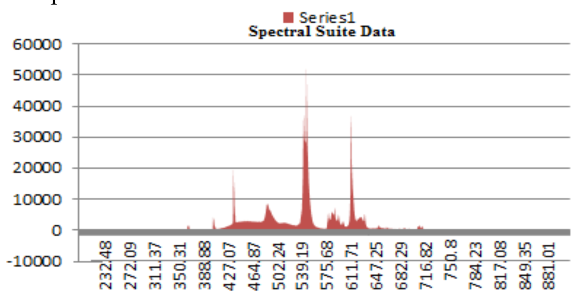

Figure 8: Spectral of T5 Fluorescent Bulb

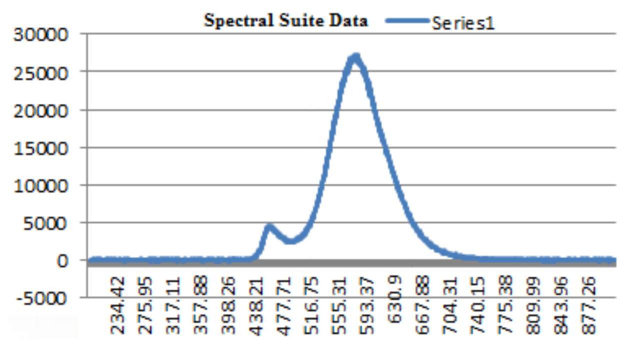

Figure 9: Spectral of Yellow LED blub

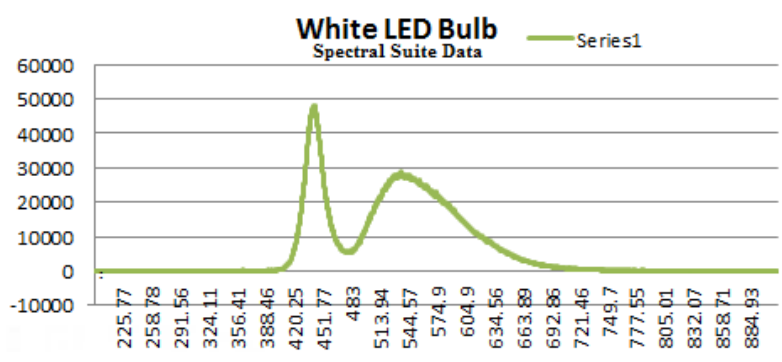

Figure 10: Spectral of White LED Bulb

CONCLUSION

The Smart Indoor gardening system is completed by using RTC Module, integrating sensor and Arduino Uno Board, which does the function of monitoring and controlling the supply of water and light to the plant. Software code was successfully written for Arduino to enable read the soil condition with respect to the plant growth. The color will change according to the three range of soil state which is dry, moist and soggy. A red LED will ON and a warning sound (buzzer) to indicate that the soil is dry, but when the water in the soil is adequate (soggy) for the plant, a green LED will turn ON and the mean water pump needed to stop pumping the water from water tank.

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ARDUINO BASED WIRELESS SYSTEM FOR MONITORING OF OIL PALM POLLINATION BAG

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ABSTRACT

Pollination is an important process in oil palm breeding as correct method increases yield of palm oil production. To ensure genetic purity that will increase yield, during pollination process the condition of pollination bag must not be punctured. However, one of the work associated, which is oil palm pollination bag monitoring is a labor intensive job. Workers climb an average height of 3 stories building only to check conditions of pollination bag, which is dangerous as risk of falling down can cause disability and deaths. This paper is on Arduino based wireless system for monitoring of oil palm pollination bag. The problem that it intends to address is the way farmers monitored oil palm pollination bags. The main aim is to come up with an Arduino based monitoring system with a view to achieving the following objectives; introduce a pollination bag inspection method, which involves no climbing effort, design a wireless sensor module, which checks the condition of bag, and then sends data back to server and design a server program that act as ground station to receive data from wireless sensor module and helps monitoring the conditions of all the bags. The main scope of this paper is to make use of two hypothesis; changes in particulate emission when air is flowing in and out of the pollination bag, the conditions of the pollination bag used oil palm plantation would be determined by placing a sensor inside the bag. The methodology used is to design mobile ground station through Arduino Uno based Programming of nRF24L01 transceiver model, water sensor and PPD42NS dust sensor. Troubleshooting, debugging and on field testing are carried out. It was observed from experiment that the data communication between the sensors model and the ground station is 94% success. Data transmission found to be effective when the oil palm trees and not more than 9m apart and 35m tall.

KEYWORDS: *Arduino, monitoring, oil palm, pollination bag, wireless*

INTRODUCTION

Before an oil palm tree bears fruit, the tree needs to be pollinated for 21 to 30 days (Bunting *et al.,* 1934). During the pollination period, a pollination bag is used. The reason for using the bag is to ensure the genetic purity of the pollen for the designated palm oil tree (Williams and Hsu, 1970). If the tree is pollinated by the specialized pollen, the production of palm oil would increase and this generates good profit. Hence, manual inspection would have to be regularly conducted. The purpose of manual inspection is to ensure that the bag is in good condition within 21 days. In other words, the bag must not be broken or punctured, so that no external foreign pollen may enter and disrupt the process. Working in agriculture field usually increase the risk of ergonomic injuries, and this is commonly associated in particular with intensive manual labor.

MATERIALS AND METHODS

This work is carried out using the fundamental components that made up the complete system and adopting a suitable methodology to enhance the success of the work. The major component used in doing this work includes: Dust sensor PPD42NS, water sensor, Arduino Uno, LIPO battery, Transceiver nRF24L01 and Altera DE2i-150.

Design of Power Supply for the System

The system is powered using a 12V regulated supply for the pumps and a 5V for microcontroller which are obtained from the mains together with a backup DC battery of 100AH, 12V. A 4700µF is used as the filter capacitor here for better filtering. A 12V regulator (LM7812) is used to obtain regulated 12V for powering the pumps and 6V regulator (LM7806) is used to obtain 6V for powering the PIC microcontroller and the relay driver circuits.

Sensors Units

Two sensors (dust and water sensor) where used to sense and relay the condition of the pollination bag to the ground station. The first sensor was chosen for detection purpose is particle sensor of Model PPD42NS; the second sensor is

the moisture sensor. The moisture sensor module is part of the Grove system (Grove - Water Sensor, 2013). It indicates whether the sensor is dry, partially damp or completely immersed in water by measuring conductivity across the open traces. The sensor traces have a weak pull-up resistor of 1 MΩ. The resistor will pull the sensor trace value high until a drop of water shorts the sensor trace to the grounded trace.
The two sensors are the inputs to our sensor module while the microcontroller processes the necessary data and send it wirelessly. Data will be relayed to the ground station using Radio Frequency (RF) communication whenever the signal is within range, as shown in Figure 1 De2i-150 board is used to display Graphical User Interface (GUI) for end user to view the result.

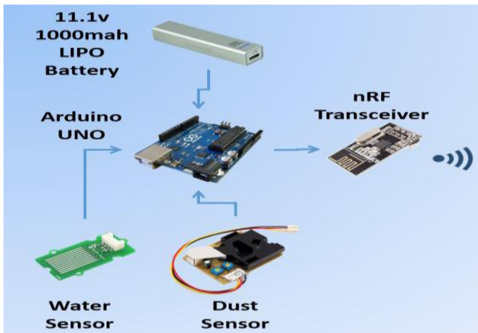

Figure 1: Flow of Mechanism in the Wireless Sensor Part

From Figure 2, it shows the full layout of the work in terms of hardware description. The ground station is made up of den2i-150 and a PC for easy visualization of data, while the two sensors are connected on the Intel Galileo and the measured data is transmitted to the ground station by the help of nRF transceiver.

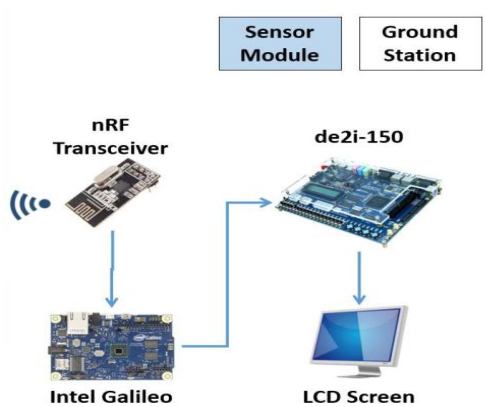

Figure 2: The Ground Station and the Sensors Station

This however prevents the risk of involved in manual climbing of the oil palm tree for the view to monitor the condition of the pollination bags. Figure 3(a) illustrated the case whereby a worker would just pass by the tree with the ground station in order to acknowledge the condition of pollination bag. It will provide precise information (moisture and dust) related to the bag, which will say a lot on the bag condition than the direct eye monitoring. In contrast Figure 3(b) clearly shows a scenario where accidentally fell from an oil palm tree.

(a) (b)

Figure 3(a): Shows a Worker using the proposed device. **Figure 3(b):** Shows the Risk involved using the Traditional Climbing Method.

Figure 3: Proposed and Traditional Monitoring Methods

Design of the Main Control Circuit using Arduino Uno

Arduino Uno has been chosen as the microcontroller for the work, due to several reasons (D'Ausilio, 2012). Though when a standard Arduino Uno runs in idle condition, it consumes more than 15mA per second. Using a typical Alkaline 9V of approximately 450mAh; it will drain the battery in just 30 hours or less than two days. This call for improvement, hence a tweaking on software strategy was deployed, which put the Arduino Uno into sleep and wakes mode. This mode reduces the current to $10\mu A$, which improves the battery life span by 10 times.

With the current consumption of 6μA and by putting the Arduino to sleep for 10 seconds, then wake up, read the value and give 0.5 seconds buzz interval and put back to sleep mode again. The improvement can be seen from the computation:

$$Averagr\ Current\ Consumption = 10m \times 0.5 + 16\mu \times 10 \times 10.5 \quad (1)$$

$$Averagr\ Current\ Consumption = 0.49mA$$

Design of the Wireless Communication Unit

A Transceiver is chosen as the hardware component of wireless data transmission. The transceiver model nRF24L01 is a 2.4GHz Radio/Wireless Transceiver, which is able to communicate between two devices of maximum ranges of 100 meter, provided no blockage in-between the ground and the monitoring station (Semiconductor, 2007).

Graphical User Interface

An open source graphical user interface (GUI) available online is used. Since the design program uses port connection, the GUI is suitable for this device. Hence, the free online GUI was used since it allows modification.

Structure Layout of Wireless Sensor Module

The sensor module is placed inside a box as seen on Figure 4, which protect it from excess sun light and rain fall. The housing gives the product a good finishing as well.

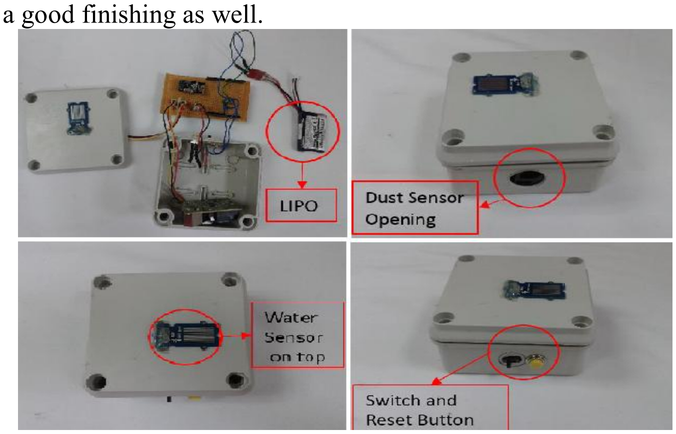

Figure 4: Shows the Final Pollination bag Monitoring Device

Comparison between the Traditional and using the Developed Device

Two different work flowcharts was compared, Appendix I shows the original workflow, where the workers need to do continuous work of climbing the tree for 30 days. It is shown as highlighted in dotted line box why the whole work of pollination monitoring is labor-intensive. Standard operating procedure requires the workers to check the bags at least once every day. In total there are over 30 times of climbing over the whole process, which are dangerous, tiring and time consumption.

Appendix II shows the complete work flow after the device is introduced. There is no more climbing work needed, as workers only need to check the ground station to refer for any changes in the bag for 30 days, duration where pollination bag is wore on the fruit bunch.

RESULTS AND DISCUSSION

The results of each of the experiments conducted are as discussed below.

Initial Tests and Experiments

Several tests were conducted with components and the hardware modules. The base reading of the water sensor part was found as 1023. Since the pin uses 1 byte of data, which is 4 bits, it is equal to data range of 1024, or from 0 to 1023, which can be seeing from Figure 5 dotted line.

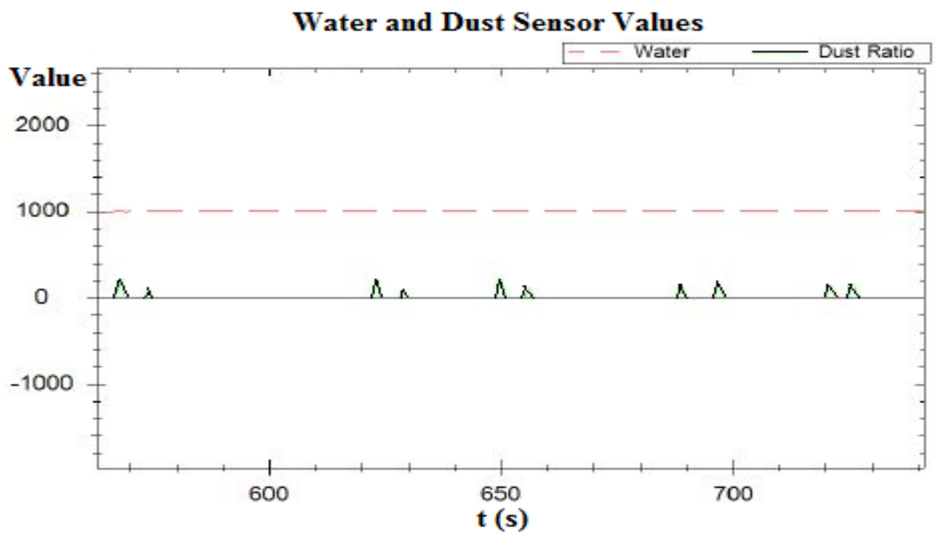

Figure 5: Baseline reading of Values obtained from Water Sensor and Dust Sensor.

The Figure 6 shows the tests conducted on the transceiver range. The real test shows that the actual range is only 35 meter, a 65 meter difference with the data sheet. The explanation behind the discrepancy is that, there may be disturbances nearby when the test is conducted.

However, the value obtained is lower than that of data sheet; this is justifiable as the result obtained is probably due to the fact that the data was obtained in a very controlled environment where no external disturbances occur. It is also shown that the nominal height of tree, which is 20 meters, is well within the ranges of sensors for the transceiver. Hence, the result is justified.

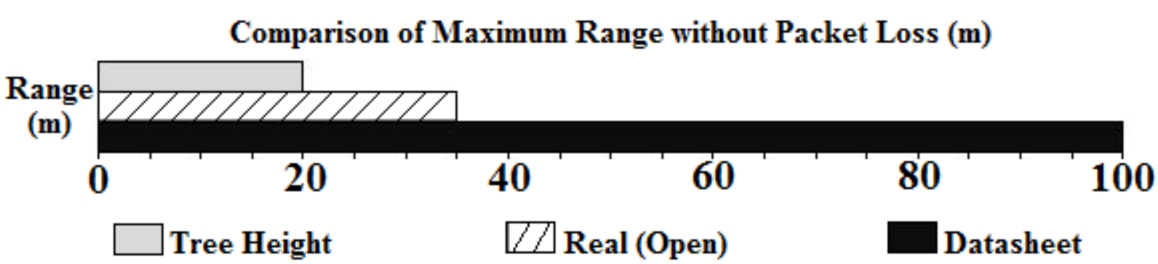

Figure 6: The comparison of ranges for the transceiver

Reliability test was conducted by sending and receiving continuous data packets to and pro between the sensors model and ground station. The result as depicted in Figure 7 has shown that, out of 100 packets relayed between server and client transceiver, it is found out that it has 94% of the data successfully transmitted. This result is good as it ensures stability of data transmission for the research.

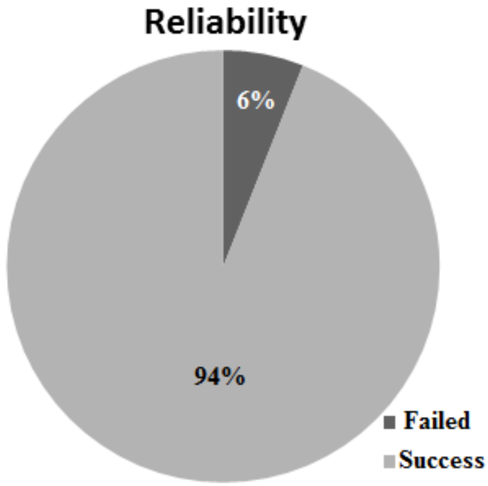

Figure 7: Successes and Failure Test

The wireless range is 35m as illustrated in Figure 8, given the fact that distance between trees are 9 meter, and nominal height of tree is 20 meter. The range is actually within the range of transmission for the transceiver. Hence our decision to use nRF24l01 transceiver is a good choice of component.

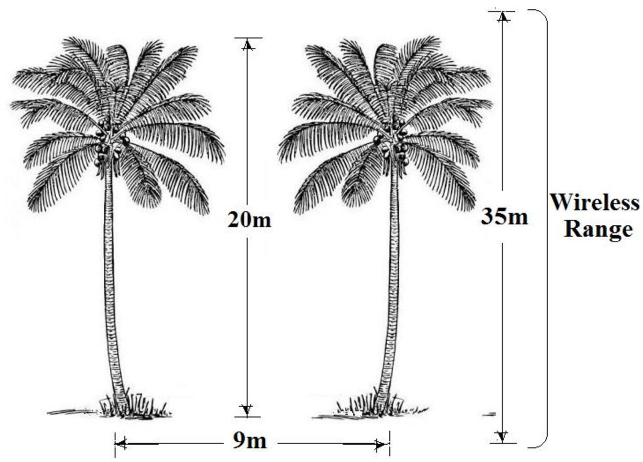

Figure 8: Transceiver covering the Range between two Trees

If the trees are within the ranges of the transceivers, they can simply be connected by network of transceivers, where the modules simply relay the data between the sensors. This prevents the workers to carry the ground stations all over the plantation.

4 Conclusions

In this paper, two sets of wireless sensor module and one ground station has been built. The prototype testing has shown that the proposed device is able to detect presence of water in different magnitude in the pollination bag. It is also able to detect changes in particle flow in the pollination bag. The data obtained by the wireless sensor module is sent through the wireless transceiver to the ground station successfully. Finally, the data received in the ground station is displayed correctly on the GUI. Hence, the method of automatic relay of pollination bag conditions would actually help to maintain hitch free practice saves time and yield more output due to its precise result. The system would ensure consistency and convenience method of monitoring exercise. It can be concluded that this system is very important and the cost of developing is also very attractive.

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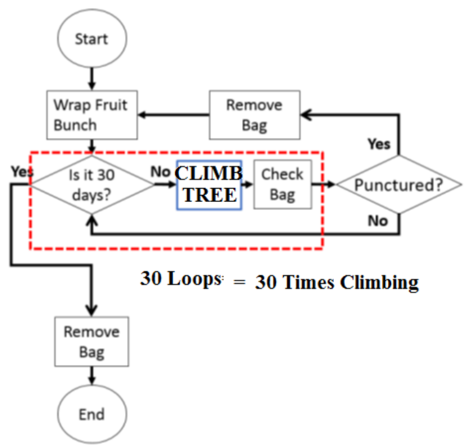
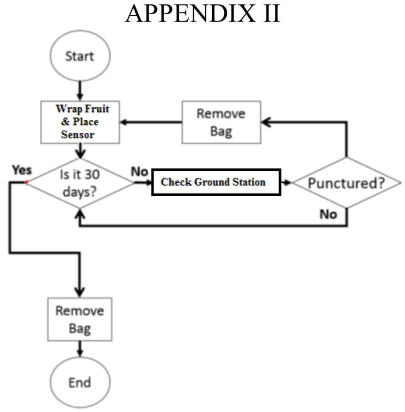
APPENDIX I



APPENDIX II



DEVELOPMENT OF A MICRO-CONTROLLER BASED HOME-GARDEN WATERING SYSTEM WITH GSM REMOTE CONTROL

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ABSTRACT

This paper presents development of a system of watering home-gardens automatically with GSM remote control option. It is implemented using ATMEGA 328 microcontroller for monitoring the soil moisture sensors and regulating the DC pumps for watering to flowers in the garden. The microcontroller is programmed using FLOWCODE (a graphical based programming language). The status of the soil moisture is monitored by the micro-controller and used to determine when to turn on DC pump to supply water to the flowers in the garden. PVC pipes network with holes punched along their length are used to deliver the water to the base of the flowers. When the sensors detect low moisture level in soil, it send signals to ATMEGA 328, which drives pump to water the flower for period of 15 minutes. One DC pump is used for pumping water to storage tank when the level is below a point where water level sensor is located in the tank. When the tank is full the ATMEGA 328 sends command to stop the pump. The pumps used are of ratings 25W, 12V DC. A GSM modem is used in such a way that you have the option of remotely controlling the watering pump using GSM phone form anywhere through the use of DTMF tunes. The designed system was simulated using FLOWCODE 4 for ATMEGA, professional version and was found working perfectly. For a big garden, the power rating of the DC pump should be increased.

KEYWORDS: *Automatic-watering, ATMEGA328, D.C pumps, GSM modem, home garden,*

INTRODUCTION

Home gardens are commonly used for beatification of residential houses. Water is very essential for the flowers to remain in good condition. The manual method of supplying water to the flowers is sometimes inefficient due to human limitations. Many electrical systems were developed for limiting the involvement of human in the garden watering process. Prathyusha and Suman (2012) designed an embedded system for the automation of drip irrigation. This work is on automation of irrigation process. This work is important in maintaining a fixed interval of supplying water to the plant. But it has no a provision for sensing the condition of the soil moisture to determine when the water is needed. Also there is no option of controlling the watering process from remote places.

Ebere and Francisca (2013) carried out a work on microcontroller based automatic garden watering control system. The work involves supplying water to plants in garden at preset intervals. This solves the problem of manual labor but it would in inefficient in its operation because sometimes water can be supplied when it is need needed.

Mansour *et al*., (2013) conducted a research work involving simulation program for testing closed circuits of mini-sprinkler irrigation system. This work helps is saving the water through sprinkling method. It also helps in eliminating the need for manual work. But this work also lacks the means of detecting when there is need of water by the plants.

Devika *et al*., (2014) developed an Arduino based automatic plant watering system. The work uses an ATMEGA based board to automate the method of watering plant. The measure limitation of this work is absence of means of sensing the soil condition and deciding when the water is needed.

Gosavi and Deshmane (2015) developed an irrigation system and water for lifting using windmill energy. This system uses a pumping system that uses wind energy to supply water to plants in irrigation farm. This system has a problem of always supplying water whenever there is available wind that drives the pump. This may have a problem over irrigating the plant, which can be injurious to them.

The microcontrollers are key components of modern day electronics systems for they can be programmed to tackle any problem based on the need and expertize of the programmer. The PIC microcontrollers and ATMEGA microcontrollers are two major classes of the microcontrollers (Han-Way, 2005).

A microcontroller, or MCU, is a computer implemented on a single very large-scale integrated (VLSI) circuit. In addition to those components contained in a microprocessor, an MCU also contains some of the following peripheral components:

Memory, Timers (real-time interrupt, and watchdog timer), Pulse-width modulation (PWM), Analog-to-digital converter (ADC), Digital-to-analog converter (DAC), Parallel I/0 interface, Asynchronous serial communication

interface (UART), Synchronous serial communication interfaces (SPI, I2C, and CAN), Direct memory access (DMA) controller, Memory component interface circuitry and Software debug support hardware (Ionive, 2000).
The amount of current that can be supplied or drained by the microcontrollers is very small. Therefore, to control large power devices like pumps, a relay driver circuit is used control the system. Figure 1 shows the simplified block schematic of ATMEGA 328 architecture (Ionive, 2000).

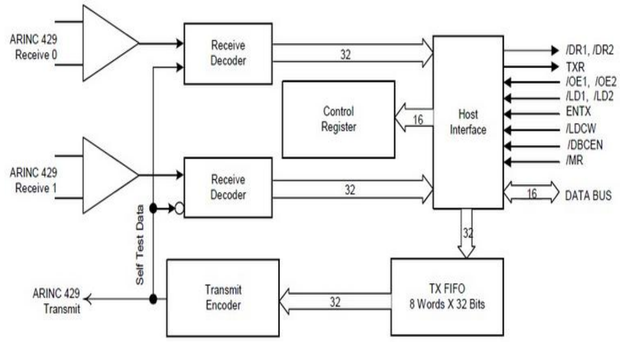

Figure 1: The simplified block schematic of ATMEGA 328 architecture

There exist many home-garden watering systems some operate automatically while some are controlled by the home owners. There are others systems which are remotely controlled from short distances using Infrared, Bluetooth and RF wireless systems.
The objectives of this work are:

1. To come up with Home-Garden watering system that can be controlled from anywhere once GSM service is available.
2. To elimination the limitations on control range that affects other wireless systems being used

MATERIALS AND METHODS

This work is carried out using the fundamental components that made up the complete system and adopting a suitable methodology to enhance the success of the work. The major components used in doing this work include: AVR Microcontroller ATMEGA 328, Moisture sensor LPA12, General purpose NPN transistor C945, Electromagnetic Relay of 6V, 5A, Free Whirling Diode 1N4007, DC pumps of 50W, 12V, Transformer of 240V/15V, Bridge Rectifier, Regulators LM7806 and LM7812 and Backup Battery of 100AH GSM Model GSM5512 and DTMF decoder IC MT8770.
All this components were sourced locally. They are available in all electronics stores.

Design of Power Supply for the System

The system is powered using a 12V regulated supply for the pumps and a 5V for microcontroller which are obtained from the mains together with a backup DC battery of 100AH, 12V. A 4700μF is used as the filter capacitor (C_1) here for better filtering.A 12V regulator (LM7812) is used to obtain regulated 12V for powering the pumps and 6V regulator (LM7806) is used to obtain 6V for powering the PIC microcontroller and the relay driver circuits.

Design of the Main Control Circuit

The general circuit used for controlling the automatic home garden watering system is shown in Figure 2.

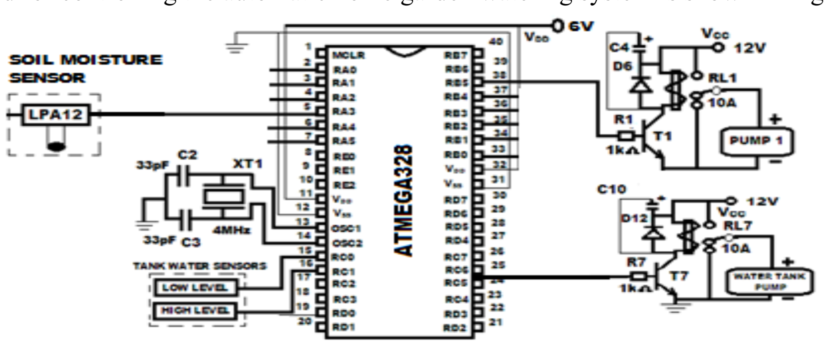

Figure 2: General Control Circuit

The system as shown in Figure 2 has microcontroller ATMEGA328 as the main brain that monitors and controls the operations. Single moisture sensors (LPPA12) is used in the garden detects the level of moisture and sends report to the microcontroller in digital form. There are two other sensors placed in water reservoir for watering the plants. Two pumps (pump 1 and 2) driven by two relay driver circuits were used for supplying water to the garden on request for dry condition detected by the sensor. One other pump (pump 2) is used for supplying water to the water reservoir tank. The operations of the Pump 1 and 2 can happen simultaneously or separately, depending on the state of the sensors controlling them.

Design of Relay Driver Circuit

Each relay drive uses an NPN transistor (C945), which is general purpose as the active component for controlling the relay. The base current to the transistor is regulated by current limiting resistor (R1 to R7). The transistor is protected from damage by back voltage generated due to self-induction of the relay coil. The freewheeling diodes (D6 to D12) have peak inverse voltages of 50V and current rating of 1.5A.

The specifications of the NPN transistors (C945) used are as follows:

Maximum power (P_D) = 0.5W, Collector Current (I_C) = 1000mA, Supply Voltage (V_{CC}) = 5V – 18V. Cut – In Voltage (V_{BE}) = 0.7V. Minimum current gain (β) = 100.

The anti – flickering capacitors (C4 to C10) are used across relays terminals to make the relay triggering very smooth. The suggested value for these capacitors as sugessted in the data sheet can take any value between 10µF and 100µF (Motorola, 2009). In this work 47µF is used because it is within the suggested range.

Design of PIC16f877A External Oscillator Circuit

An external oscillator (XT1) is connected between pins 13 (OSC1) and 14 (OSC2) to complete in–built oscillator circuit of ATMEGA328. All instructions were executed within one single instruction cycle, except for program branches, which are two-cycle. In this case, the execution takes two instruction cycles with the second cycle executed as a NOP (No operation). One instruction cycle consists of four oscillator periods. Thus, the oscillator frequency of the crystal is related with instruction cycle time as in equation (1) (Microchip Technology Inc., 2012):

$$Instruction\ Cycle\ Time = \frac{4}{Oscillator\ Frequency} \qquad (1)$$

The recommended instruction cycle by the manufacturer is from 0.4µs to DC (infinity) (Microchip Technology Inc.). If a 4MHz crystal oscillator (XT2) is used, the instruction cycle time is obtained using equation as:

Using equation (1)

$$Instruction\ Cycle\ Time = \frac{4}{4\ x\ 10^6}$$

$$Instruction\ Cycle\ Time = 1\mu s$$

The instruction cycle time of 1µs calculated is within the accepted range.

Capacitors C_2 and C_3 connected between crystal oscillator and ground are used to improve the stability of oscillation. The recommended values for these capacitors are given by the manufacturer as shown in Table1 (Microchip Technology Inc., 2012).

Table 1 Recommended Value of Capacitors C_2 and C_3 (Microchip Technology Inc., 2012)

Ranges Tested			
Oscillator Type	Frequency	C_2 (OSC1) (pF)	C_3 (OSC2) (pF)
Crystal Oscillator	455kHz	47 – 100	47 – 100
	2.0MHz	15 – 33	15 – 33
	4.0MHz	15 – 33	15 – 33
High Speed Resonator	8.0MHz	15 – 33	15 – 33
	10.0MHz	15 – 33	15 – 33

Recommended values of C2 and C3 should be identical. Higher capacitance increases the stability of the oscillator but also increases the start-up time. Therefore, for the 4MHz crystal oscillator used in this work, 33pF capacitors are selected as C2 and C3.

Configuring the Ports of PIC16F877A

The microcontroller PIC16F877A has five ports. Port A has six pins: RA0 to RA5. Port B has eight pins: RB0 to RB7. Port C has eight pins: RC0 to RC7. Port D has eight pins: RD0 to RD7 and port E has three pins: RE0 to RE2.

Table 2 shows how we did the ports configurations of the microcontroller ATMEGA328.

Table 2 PIC Ports Configurations of PIC16F877A

Sensors	**Port A pins**	**Port B pins**	**Relay Driver Circuits**	**Water Level Sensor**	**Port C**
LPA12 SENSOR →	RA0	RB0 →	Pump 1	Low Level →	RC0
LEVEL SENSOR →	RA1	RB1 →	Pump 2	High Level →	RC1

Programming the ATMEGA328

The microcontroller, ATMEGA328 is programmed using FLOWCODE 5.3 for AVR. The design begins by developing a program flowchart that described the main function to be performed by the microcontroller. Figure 3 gives the program flowchart.

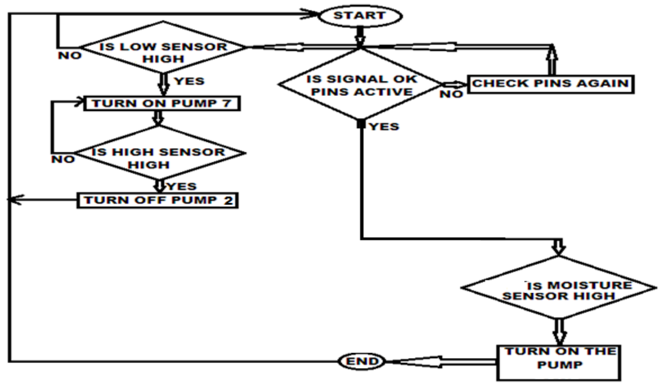

Figure 3: ATMEGA 328 Programming Flowchart

When it is on, it would continuously check the status of soil moisture sensor. When the sensor detects dryness in the soil pump is put ON to supply water to the soil. When the microcontroller is started, it simultaneously checks the status of water level sensors in the reservoir tank. When the low level sensor is high, the pump 2 is started to supply water to the tank. The pump continues to work until the high level sensor becomes high to stop the pump. The compiled hex version of the program is given on the appendix.

Interfacing the GSM Module and DTMF Decoder with ATMEGA328

The GSM module is provided with a SIM card, which can be called using any other phone and it is configured in auto-answer mode. When it receives calls, the keys on the calling phone when pressed produces DTMF tones which MT8770 decodes into decimal digits '0 – 9' and symbols '*' and '#' pressed on the handset were converted into 4 – bit binary data as given in Table 3 (Microsemi , 2013)

Table 3 DTMF Keys and their Binary Output Equivalents (Microsemi, 2013)

KEY	Q 4	Q 3	Q2	Q1
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
0	1	0	1	0
*	1	0	1	1
#	1	1	0	0

Same as in tables 1 and 2

Since there are only two relays to be controlled; only keys 1 to 2 were used for ON/OFF control of the phone. The microcontroller was programmed to check binary inputs it receives from the DTMF decoder and activate corresponding output pin that drives relay driver circuit. Figure 4 shows the general block diagram of the system.

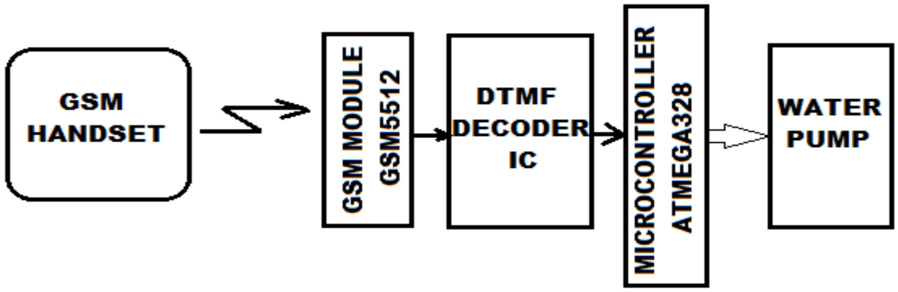

Figure 4: General Block Diagram of the System

RESULTS AND DISCUSSIONS

The developed system was simulated using AVR Flowcode ® 5.3, professional version. Three (3) toggle switches were used in the software to serve as the one soil moisture sensor in the garden and the remaining two switches were used as the low level and high level water sensors in the storage tank. Light Emitting Diodes (LEDs) were used to represent the two pumps. The Source code was developed using the flowchart of the Flowcode software and the developed program was loaded to the AVR microcontroller used (ATMEGA328). When the simulated project was run the circuit was functioning well by responding the sensors signal and the GSM call segment was also simulated and found working normally. This confirms the normal operation of the proposed system.

CONCLUSION

Proper and regular watering of home gardens is very important. This proposed method of automatic and remote watering system would actually help to maintain a good home. The system would ensure consistency and convenience in the watering exercise. It can be concluded that this system is very important.

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APPENDIX

COMPILED HEX PROGRAM OF THE MICROCONTROLLER PIC16F877A

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:08000800FF00030E8312031335
:10001000B4000A0EB500040EB6008A110A12A
E2A
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:1001D0000230C300C40167203330D600D7017A
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2003
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:100250009F00C0308100FF3083160504850 0831
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COMPARISON OF GHG EMISSIONS BETWEEN EFFICIENT AND INEFFICIENT BROILER FARMS IN KADUNA STATE OF NIGERIA USING DATA ENVELOPMENT ANALYSIS (DEA): ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT

This study applied a non-parametric method in determining efficiency of farmers, discriminate efficient farmers from inefficient ones, and identify wasteful uses of energy in order to optimize the energy inputs for broiler production. Furthermore, the effect of energy optimization on greenhouse gas (GHG) emission was investigated and the total amount of GHG emission of efficient units was compared with inefficient units. A total sample size of 55 broiler farmers were selected from Kaduna State viz. multi-stage sampling technique. Total energy used in various operations during broiler production was 77916.14 MJ (500bird)$^{-1}$. Results revealed that 63percent of producers were technically efficient, while 43 producers under PTE were identified efficient (79.6%). Mean values of TE, PTE and SE of farmers were observed to be 0.976; 0.993 and 0.983, respectively. Also, it was concluded that 1.38 percent [1071.54 MJ (500birds)$^{-1}$] of overall input energies can be saved if the performance of inefficient farms rose to a high level. Finally, comparative results of GHG emissions revealed that the amount of CO_2 emissions in efficient units was less than inefficient farms.

Keywords: *Environment; GHG emission; Efficient vs. Inefficient; Broiler; DEA*

INTRODUCTION

The quality of environment emerged as a public discourse during the early sixties as a result of some outstanding write ups on environmental crisis. These and few other literary explosions and the almost simultaneous occurrence of several ecological disasters led many to ask: "Economic growth-at what cost?" Though few growing economies today challenge unlimited growth, their continued growth of output and population will eventually lead to environmental crisis. Man must begin to see earth as a close system, in contrast to the older conception that natural resources are boundless and that man can develop and exploit them without limit. Thus, conservationists view the prospect of unnecessary destruction of environmental resources with horror. Environmental resources should be viewed as essential irreplaceable social capital that must be conserved intact for future generation. The foregoing discussions amply demonstrate how agriculture and environment can come in conflict with each other. That this conflict was not recognized in time has led to different forms of environmental degradations; adverse effects of agriculture and its growth on environment may be more indirect than in industry. While new technologies are immensely important for agricultural development, how much cost do we have to pay in terms of degrading environmental condition has to be carefully considered. A pertinent question arises which invites the immediate attention of the planners; will the present agricultural development sustain itself the way it is going? This point to an exercise of rational exploitation of what environment is offering to mankind so that the future generations with even greater demands do not change with cruelty.

Evolution of new technology brought inter-bread of hens, so chicks in a short period attain desirable weight. The intensity of energy use on broiler farms is high and studies on input-output energy pattern on broiler farms are very important. Efficient use of agricultural product energies helps to achieve increased production, productivity and contributes to the profitability and competitiveness of agriculture sustainability in rural areas (Heidari, 2011). According to literature, the only study conducted on energy optimization in broiler production using DEA was by Heidari (2011); with no effort of investigating effect of energy optimization on GHG emission in broiler production, thus, making this present study first of its kind. However, literature revealed recent studies which used DEA to estimate GHG emissions in crops production viz. Pishgar-Komleh et al.(2012); Pishgar-Komleh et al.(2013); Mohammadi et al.(2013); Khoshnevisan (2013a); Khoshnevisan (2013b); Qasemi-Kordkheili and Nabavi-Pelesaraei (2014); Nabavi-Pelesaraei et al.(2014); Sadiq et al.(2015) and Sadiq et al.(2016). In this study, the same methodology was adopted for broiler farms in Kaduna State, with the objectives to specify energy use for broiler production, segregate efficient farmers from inefficient ones, identify wasteful uses of energy inputs and investigate the effect of energy optimization on GHG emission in broiler production.

RESEARCH METHODOLOGY

Kaduna State is located between latitudes 9^0 08' and 11^0 07'N and longitudes 6^0 10' and 8^0 48'E, with a land mass of about 45,567 square kilometres; estimated population of 6,066,562. Agriculture constitutes the largest occupation of the people with many citizens participating in small scale farming. The State is a major region of animal husbandry. Multi-stage sampling technique was used for the study. Firstly, five LGAs *viz.* Kaduna North, Kaduna South, Kachia, Zaria and Makarfi were purposively selected due to high intensity of poultry production; followed by stratification of poultry producers into broilers and layers in each selected LGAs, and then random selection of 11 respondents from boiler strata in each selected LGAs, thus, given a total sample size of 55 broiler farmers. However, only 54 valid questionnaires were retrieved and subsequently treated. Data were elicited *viz.* pre-tested questionnaire coupled with interview schedule, and subsequently subjected to DEA analytical technique.

Table 1: Equivalents for various sources of energy

Items	Unit	Equivalent MJ
Human Labour	Man-hour	1.96
Chick	Kg	4.56
Broiler	Kg	4.56
Manure	Kg	18.0
Maize	Kg	7.9
Soyabean meal	Kg	12.06
Fish meal (FA)	Kg	9
Di calcium phosphate	Kg	10
H_2o	m^3	1.02
Petrol	L	48.23
Kerosene	L	36.7
Electric motor	Kg	64.8
Electricity	kWh	11.93

Empirical model

Data envelopment analysis

DEA technique builds a linear piece-wise function from empirical observations of inputs and outputs. DEA is a nonparametric approach for estimating productive efficiency based on mathematical linear programming techniques. Unlike parametric methods, DEA does not require a function to relate inputs and outputs. The DEA envelops the data in such a way that all observed data points lie on or below the efficient frontier (Coelli, 1996). The efficient frontier is established by efficient units from a group of observed units. Efficient units are those with the highest level of productive efficiency. In DEA an inefficient DMU can be made efficient either by minimizing the input levels while maintaining the same level of outputs (input oriented), or, symmetrically, by maximizing the output levels while holding the inputs constant (output oriented).

Technical efficiency (TE)

TE can be defined as the ability of a DMU (e.g. a farm) to produce maximum output given a set of inputs and technology level. The TE score (θ) in the presence of multiple-input and output factor can be calculated by the ratio of sum of weighted outputs to the sum of weighted inputs or in a mathematical expression given below (Cooper *et al.*, 2004):

$$\theta = \frac{U_1Y_1j + U_2Y_2j + ... + UsYsj}{V_1X_1j + V_2X_2j + ... + VmXmj} = \frac{\sum_{r=1}^{s} UrYrj}{\sum_{i=1}^{m} ViXij} \quad .... (1)$$

Let the DMU*j* to be evaluated on any trial be designated as DMU*o* (*o* = 1, 2 . . . *n*). To measure the relative efficiency of a DMU*o* based on a series of *n* DMUs, the model is structured as a fractional programming problem, and specified as follows (Cooper *et al.* 2006):

$$\text{Max: } \theta = \frac{\sum_{r=1}^{s} UrYr0}{\sum_{i=1}^{m} ViXi0} \quad .... (2)$$

$$\text{Subject to: } \frac{\sum_{r=1}^{s} UrYrj}{\sum_{i=1}^{m} ViXij} \leq 1 \quad j=1, 2 .... n$$

$$Ur \geq 0, \quad Vi \geq 0$$

where *n* is the number of DMUs in the comparison, *s* the number of outputs, *m* the number of inputs, *Ur* (*r* = 1, 2, …, *s*) the weighting of output *Yr* in the comparison, *Vi* (*i* = 1, 2, …, *m*) the weighting of input *Xi*, and *Yrj* and *Xij* represent the values of the outputs and inputs *Yj* and *Xi* for DMU*j*, respectively. Equation (2) can equivalently be written as a linear programming (LP) problem as follows:

Max: $\theta = \sum_{r=1}^{s} UrYro$ .... (3)

Subject to: $\sum_{r=1}^{s} UrYrj - \sum_{i=1}^{m} ViXij \leq 0$ J=1, 2……….. n

$$\sum_{i=1}^{m} UiXio = 1$$

$Ur \geq 0, Vi \geq 0$

The dual linear programming (DLP) problem is simpler to solve than Equation (3) due to fewer constraints. Mathematically, the DLP problem is written in vector–matrix notation as follows:

Min: θ……………………………. (4)

Subject to: $Y\lambda \geq y0$

$X\lambda - \theta X0 \leq 0$

$\lambda \geq 0$

Where *Yo* is the *s* x 1 vector of the value of original outputs produced and *Xo* is the *m* x 1vector of the value of original inputs used by the o^{th} DMU. *Y* is the *s* x *n* matrix of outputs and *X* is the *m* x *n* matrix of inputs of all *n* units included in the sample. λ is a *n* x 1 vector of weights and Θ is a scalar with boundaries of one and zero which determines the technical efficiency score of each DMU. Model (4) is known as the input-oriented CCR DEA model. It assumes constant returns to scale (CRS), implying that a given increase in inputs would result in a proportionate increase in outputs.

Pure technical efficiency (PTE)

The TE derived from CCR model, comprehend both the technical and scale efficiencies. So, Banker *et al.* (1984) developed a model in DEA, which was called BCC model to calculate the PTE of DMUs. The BCC model is provided by adding a restriction on λ (λ =1) in the model (4), resulted to no condition on the allowable returns to scale. This model assumes variable returns to scale (VRS), indicating that a change in inputs is expected to result in a disproportionate change in outputs.

Scale efficiency (SE)

SE relates to the most efficient scale of operations in the sense of maximizing the average productivity. A scale efficient farmer has the same level of technical and pure technical efficiency scores. It can be calculated as follow:

SE = TE ÷ PTE ……………………………. (5)

SE gives the quantitative information of scale characteristics. It is the potential productivity gained from achieving optimum size of a DMU. However, scale inefficiency can be due to the existence of either IRS or DRS. A shortcoming of the SE score is that it does not indicate if a DMU is operating under IRS or DRS conditions. This problem is resolvable by solving a non-increasing returns of scale (NIRS) DEA model, which is obtained by substituting the VRS constraint of $\lambda = 1$ in the BCC model with $\lambda \leq 1$. IRS and DRS can be determined by comparing the efficiency scores obtained by the BCC and NIRS models; so that, if the two efficiency scores are equal, then DRS apply, else IRS prevail. The information on whether a farmer operates at IRS, CRS or DRS status is particularly helpful in indicating the potential redistribution of resources between the farmers, thus, enables them to achieve higher output.
The results of standard DEA models divide the DMUs into two sets of efficient and inefficient units. The inefficient units can be ranked according to their efficiency scores; while, DEA lacks the capacity to discriminate between efficient units; number of methods are in use to enhance the discriminating capacity of DEA. In this study, the benchmarking method was applied to overcome this problem. In this method, an efficient unit which was chosen as the useful target for many inefficient DMUs and so appears frequently in the referent sets is highly ranked.
In the analysis of efficient and inefficient DMUs, the energy saving target ratio (ESTR) was used to specify the inefficiency level of energy usage for the DMUs under consideration. Following Sadiq *et al.*(2015); Sadiq *et al.*(2016), the formula is given below:

$$ESTR\ (\%) = \frac{(\text{Energy saving target})}{(\text{Actual energy input})} \times 100$$

Where energy saving target is the total amount of energy inputs reduced, which could be saved without reducing the output level. A higher ESTR percentage implies higher energy use inefficiency, and thus, a higher energy saving amount.

GHG emissions

CO_2 emission coefficients of inputs were used to quantifying GHG emissions in broiler production. GHG emission was calculated by multiplying the input application rate by its corresponding emission coefficient (Table 2).

Table 2: GHG emission coefficients of inputs

Items	Unit	GHG coefficient (kg CO_2eq. unit^{-1})
Petrol	L	1.85
Kerosene	L	1.85
Electric motor	MJ	0.071
Electricity	kWh	0.608

RESULTS AND DISCUSSION

Energy Use Pattern in Broiler Production

Table 3 presents the amount of inputs, output and their energy equivalents for broiler production. The total energy consumption was 77916.14MJ (500birds)$^{-1}$. Feed with approximate share of 72.7% was the most energy consumed, followed by electricity. The main reason for high feeds energy consumption was that farmers did not have appropriate knowledge about the proper time and amount of feeds usage, and also the common belief that increased use of feeds energy resource will increase output. Contribution of human labour, machinery (electric motor) and H_2O in comparison with other inputs in the total input energy is negligible. However, total output energy observed in the studied area was 142458.26 MJ (500birds)$^{-1}$; average output of broiler and manure were 816.86Kg and 7707.41 Kg, respectively, per 500 birds.

Table 3: Amounts of inputs, output and their energy equivalents for broiler production

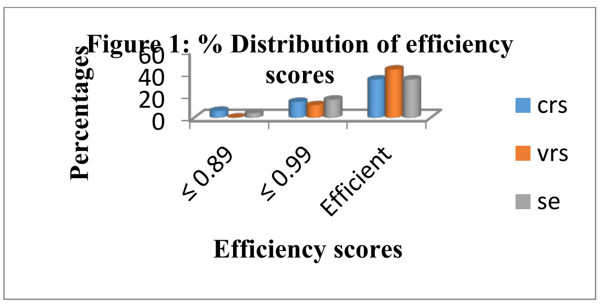
Inputs	Quantity(500birds)$^{-1}$	Total energy equivalent [MJ(500birds)$^{-1}$]	(%)
Chicks (kg)	222.33	1013.84	1.3
Human labour (mhr)	78.83	154.5	0.2
Feeds (kg)			

a. Maize	1434.076	11329.20	14.5
b. Soyabean meal	1878.806	22658.40	29.1
c. Fatty meal (FA)	2014.079	18126.71	23.3
d. Di-calcium phosphate	453.168	4531.68	5.8
H_2O (m^3)	0.1028	0.1049	0
Petrol (L)	44.63	2152.49	2.8
Kerosene (L)	13.704	502.93	0.7
Electric motor (kg)	3.045	197.32	0.2
Electricity (kWh)	1445.847	17248.96	22.1
Total energy input		**77916.14**	**100**
Output			
a. Broiler (kg)	816.86	3724.88	
b. Manure (kg)	7707.41	138733.38	
Total energy output		**142458.26**	

Source: Field survey, 2015

Efficiency Measurement of Broiler Farmers

Results of farmers' distribution based on the efficiency score obtained by the application of CCR and BCC DEA models are shown in Figure 1. Evidently, 63 percent (34farmers) and 79.6 percent (43 farmers) from total farmers were identified as efficient farmers under constant and variable returns to scale assumptions, respectively; implying these farms could shift on CCR and BCC frontier. Furthermore, approximately 25.9 percent and 20.4 percent of TE and PTE respectively, had efficiency scores between 0.99 and 1.00. However, if the BCC model is assumed, only 11.1 percent had efficiency scores of less than 0.89; whereas, if the CCR model is considered, none had efficiency score of less than 0.89. The results of returns to scale estimation indicated that all of the technically efficient farmers (based on the CCR model) were operating at CRS, indicating optimum scale of their practices.



Summarized statistics for the three estimated measures of efficiency are given in Table 4. Results revealed that the average values of technical and pure technical efficiency scores were 0.976 and 0.993, respectively. The technical efficiency scores varied from 0.814 – 1.00; while pure technical efficiency scores ranged from 0.904-1.00. The small variation in the technical efficiency implies that all the farmers were fully aware of the right production techniques but did not apply them properly; while mild variation in pure technical efficiency indicates that the farmers were almost rational in allocation of resources at their disposal. Average PTE provides information about the potential resource savings that could be achieved while maintaining the same output level.

Table 4: Deciles frequency distributions of efficiency scores

Efficiency level	TE	PTE	SE
≤ 0.89	6 (11.1)	0	4 (7.4)
≤ 0.99	14 (25.9)	11 (20.4)	16 (29.6)
1.00	34 (63)	43 (79.6)	34 (63)
Total	54	54	54
Minimum	0.814	0.904	0.814
Maximum	1.00	1.00	1.00

Mode	1.00	1.00	1.00
Mean	0.976	0.993	0.983
SD	0.047	0.021	0.040

Source: Computed from DEAP 2.1 computer print-out
Figures in parenthesis are percentages

In the case of TE, farmers with efficiency scores of less than one, are technologically inefficient in energy use, while for PTE, farmers with less than one efficiency scores are wasting energy resources than required, indicating ample scope for target farmers to improve their operational practices in enhancing their energy use efficiency for adjustment strategy. If technical efficiency is assumed, average farmers need to increase their efficiency scores by 2.4 percent; worst inefficient farmers require TE adjustment scores of approximately 18.6 percent, and best inefficient farmers require approximately 0.7 percent adjustment, respectively, to be on the frontier surface. However, if an adjustment for pure technical efficiency scores is assumed, average farmers need to reduce their energy inputs by 0.7 percent; worst inefficient farmers' needs approximately 9.6 percent input reduction, and best inefficient farmers require 0.2 percent input reduction, respectively, to be on the frontier surface. Based on pure technical efficiency, 34 farmers were globally efficient and operating at the most productive scale sizes of production, while 9 farmers were locally efficient entities operating at an inferior scale sizes. The average scale efficiency score was relatively low (0.983), showing the disadvantageous conditions of scale size. This indicates that if all of the inefficient farmers operated at the most productive scale size, about 1.7 percent savings in energy use from different sources would be possible without affecting the output level.

Returns to Scale Properties in Broiler Production

The BCC model includes both IRS and DRS, while NIRS model gives DRS. To determine whether a DMU has IRS or DRS, an additional test is required. The values of TE for both BCC and NIRS were calculated and their values were compared. The same values of TE for NIRS and BCC models show that the DMU has DRS, while different values imply that the farm has IRS. Results of RTS for some selected DMUs revealed that 34 DMUs had CRS; 12 DMUs had DRS, while 8 DMUs were found to be operating at IRS (Table 5). Therefore, a proportionate increase in all inputs leads to more proportionate increase in outputs; and for considerable changes in yield, technological changes in practices are required. The information on whether a farmer operates at IRS, CRS or DRS is particularly helpful in indicating the potential redistribution of resources between the farmers, thus, enables them to achieve higher output.

Table 5: Characteristics of farms with respect to return to scale

Scale	**No. of farms**	**Mean energy output (MJ)**	
		Broiler	**Manure**
Sub-optimal	8	3438.38	128025
Optimal	34	3753.48	144158.82
Super-optimal	12	3834.87	130500

Source: Computed from DEAP 2.1 computer print-out

Ranking Analysis of Broiler Production

Identifying efficient operating practices and their dissemination will help to improve efficiency not only in the case of inefficient farmers but also for relatively efficient ones, because efficient farmers obviously follow good operational practices. However, among the efficient farmers, some show better operational practices than others, therefore, discrimination need to be made among the efficient farmers while seeking the best operational practices. In order to have the efficient farmers ranked, the number of times an efficient DMU appears in a referent set was counted (Table 6). Only efficient farms serve as peers for the inefficient farms and in this instance farms 1-2, 15-16, 17-20, 21-24, 25-26, 28-29, 31-33, 37-39, 40-41, 44-45, 47-48, 49-50, 51 and 52 are the peers. Farm 24, for example, was a peer for 7 farms making it the most comparator used farm. These efficient farms can be selected by inefficient DMUs as best practice DMUs, making them a composite DMU instead of using a single DMU as a benchmark. While the referent set is composed of the efficient units which are similar to the input and output levels of inefficient units, efficient DMUs with more appearance in referent set are known as superior unit/spark plug in the ranking. Results of such analysis would be beneficial to inefficient farmers to manage their energy sources usage in order to attain the best performance of energy use efficiency. However, these superior units/spark plugs can be use as reference means of dissemination of farm improvement by extension delivery services.

Table 6: Benchmarking of efficient DMUs

DMUs	Frequency in referent set	Ranking	DMU(farm)	Frequency in referent set	Ranking
F24	7	1	**F51**	2	5
F01	5	2	**F02**	1	6
F39	5	2	**F16**	1	6
F44	5	2	**F31**	1	6
F26	4	3	**F33**	1	6
F40	4	3	**F37**	1	6
F20	3	4	**F45**	1	6
F41	3	4	**F47**	1	6
F15	2	5	**F48**	1	6
F17	2	5	**F49**	1	6
F21	2	5	**F50**	1	6
F25	2	5	**F52**	1	6
F28	2	5			
F29	2	5			

Source: Computed from DEAP 2.1 computer print-out

Performance Assessment of Broiler Farms

Table 7 shows the peers for each farm and the weights that these peers account for. For each inefficient farm there are peers which serve as comparators against which the farm is measured. Efficient farms do not have any peers other than themselves as they are on the efficient frontier, thus defining the efficiency. It stands to reason that the weight will be unity in the case of efficient farms. The higher the weight the more important that particular farm is as a peer for the inefficient farm in question. This means that the inefficient farm is better off comparing itself to the peer with the highest weight in order to improve its efficiency by emulating its peers. The identification of peers is important in that the peers' production technology, in this case pollution minimizing technology, can be studied and implemented by the inefficient farms. Result shows the worst inefficient DMU (DMU22) and the best inefficient DMU (DMU12). For instance, in the case of DMU22 the composite DMU that represents the best practice or reference composite benchmark DMU is formed by combination of DMU40, DMU51, DMU17, DMU1 and DMU5.
This means DMU22 is close to the efficient frontier segment formed by these efficient DMUs, represented in the composite DMU. The selection of these efficient DMUs is made on the basis of their comparable level of inputs and output to DMU22. The benchmark DMU for DMU22 is expressed as 40(0.484); 51(0.127); 17(0.099); 1(0.267) and 5(0.024), where 40, 51, 17, 1 and 5 are the DMU numbers while the values in the brackets are the intensity vector λ for the respective DMUs. The higher value of the intensity vector λ for DMU40 (0.484) indicates that its level of inputs and output is closer to DMU22 compared to the other DMUs.

Table 7: Performance assessment of broiler farms

DMUs	PTE score (%)	Benchmarks
F22	90.4	40(0.484) 51(0.127) 17(0.099) 1(0.267) 5(0.024)
F11	91.6	28(0.212) 24(0.276) 40(0.194) 26(0.068) 39(0.250)
F13	99.5	24(0.143) 48(0.004) 1(0.190) 41(0.459) 49(0.034) 29(0.059) 20(0.111)
F35	99.5	24(0.011) 20(0.094) 29(0.122) 44(0.205) 39(0.469) 1(0.099)
F12	99.8	20(0.041) 1(0.507) 44(0.392) 24(0.060)

Source: Computed from DEAP 2.1 computer print-out

Setting Realistic Input Levels for Inefficient Broiler Farmers

A pure technical efficiency score of less than unity for a farmer indicates that, at present conditions, he is using energy values more than required. Therefore, it is desirable to suggest realistic levels of energy to be used from each source for every inefficient farmer in order to avert energy wastage. Results in Table 8 presents the average energy usage in actual and optimum conditions [MJ (500 birds)$^{-1}$], possible energy savings and ESTR percentage for different energy sources. It is evident that, total energy input could be reduced to 76844.60 MJ (500 birds)$^{-1}$; while, maintaining the current production levels and also assuming no other constraining factors. Required energies for petrol, kerosene, machinery (electric motor) and electricity were 2086, 495.55, 192.43and 16922.59 MJ (500 birds)$^{-1}$, respectively; while chicks, human labour, feeds and H_20 energies required were 1003.28, 151.72, 55992.3 and 0.1046MJ (500 birds)$^{-1}$, respectively.

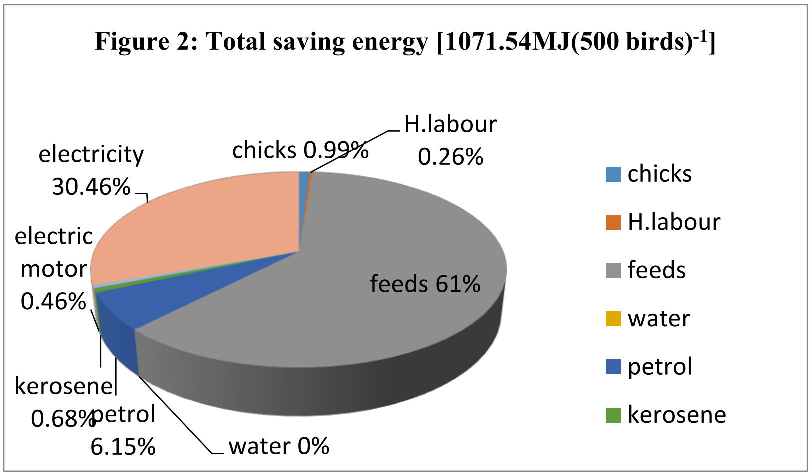
Furthermore, ESTR results showed that if all farmers operated efficiently, reduction in petrol and machinery energy inputs, with respect, by 3.06 percent and 2.48 percent would be possible without affecting the output level. These energy inputs had the highest inefficiency which owed mainly to lightening of poultry huts. Artificial lighting is important in raising the production of chickens; if the housing is lit in the cooler hours before sunrise or after sunset, the chickens are able to eat more and grow well. However, day length must not be increased during the growing period of the young chicks until just before four weeks. In order to improve the farms environment as well as reduction in consumption of petrol fuel, it is strongly suggested that the heating system efficiency be raise or replace with alternative sources of energy such as biogas, solar energy, wind etc. Moreover, the ESTR percentage for total energy input was 1.38 percent, indicating that by adopting the recommendations obtained from this study, on average, about 1.3 percent [1071.54MJ(500 birds)$^{-1}$] from total input energy in broiler production could be saved without affecting the output level.

Table 8: Energy saving [MJ (500birds)$^{-1}$] from different sources if recommendations of study are followed

Input	Actual energy used [MJ(500birds)$^{-1}$]	Optimum energy requirement [MJ(500birds)$^{-1}$]	Energy saving [MJ(500birds)$^{-1}$]	ESTR (%)
Chicks	1013.84	1003.28	10.56(0.99)	1.04
Human labour	154.5	151.72	2.78(0.26)	1.8
Feeds	56645.99	55992.3	653.69(61)	1.15
H_2O	0.1049	0.1046	0.0003(0)	0.29
Petrol	2152.49	2086.62	65.87(6.15)	3.06
Kerosene	502.93	495.55	7.38(0.68)	1.47
Electric motor	197.32	192.43	4.89(0.46)	2.48
Electricity	17248.96	16922.59	326.37(30.46)	1.89
Total energy input	77916.14	76844.60	1071.54	1.38

Source: Computation from DEAP 2.1 computer print-out
Figures in parenthesis are percentages

Figure 2 shows distribution of saving energy from different sources for broiler production. It is evident that the maximum contribution to total saving energy is 61 percent from human labour. However, human labour and electricity energy inputs contributed to the total saving energy by about 91.46 percent. From these results it is strongly suggested that improving the usage pattern of these inputs be considered as priorities providing significant improvement in energy productivity for broiler production in the study area. Improving energy use efficiency of human labour *viz.* channeling of its excess to other sectors is suggested to prevent wastage by inefficient farmers. Applying alternatives sources of energy such as biogas, solar energy, wind are suggested to prevent electrical energy wastage by inefficient farmers.



Improvement of Energy Indices for Broiler Farms

Comparison between energy indices in the actual and optimum energy use showed improvements of these indices (Table 8). Obviously, by optimization of energy use, both energy ratio and energy productivity indicators can improve by 1.09 percent and 1.84 percent, respectively. Also, in optimum consumption of energy inputs, the net energy indicator by improvement of 1.66 percent would increase to 65613.66MJ $(500birds)^{-1}$. In otherwords, energy ratio, energy productivity, specific energy and net energy were 1.83; 0.109 Kg MJ$(500birds)^{-1}$; 9.14MJ$(500birds)^{-1}$ and 64542.12MJ$(500birds)^{-1}$, respectively, and they can be improved to 1.85; 0.111 Kg MJ$(500bird)^{-1}$; 9.02 MJ$(500birds)^{-1}$ and 65613.66MJ$(500birds)^{-1}$.Therefore, it is obvious that broiler production had relatively high requirements for nonrenewable energy resources and to certain extent feeds energy (renewable energy); its electrical energy requirement is high and need high amount of petrol fuel consumption in situation of power outage. In the case of feeds, farmers mainly don't have enough knowledge on more efficient input use and there is a common belief that increased use of feed energy resource will increase output. These situations occur simply because the farmers mainly don't have enough knowledge on more efficient input use. Methods presented in this study demonstrate how energy use efficiency in broiler production may improve by applying the operational management tools to assess the performance of farmers. On an average, considerable savings in energy inputs may be obtained by adopting the best practices of benchmarking/ high-performing DMUs in broiler production process. Adoption of more energy-efficient poultry systems would help in energy conservation and better resource allocation. Strategies such as providing better extension and training programs for farmers and use of advanced technologies should be developed in order to increase the energy efficiency of broiler productions in the studied area. The farmers should be trained with regard to the optimal use of inputs, especially, electricity, petrol and feeds as well as employing the new production technologies. Therefore, agricultural institutes in the state have an important role in this case to establish the more energy efficient and environmentally healthy broiler production systems in the studied area.

Table 8: Improvement of energy indices for broiler farms

Items	Unit	Qty in Actual use	Qty in optimum use	Change (%)
Energy ratio	-	1.83	1.85	1.09
Energy productivity	KgMJ^{-1}	0.109	0.111	1.84
Specific energy	MJKg^{-1}	9.14	9.02	-1.3
Net energy	MJ(500birds)$^{-1}$	64542.12	65613.66	1.66
Total input energy	**MJ(500birds)$^{-1}$**	**77916.14**	**76844.60**	**-1.38**

Source: Authors computation, 2015

Comparison of Input Use Pattern of Efficient and Inefficient Farms

The quantity of source wise physical inputs and output for 3 truly most efficient and inefficient broiler farms based on CCR model were compared (Table 9). Results revealed that the use of all inputs by efficient farmers were less than that of inefficient farmers. However, use of petrol fuel caused the main difference between efficient farmers and inefficient ones; efficient farmers used approximately 30.6 percent less petrol fuel than inefficient farmers.

Furthermore, inefficient farmers had lower broiler (1.02%) and manure (22.84%) productions, respectively, than the efficient ones.

Table 9: Input use [MJ (500 Birds)$^{-1}$] for Efficient and Inefficient Broiler Production Farms

Inputs	Inefficient farms (A)	3 Top Efficient farms (B)	Difference (%) [(A-B)/A]*100
Chicks	1008.78	988	2.06
Human labour	156.89	130.33	16.9
Feed	55471.9	53754.13	3.1
H_2O	0.1036	0.095	8.6
Petrol	2083.78	1446.9	30.6
Kerosene	424.22	354.77	16.4
Electric motor	198.19	179.33	9.5
Electricity	16386.73	14634.33	10.7
Outputs			
Broiler	3742.93	3781	-1.02
Manure	130418.2	160200	-22.84

Source: Computation from DEAP 2.1 computer print-out

Comparison of GHG Emissions of Efficient and Inefficient Broiler Farms

GHG emission of efficient and inefficient DMUs was investigated to determine the role of energy optimization in environmental condition of broiler production in the studied area (Table 10). Results indicated the GHG emissions of 3 truly most efficient and inefficient broiler farms to be 831.94kgCO_{2eq} and 950.53kgCO_{2eq}, respectively. It is obvious that the total GHG emissions of inefficient units were more than 3 truly most efficient broiler farms by approximately 12.48%.; petrol fuel accounted for the major difference (30.57%). Therefore, consumption of inefficient units should be close to 3 truly most efficient farms. Furthermore, alternative environmental friendly energy sources *viz*. biogas, solar and wind energies are the best option.

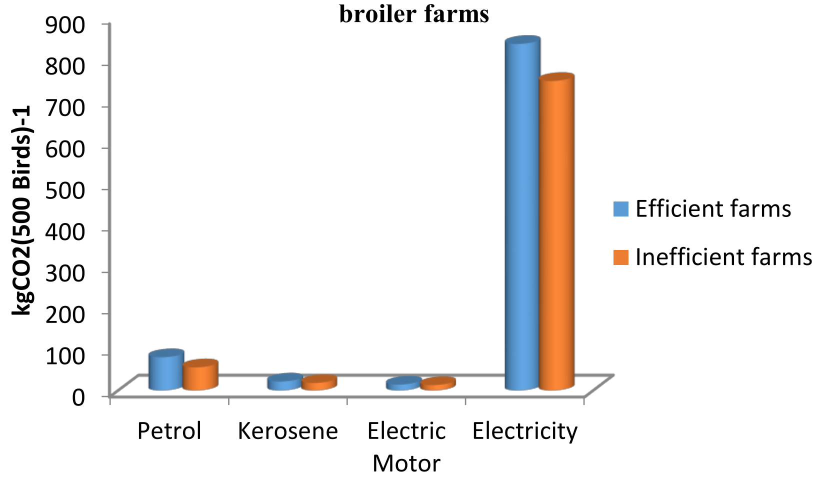
Table 10: GHG emissions of 3 truly efficient and inefficient broiler farms

Inputs	Inefficient farms (kgCO_2eq) (C)	Efficient farms (kgCO_2eq) (D)	Difference (%) [(C-D)/D]*100
Petrol	79.94	55.5	30.57
Kerosene	21.39	17.89	16.36
Electric motor	14.07	12.73	9.52
Electricity	835.13	745.82	10.69
Total GHG emissions	**950.53**	**831.94**	**12.48**

Source: Computation from DEAP 2.1 computer print-out

Figure 3 displays the amount of each input for 3 truly most efficient and inefficient units from GHG emissions point of view. Results indicted GHG emissions of petrol fuel to be highest; followed by kerosene fuel, electricity and electric motor. It's obvious, that petrol fuel consumption of inefficient units was much more than efficient units. Accordingly, the main inputs of GHG creator were identical for efficient and inefficient. As such, the researchers opined that the consumption of all these inputs should be reduced.

Figure 3: Quantity of GHG for 3 efficient and inefficient broiler farms



CONCLUSION

This study determines the possibilities of energy use improvement in broiler production using DEA approach. This method helped to identify the impact of energy use from different inputs on output, measure efficiency scores of farmers, segregate efficient farmers from inefficient farmers, ranking efficient farmers, identifying wasteful energy uses by inefficient farmers, compare GHG emission of 3 most efficient farms and inefficient farms aimed at determining the role of energy optimization in environmental condition of broiler production in the studied area. Results indicated that there were substantial production inefficiencies by farmers; such that, potential of 1.38 percent reduction in total energy input use may be achieved if all farmers operated efficiently and assuming no other constraints on this adjustment. In other words, the total energy input could be reduced by 1.38 percent without reducing the present output level by adopting study based recommendations. Average broiler outputs were 820.82 and 829.17 kg per 500birds for efficient and inefficient broiler farms, respectively. Thus, about 1.02 percent of broiler output declined in inefficient broiler farms. Comparative results of GHG emissions revealed that the amount of CO_2 emissions in efficient units was less than inefficient farms. Moreover, results revealed that broiler production in the studied area showed a high sensitivity to non-renewable energy sources which may result in both the environmental deterioration and rapid rate of depletion of these energetic resources. Therefore, policies should emphasize on development of new technologies to substitute fossil fuels with renewable energy sources aiming efficient use of energy and lowering the environmental footprints; limited fossil fuels sources implies that policy makers need to come up with best management in productivity improvement of broiler production in the studied area. Development of renewable energy usage technologies such as lightening systems using biogas, wind or solar power, using better management techniques, utilization of alternative sources of energy such as biogas, wind and solar energy are suggested to reduce the environmental footprints of energy inputs and to obtain sustainable broiler production systems. However, modern and well established scientific practices should be use to obtain higher technical efficiency in broiler production *viz.* having good knowledge of broiler feeds consumption; specifically the quantity of required feeds per meat Kg (feed conversion ratio); capacity training of poultry farmers and processors to enable them cope with the present challenges of modern poultry farming and commercialization of the poultry sub-sector in the state in particular and the country in generally. Also, losses at the farmers' level can be minimized through opening and strengthening of Agricultural Technology Information Centre (ATIC) in agricultural institution. Further, local level extension systems needs to be strengthened for effective transfer of technology.

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Appendix: Efficiency scores

DMUs	CRSTE	VRSTE	SE	Return to Scale	DMUs	CRSTE	VRSTE	SE	Return to Scale
F01	1.000	1.000	1.000	CRS	**F31**	1.000	1.000	1.000	CRS
F02	1.000	1.000	1.000	CRS	**F32**	1.000	1.000	1.000	CRS
F03	1.000	1.000	1.000	CRS	**F33**	1.000	1.000	1.000	CRS
F04	0.888	1.000	0.888	IRS	**F34**	0.991	1.000	0.991	IRS
F05	1.000	1.000	1.000	CRS	**F35**	0.992	0.995	0.997	IRS
F06	0.960	0.988	0.972	IRS	**F36**	1.000	1.000	1.000	CRS
F07	0.920	1.000	0.920	IRS	**F37**	0.987	1.000	0.987	DRS
F08	0.968	0.971	0.997	DRS	**F38**	0.977	1.000	0.977	DRS
F09	0.854	1.000	0.854	IRS	**F39**	1.000	1.000	1.000	CRS
F10	0.814	1.000	0.814	IRS	**F40**	1.000	1.000	1.000	CRS
F11	0.886	0.916	0.968	DRS	**F41**	1.000	1.000	1.000	CRS
F12	0.990	0.998	0.992	DRS	**F42**	1.000	1.000	1.000	CRS
F13	0.993	0.995	0.998	IRS	**F43**	0.962	0.980	0.982	DRS
F14	0.836	0.922	0.907	DRS	**F44**	1.000	1.000	1.000	CRS
F15	1.000	1.000	1.000	CRS	**F45**	1.000	1.000	1.000	CRS
F16	1.000	1.000	1.000	CRS	**F46**	0.951	0.965	0.986	DRS
F17	1.000	1.000	1.000	CRS	**F47**	1.000	1.000	1.000	CRS
F18	0.891	1.000	0.891	DRS	**F48**	1.000	1.000	1.000	CRS
F19	1.000	1.000	1.000	CRS	**F49**	1.000	1.000	1.000	CRS
F20	1.000	1.000	1.000	CRS	**F50**	1.000	1.000	1.000	CRS
F21	1.000	1.000	1.000	CRS	**F51**	1.000	1.000	1.000	CRS
F22	0.900	0.904	0.995	DRS	**F52**	1.000	1.000	1.000	CRS
F23	0.977	0.979	0.998	DRS	**F53**	1.000	1.000	1.000	CRS
F24	1.000	1.000	1.000	CRS	**F54**	1.000	1.000	1.000	CRS
F25	0.982	1.000	0.982	DRS					
F26	1.000	1.000	1.000	CRS					
F27	1.000	1.000	1.000	CRS					
F28	1.000	1.000	1.000	CRS					
F29	1.000	1.000	1.000	CRS					
F30	1.000	1.000	1.000	CRS					

EFFECT OF TOTAL SOLID CONCENTRATION OF FAECAL MATTER ON BIOGAS PRODUCTION AND PATHOGENS REDUCTION

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ABSTRACT

The objective of this research was to determine the effect of total solid (TS) concentration on biogas production and pathogens (faecal coliform and Salmonella spp.) reduction in an effective mesophilic anaerobic digestion (MAD) process. A MAD process was carried out in the laboratory for 33 days. The results showed that the process was able to reduce high percentage of pathogens. Faecal coliform reduced from 2.5×10^7, 3.7×10^7 and 5.0×10^7 cfu/g TS to 4.3×10^4, 8.3×10^3 and 3.4×10^3 cfu/g TS at TS concentration of 4%, 6% and 8% respectively, and Salmonella spp. reduced from 2.6×10^6, 3.8×10^6 and 5.1×10^6 MPN/g TS, to 1.4×10^3, 1.7×10^3 and 3.7×10^3 MPN/g TS, at TS concentration of 4%, 6% and 8% respectively. The cumulative biogas produced were 9,900 mL, 10,160 mL and 10,130 mL, at 4%, 6% and 8% TS respectively. The methane content averagely stabilized within the range of 70% - 75% at the stable operation phase.

Keywords: *faecal matter, total solid, pathogen reduction, biogas production*

INTRODUCTION

The untreated and indiscriminate discharge of faecal matter into rivers, lakes and ground water contamination in developing and some parts of developed countries have posed great challenges to the environment and health risk (Montangero and Strauss, 2004). Globally, lack of potable drinking water and basic sanitation kills a child at every 20s, i.e. 1.6 million children under the age of 5 years die annually (WHO and UNICEF, 2006).

Recently, initiatives towards faecal matter management (anaerobic digestion inclusive) and constructive applications have been greatly improved and developed, particularly in some West African countries, South East Asia and Latin America (WHO and UNICEF, 2006). Anaerobic digestion is one of the best processes for sewage sludge stabilization (Lu *et al.,* 2008). In comparison with other methods of waste treatment, such as land filling, incineration and composting, it has some advantages of reducing the amount of waste produced and generating biogas, which is a renewable energy source (Taleghani and Kia, 2005). Biogas technology has been observed recently as a very good source of sustainable waste treatment / management (Balat and Balat, 2009). The effluent of this process is a residue rich in essential inorganic elements needed for healthy plant growth known as bio-fertilizer, which when applied to the soil enriches it with no detrimental effects on the environment (Dinuccio *et al.,* 2010).

Several literatures have been sighted to see how anaerobic digestion could be an efficient solution to this menace. But little information was gathered about the level of reduction of pathogens in mesophilic anaerobic digestion of faecal sludge at different TS concentrations. The objective of this study was to propose the effectiveness of the MAD process in reducing *faecal coliform*, *Salmonella spp.* and energy recovery. Besides, this study comprehensively evaluated the impact of total solid (TS) of faecal matter on the process stability. The influence of different conditions were evaluated in terms of biogas production, organic matter degradation, gas production per unit volatile solids (VS) digested, methane concentration in biogas, and the process stability.

MATERIALS AND METHODS

Faecal Matter

The raw faecal matter used as substrate was obtained from a septic tank in the University of Science and Technology, Beijing (USTB), China. In order to reduce the influence of temperature, the pre-thickened sludge was put into a water bath for preheating (37±1) ºC before digestion. The characteristics of raw materials are presented in Table 1 in the results.

Analytical methods

Some parameters were measured in order to study the pathogens reduction and process stability. The multiple-tube fermentation technique was used for the testing of *faecal coliform* and *salmonella spp.* Total solids (TS) and volatile solids (VS) concentrations were determined according to the APHA standard methods (Greenberg *et al.,* 1992). The pH was measured using a pH meter (HI 9125N). Total alkalinity (TA) and volatile fatty acids (VFA) were measured by chemical titration. Total organic carbon (TOC) was analyzed by potassium dichromate volumetric method. Total nitrogen (TN) was analyzed by Kjeldahl method (Novozamsky *et al.,* 1983). Biogas production was determined by water displacement method. And the methane content was obtained by the biogas analyzer (Geotech-Biogas check). All assays were performed in triplicates.

Experimental setup

Experimental setup shown in Fig. 1 consists of 1L jars as digesters and 1L graduated cylinders as biogas collectors. The digesters were kept in a controlled thermostat water bath with a constant temperature of (37±1)ºC to maintain constant mesophilic reaction, and the reactors were manually shaken once in a day to get the materials fully mixed. Biogas generated in the digesters was led by a rubber pipe into graduated cylinders, which pressed the same volume of water out of the graduated cylinders into the water tank. The biogas production yields were monitored at 10:00 am on daily basis and the methane gas content analyses were done at the interval of two days.

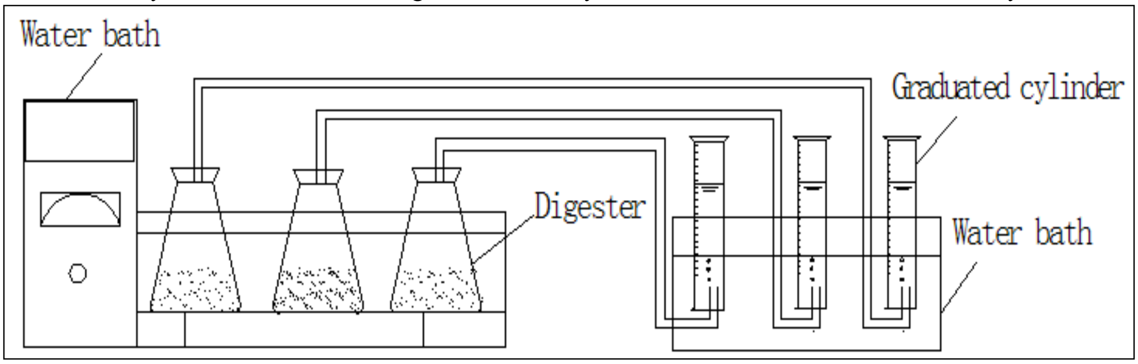

Fig. 1 The experimental setup of 1 liter jar digestion

Data Analysis

The experiment was conducted for 33 days. The effect of TS concentrations on reduction of *Faecal coliform* and *Salmonella spp.*, biogas production, and process stability were studied and determined. The experimental results were subjected to Analysis of Variance (ANOVA) for single factor experiment to determine the significant differences using Microsoft Excel 2010 for windows XP.

Table 2 Uniform design and experimental data

NO.	1	2	3
TS/%	4.0	6.0	8.0
Sludge/g	500	500	500
Inoculum/ml	0	0	0
Water/ml	586.25	224.17	43.13

RESULTS AND DISCUSSION

3.1 Table 1. Initial characterization of raw faecal matter used

Analytical parameters	Raw sludge
TN/TS	0.023
TOC/TS	0.55
C/N	23.9
TS	8.69%
VS	85.7%
pH	6.8-7.1
TOM/TS	85.72
Faecal coliform (cfu/g TS)	5.43×10^{7}
Salmonella spp. (MPN/g TS)	5.54×10^{6}

TN: Total Nitrogen; **TOC:** Total Organic Carbon; **TOM:** Total Organic Matter

Faecal *coliform and Salmonella spp.* removal

Pathogenic microorganisms were analyzed at several operational stages of the process as shown in Fig.2 below. The highest *faecal coliform* removal was detected in the stabilization phase of the MAD process, which was operated at the last day. At the same time, the final concentrations of *faecal coliform* in the 3 reactors were 4.3×10^4, 8.3×10^3 and 3.4×10^3 cfu/g TS, respectively, lower than African Class B limit (1.0×10^6) (LeBlanc *et al.,* 2008). Statistical analysis of the experiment showed that there was a significant difference ($p\leq0.05$) in raw "*faecal coliform*" (2.5×10^7, 3.7×10^7 and 5.0×10^7 cfu/g TS, respectively) and the final concentrations. This could be attributed to processing activities and the retention period in the digesters. Similar results were reported by Forster-Carneiro *et al*. (2010) and Chen *et al*.(2012), who obtained *faecal coliform* densities of 10^5 cfu/g TS in mesophilic batch reactor of sewage sludge. The reduction of *faecal coliform* of 4%, 6% and 8% were 2.76, 3.65 and 4.17 log unit respectively at MAD. The results showed that TS has a significant effect on the *faecal coliform* reduction.

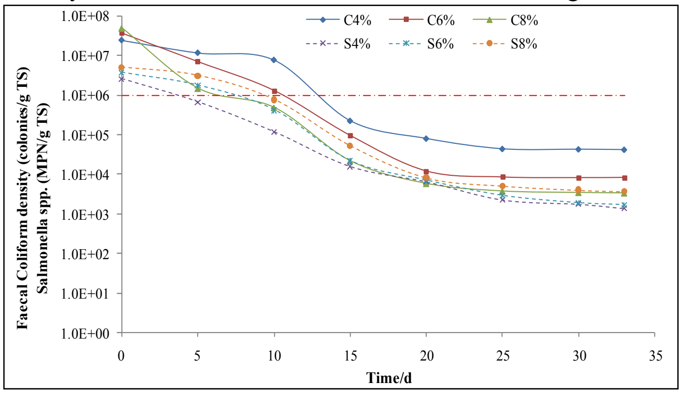

Fig. 2. Variation of the *Faecal coliform* and *Salmonella spp.* with the digestion time

The effect of MAD on reduction of number of colonies of *Salmonella spp.* in the faecal matter samples are shown in Fig. 2. Raw samples at 4%, 6% and 8% were 2.6×10^6, 3.8×10^6 and 5.1×10^6 MPN/g TS, respectively, which were significantly higher ($p\leq0.05$) than those foun Time (days) of the digester. The highest percentage of *Salmonella spp.* (MPN/g TS) removal also occurre ion phase of the process. At the end of the experiment, the final concentration of *Salmonella spp.* were 1.4×10^3, 1.7×10^3 and 3.7×10^3 MPN/g TS, and the reduction of *Salmonella spp.* of 4%, 6% and 8% were 3.27, 3.35 and 3.14 log unit, respectively, indicating that *Salmonella spp.* reduction was achieved by MAD. This reduction of *Salmonella spp.* may be probably due to the reduction of metabolic activities and the retention period. The result obtained was in conformity with Chen *et al.* (2012), who observed a drastic removal of *Samonella spp.* and E.coli at 35ºC for sewage sludge anaerobic digestion.

Biogas Production and Methane Content

It was observed that the biogas yield was very similar in the 3 reactors as depicted in Fig. 3. The cumulative biogas production in reactor 4%, 6%, and 8% were 9,900mL, 10,160mL and 10,130mL respectively. With the increase of the concentration of sludge (TS), the organic load rate increased and the cumulative biogas output was gradually increased till the digestion was completed. This is in line with Lee *et al.* (2011), who observed increase in cumulative biogas as solid retention time increased. In the first 20 days, the amount of cumulative biogas produced could reach more than 90% of total biogas production. This might be as a result of more CO_2 being dissolved in the digester as there was increase in the retention period.

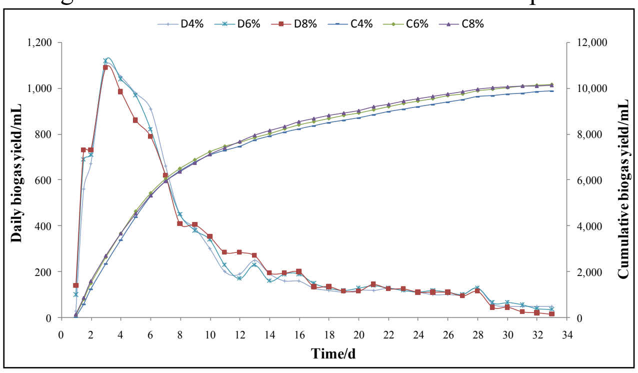

Fig. 3. The effect of TS on the cumulative biogas yield

At the beginning of the daily gas production (Fig. 3), an obvious wave-like increase of biogas was first noticed and this later decreased. In the third day, biogas production increased due to exponential growth of microorganisms. Each reactor reached biogas pro Time (days) the methane content was lower than normal

(40% - 50%). This may probably be due to the fact that the faecal matter that was obtained from the septic tank, had initially undergone biodegradation, so the microorganisms had adapted to anaerobic environment.

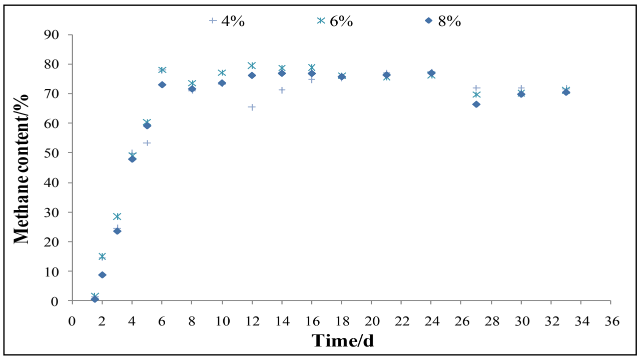

Fig. 4. The effect of TS on the methane content

The activity of methanogenic bacteria gradually increased, and prompted the methane content to also increase. After the 6th day, till the last day of the exp ane content was averagely reached 73%, 75% and74% for 4%, 6% and 8% of TS respectively Time (days) . 4. Subsequently, the gas production continuously decreased, due to the easily degradable or was consumed by anaerobic microorganisms.

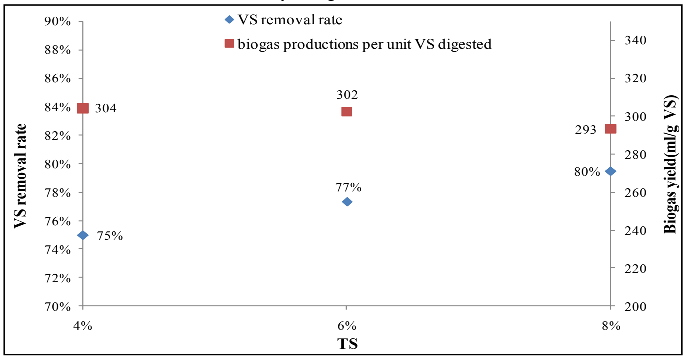

Fig. 5. VS removal rate and biogas productions per unit VS digested evolution

The biogas productions per unit VS digested of 4%, 6% and 8% were 304 mL/g, 302 mL/g and 293mL/g, respectively, as shown in (Fig. 5). As the faecal matter concentration increased, the biogas production per unit VS digested decreased, at 75% - 80% rate of TS removed. Under mesophilic conditions, the methane bacteria in the faecal matter strengthened its activity and improved the affinity to the organic matter (Kim *et al.,* 2004), so the biogas production per unit VS digested was high. It's observed that one of the advantages of the fecal matter is that, it requires a short time for MAD, and the biogas production has high methane content.

Process Stability

pH plays an important role in the growth of microbes during anaerobic digestion. It should be kept within neutrality range because of sensitivity of microorganisms. The amount of carbon dioxide and volatile fatty acids produced during the anaerobic process affects the pH of the digester contents (Raposo *et al.,* 2006). Therefore, the digestion process may be inhibited by excessive acidity.

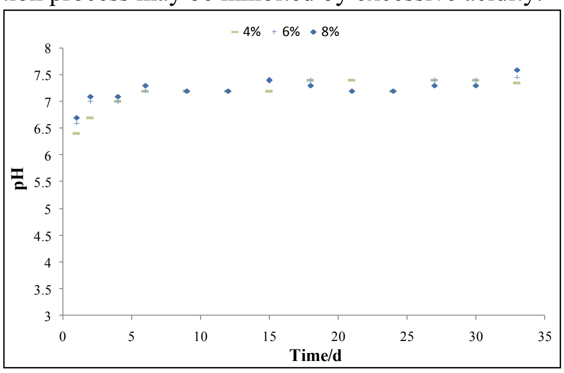

Fig. 6. The variation of pH with digestion time

Time (days)

The pH value was at low level at the initial stage of the process as shown in Fig. 6; this was due to the balance of organic matter decomposition and volatile fatty acids formation, as a result of the effect of the accumulation of VFA and basicity factors of fermented liquid itself (Forster-Carneiro *et al.,* 2010). Soon after, an increase in pH to 7.1 was observed for three days. As the alkalinity increased and methanogenic bacteria digested VFA, pH gradually increased. Throughout the entire process of digestion, the pH of the system was in the range of 6.3 to 7.6, and there was no serious acidification or alkalization phenomenon which was not suitable for the survival of anaerobic bacteria. These observations were in line with (Parawira *et al.,* 2006).
However, only pH cannot be a yardstick for evaluating the stability of the process, as was pointed out by Raposo *et al.,* (2006). Therefore, the VFA and TA were tested to further evaluate the stability of the process.

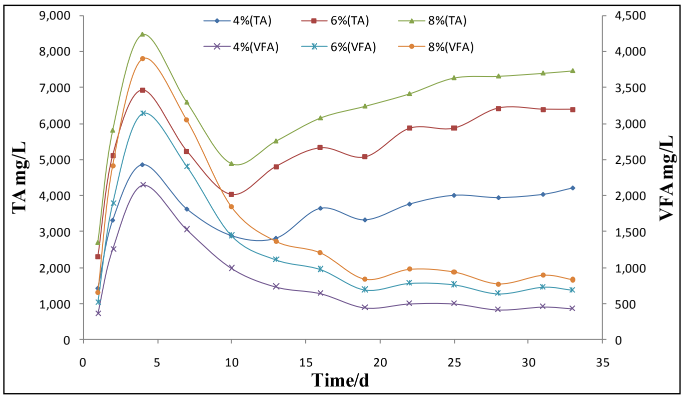

Fig. 7. The variations of VFA and TA with digestion time

The increase in VFA's up to 2,141 mg/L, 3,136 mg/L and 3,897 mg/L in first four days at different TS of 4%, 6% and 8% respectively, was observed in Fig. 7. T Time (days) tion phase corresponded to the hydrolysis-acidogenesis phase. The decrease in VFA after th due to VFA consumption by bacteria at the acetogenesis phase, leading to increase in pH. About 33 days of anaerobic digestion, most of the VFA had been degraded. Therefore, the VFA concentration within the whole system gradually stabilized, reduced to a low level of about 429 mg/L, 687 mg/L and 836 mg/L at 4%, 6% and 8% of TS respectively.
Curve of alkalinity change with time in this experiment was shown in Fig. 7, at the beginning of the anaerobic digestion, the alkalinity of the different TS group of 4%, 6% and 8% increased to 4,854 mg/L, 6,927 mg/L and 8,473 mg/L, respectively. It is very helpful to avoid accumulation of acid at the initial stage of the anaerobic digestion. With the anaerobic digestion process, the peak of the accumulation of VFA gradually decreased, which led to the reduction of the alkalinity (Bolzonella *et al.,* 2005). At the later stage of the anaerobic digestion, most of the easily degradable organic matter in the sludge had already been consumed; lack of nutrients led to microbial death, the nitrogen in the microbial cells was released, resulting in a high amount of ammonium salt, thereby increasing the TA of the 4%, 6% and 8% digesters to about 4,208 mg/L, 6,393 mg/L and 7,466 mg/L respectively.

CONCLUSIONS

Biogas from faecal matter has been proved to be an affordable and a sustainable form of energy, and thus improves sanitation. From the experimental results and analysis, it could be deduced that total solid concentrations have a significant difference ($p \leq 0.05$) on biogas production and pathogens (*faecal coliform* and *Salmonella spp.*) reduction, which was operated at (37±1) ºC for 33 days.
This study showed that operating MAD at 6% TS has the highest cumulative biogas yield and methane yield at 10,160mL and 75% respectively. Conclusively, putting into consideration, the shortening of anaerobic digestion cycle, costs saving, effective reduction of pathogens, and increasing economic benefits; choosing TS within the range of 6% and 8% is more desirable for fecal matter under MAD.

ACKNOWLEDGMENTS

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Management of Cattle and Poultry Waste through Anaerobic Digestion to Reduce Its Environmental Nuisance Value

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ABSTRACT
This study was conducted to examine the effectiveness of anaerobic digestion (AD) in managing wastes from cattle and poultry birds. Experiments were conducted in continuous flow Chinese-type digesters for 25 days. The mixing ratios of water to cattle and poultry slurry were 1:1 and 3:1 respectively. Three hundred (300) grams of cattle and poultry waste were obtained before and during experimentation, and were taken to the laboratory for analysis. The results obtained show the percentage reduction of the following parameters during experimentation. For cattle waste, the percentage reductions were 82.4%H_2S, 89.2% NH_4^+, 72.1% total phenol, 83.2 % total amine, 41.1% COD, 38.6% BOD, 86.7% total coliform, 92.7% E.coli. Also for Poultry waste, the percentage reductions were 85.7%H_2S, 78.1%NH_4^+, 63.8% total phenol, 80.6% total amine, 25.9% COD, 25.2% BOD, 90.3% total coliform, 90.5% E.coli.. It's concluded that anaerobic digestion was successfully used in reducing the studied parameters to the minimum level after 25 days of bio-digestion.
Keywords: *anaerobic digestion, cattle waste, poultry waste, digester, loading rate*

INTRODUCTION

Cattle wastes are often poorly managed and sometimes dumped indiscriminately, thus causing environmental and public health hazards such as odour nuisance and land pollution in the environment. Besides, disposal of the wastes is a serious problem because un-decomposed waste causes health and environment impacts including aesthetic nuisance, organic pollution, uncontrolled methane emission, and various water-borne diseases (Jimoh, 2005).

Cattle waste that is found in large quantities in farms where cows are confined, along the grazing parts and in abattoirs where it constitutes the main waste generated, in addition to waste waters, etc (Kjeldsen, *et al*, 2002; Abdulkareem, 2005; Okonko, 2012).

This potential for environmental pollution is gaining importance in Nigeria as the country's livestock industry expands (Ojolo *et al.,* 2007). Federal Ministry of Agriculture and Natural Resources, FMANR (1997) estimated the population of Nigeria's cattle, sheep, goat, pigs and poultry to be 18, 33.2, 53.8, 8.3 and 97.3 millions, respectively. These livestocks generate huge quantities of wastes daily, which constitute a threat of polluting the environment, unless they are managed and treated in an environmentally safe and economically useful manner.

The main odourants in livestock wastes include ammonia, hydrogen sulphide, amines, and phenols among others (Curtis, 1993). There has been considerable interest in recent years in slurry treatment technologies, and in particular anaerobic digestion (Adelekan and Bamgboye, 2009).

Anaerobic digestion is the degradation of organic waste in the presence of anaerobic microorganisms (Chen, 2008). Edward *et al*., (2012) also reported that anaerobic digestion process enables us to do away with organic wastes whose accumulation in the environment would otherwise lead to numerous health related problems.
The purpose of this study was to examine the use of anaerobic digestion to manage cattle and poultry wastes, using AD in treating both wastes in order to reduce their environmental impacts.

MATERIALS AND METHODS

Raw Materials Collection and Equipment

Sources and collection of manure

Freshly voided poultry and cattle wastes were collected from livestock farms at the Teaching and Research Farm, of the University of Ibadan, Ibadan, Nigeria. Four thousand (4000) litres continuous flow Chinese-type anaerobic digesters were used in this experiment.

Experimental Set-up

Prior to loading into the digester, leaves, waste feed, sticks, stones and other foreign materials were carefully hand-picked from the waste, which was then properly stirred to break the lumps into finer particles.

The ratios of water mixing with slurry were 1:1 and 3:1 by mass for cattle and poultry waste respectively, i.e. 700kg of cattle wastes were measured and mixed with 700L of water in a mixing tank; and it was stirred thoroughly for about 25 minutes to homogenize the mixture prior to loading into the digester, so as to ensure sufficient dispersal of the waste particles. Also, 2100 kg of poultry waste was measured and mixed with 700 L of water in a mixing tank, and the same procedure was used to load the waste into the digester.

The two experiments were subjected to a retention period of 25 days each, and exposed to ambient temperatures, which ranges from 20-39°C.The contents of the digester were vigorously shaken twice daily in the morning at 10:00am and 6:00pm in the evening throughout the retention period. The loading of the digesters was done with a loading corresponding to 35% of the size of the digester. Three replicates were used for each experiment.

Measurement Procedure

The same parameters were determined according to American Public Health Association (APHA) Standard Methods (2005) from the effluents of the digested waste after 5 days, 10 days, 15 days, 20 days and 25 days for the two experiments.

Undigested samples were taken to the laboratory for analysis using standard laboratory procedures according to American Public Health Association (APHA) Standard Methods (2005). The parameters analyzed were hydrogen sulphide (H_2S), Ammonium nitrogen (NH_4^+), Phenols, Amines, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Coliform count and Escherichia coli (E. *coli*).

The pH value was measured using a digital pH meter (Seven Multi SK40, Switzerland).

The results obtained were analyzed using Microsoft excel package to determine the percent reduction of the parameters.

RESULTS AND DISCUSSION

The figures below show percentage reductions in odour parameters of fresh and digested cattle and poultry wastes.

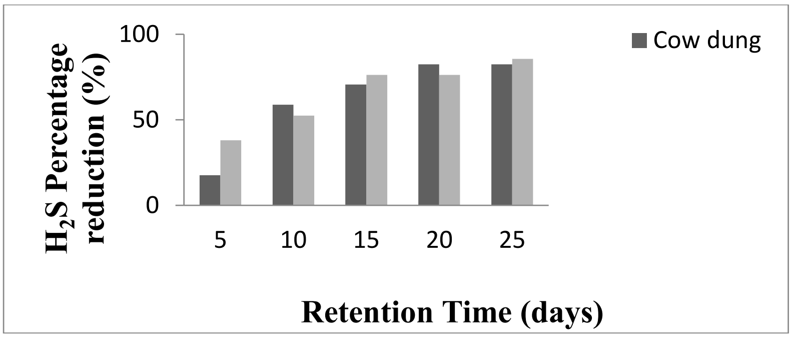

Figure 1: Percentage Reduction in H_2S with Retention Period

Fig. 1, depicts the percentage reduction of H_2S for both cattle and poultry waste during the retention period.

The above Figure 1 reveals that H_2S attained 82.4% and 85.7% reduction for both cattle and poultry waste at 25 day retention time respectively.

This significant reduction in H_2S was probably due to the fact that the sulphate is reduced to sulphide by sulphate reducing bacteria such as desulfobacterales and corrosionpedia among others. Higher reduction of H_2S indicated a good reduction in odour intensity. Besides, its unpleasant smell and corrosive nature could reduce the lifespan of pipework and other different installations in biogas industry. According to the observation made by Charlier *et al.*, (2007), who reported that formation of gaseous sulphur-containing compounds such as hydrogen sulphide may cause unpleasant odour due to predomination of anaerobic conditions.

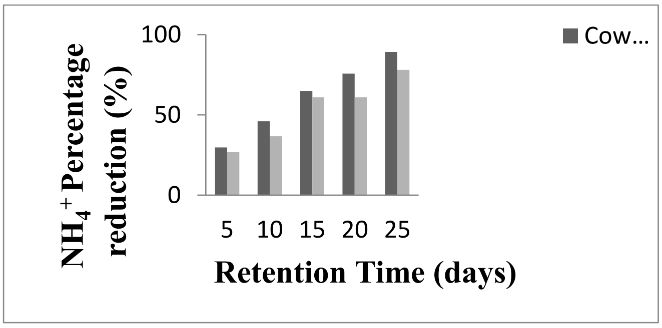

Figure 2: Percentage Reduction in $NH4^{+}$ with Retention Period

Fig. 2, shows the percentage reduction of $NH4^{+}$ for both cattle and poultry waste within the 25 days retention period. It was observed from Figure 2, that the percentage reduction of $NH4^{+}$ within the 25 days retention period is 89.2% and 78.1% respectively. The percentage reduction in ammonia-nitrogen for both wastes occurred due to the fact that the increase in the specific activity of methanogenic bacteria was found to be responsible for decreasing concentrations of ammonia-nitrogen (Chen *et al*., 2008). Therefore, high concentration of ammonia nitrogen should be avoided because it is toxic to anaerobes, which will decrease the efficiency of the digestion and upset the process.

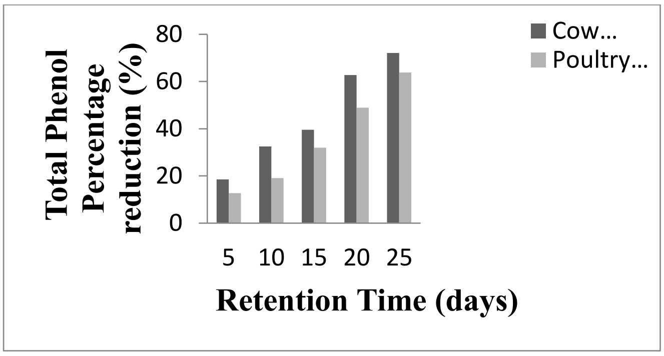

Figure 3: Percentage Reduction in Total phenol with Retention Period

The percentages of reduction of total phenols were 72.1% and 63.8% for cattle and poultry waste respectively (fig. 3). This reduction is very close to 75% final percentage reductions reported by Semih and Selek (2012), during anaerobic digestion process of phenols in the up-flow digester, and 45% reduction of phenol in fixed-bed digester. The percentage reduction observed in this experiment may be due to the nature of the substrates. However, a very good reduction in concentration of phenols was observed by other researchers (Karlsson *et al.,* 1999; Fang *et al*., 2006).

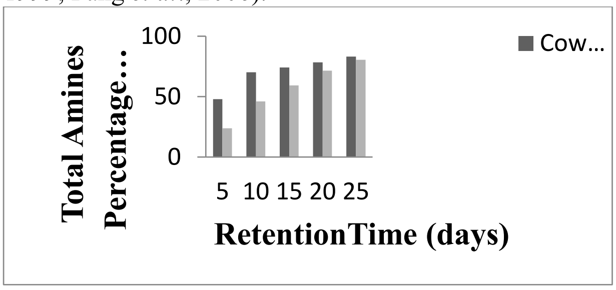

Figure 4: Percentage Reduction in Total amine with Retention Period

From fig 4, the research showed percentage reduction of 83.2% and 80.6% for total amines within 25 days retention period for cattle and poultry waste respectively. This reduction is probably attributed to the nature of the substrates.
Therefore, the observed percentage reduction of H_2S, NH_4^{+}, total phenols and total amines in anaerobic treatment indicates a significant reduction in odour associated with undigested cattle and poultry waste.

Pollutants Removal during Anaerobic Digestion Treatment
The percentage reduction of pollutants: biological oxygen demand (BOD), chemical oxygen demand (COD), total coliforms and E. *coli* during anaerobic digestion of cattle and poultry wastes for a 25 day retention time are shown in figures 5, 6, 7, and 8 respectively.

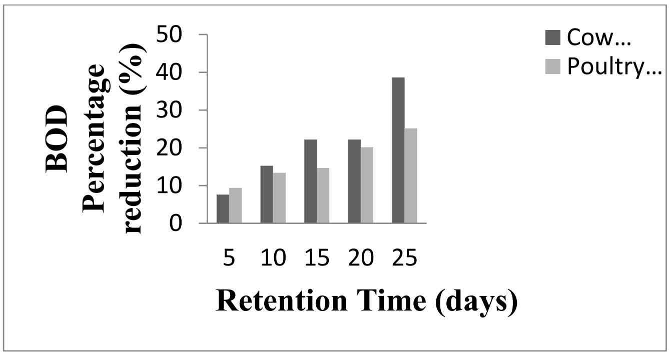

Figure 5: Percentage Reduction in BOD with Retention Period

Figure 5 above, shows percentage BOD removal of 38.6% and 25.2% for cattle and poultry wastes respectively. This shows a slight variation in the percentage reduction of the two waste. This finding is supported by earlier work done by Morris (1976), who reported 37.6% BOD reduction at a hydraulic retention period of 30 days in a bench-scale anaerobic digester.

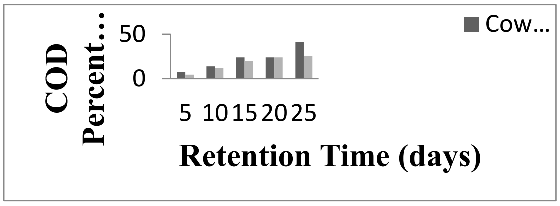

Figure 6: Percentage Reduction in COD with Retention Period

As shown in fig. 6 above, the COD percentage removal were 41.1% and 25.9% for cattle and poultry waste respectively. However, this percent reduction is very close to 45% COD removal reported by by Semih and Selek, (2012) in an anaerobic reactor. Furthermore, Baba and Nasir (2012) also reported 48.5% COD removal in anaerobic digestion of cattle waste for biogas production.

From Figure-6, it can be seen that the COD removal efficiency were 41.1% and 25.9%, which is comparatively lower than the commonly obtained COD removal from cattle manure (51-79%) (Castrillon, *et al*., 2002).

The amount of BOD and COD was found to be reduced by 38.6%, 25.2% and 41.1%, 25.9% for 25 days retention period at mesophilic temperature respectively.This reduction in BOD and COD in the digestates could be traced to the biodegradation of the organic matter in the substrate due to the activities of mesophilic microorganisms and the high initial C/N ratio of the feedstock (Yun, *et al*., 2000).

Also, Zeeman, *et al*. (1988) stated that the reduction in COD and BOD in anaerobic digestion may be due to the consumption of fermenting and methanogenic bacteria. The reduction in BOD and COD in the digested cattle and poultry waste will thereby improve the environmental condition and this reduction increases throughout the retention period.

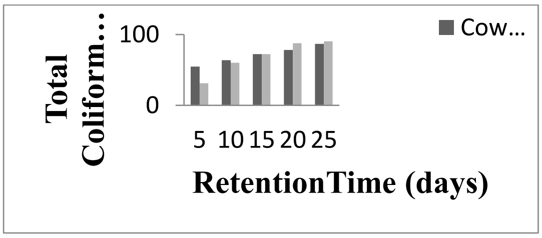

Figure7: Percentage Reduction in Total coliform with Retention Period

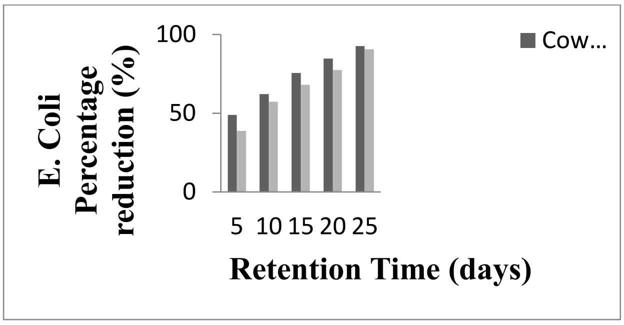

Figure 8: Percentage Reduction in E.*coli* with Retention Period

It could be deduced from figure 7 and 8, that the total coliform and Escherichia coli were reduced from (54.6% - 86.7%), (31.3% - 90.3%) and (48.9% - 92.7%), (38.7% - 90.5%) for cattle waste and poultry wastes respectively. However, it is interesting to note that significant percentage reduction was observed in total coliform and E. *coli* with maximum percentage reduction of 90.5% and 92.7% respectively (see figure 7&8). Kumar *et al*., (1999) observed a faster elimination of Escherichia coli and Salmonella at 35°C than at room temperature during anaerobic digestion of cattle slurry.

Cote *et al*. (2006) reported that indicator micro-organisms (E. *coli* and coliforms) were both reduced in anaerobic digestion of swine manure slurry at 20°C for 20 days in an intermittently fed sequence batch reactor by 97.94 – 100% and 99.67 – 100%. However, the percent reduction observed in this study may be due to the nature of the substrate, retention time and operating temperature are decisive factors for indicator organisms and pathogens survival during anaerobic digestion of effluents. There is a very good reduction in the total coliform counts (90.3%) and E. coli (92.7%) implying lesser contamination can take place with the use of the effluent.

It appears that under the conditions of this experiment, retention time of 25 days at mesophilic temperature range was sufficient to ensure a stabilization of the liquid cattle and poultry manure.

CONCLUSIONS

Cattle and poultry wastes normally constitute refuse in the areas where they are dumped and on the farm where the animals are reared thereby creating environmental pollution and health hazards.

Therefore, this study has shown that anaerobic digestion has a great potential of managing cattle and poultry wastes by reducing odour nuisance value and reduction of pathogenic organisms.

ACKNOWLEDGMENTS

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Management of Cattle and Poultry Waste through Anaerobic Digestion to Reduce Its Environmental Nuisance Value

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ABSTRACT
This study was conducted to examine the effectiveness of anaerobic digestion (AD) in managing wastes from cattle and poultry birds. Experiments were conducted in continuous flow Chinese-type digesters for 25 days. The mixing ratios of water to cattle and poultry slurry were 1:1 and 3:1 respectively. Three hundred (300) grams of cattle and poultry waste were obtained before and during experimentation, and were taken to the laboratory for analysis. The results obtained show the percentage reduction of the following parameters during experimentation. For cattle waste, the percentage reductions were 82.4%H_2S, 89.2% NH_4^+, 72.1% total phenol, 83.2 % total amine, 41.1% COD, 38.6% BOD, 86.7% total coliform, 92.7% E.coli. Also for Poultry waste, the percentage reductions were 85.7%H_2S, 78.1%NH_4^+, 63.8% total phenol, 80.6% total amine, 25.9% COD, 25.2% BOD, 90.3% total coliform, 90.5% E.coli.. It's concluded that anaerobic digestion was successfully used in reducing the studied parameters to the minimum level after 25 days of bio-digestion.
Keywords: *anaerobic digestion, cattle waste, poultry waste, digester, loading rate*

INTRODUCTION

Cattle wastes are often poorly managed and sometimes dumped indiscriminately, thus causing environmental and public health hazards such as odour nuisance and land pollution in the environment. Besides, disposal of the wastes is a serious problem because un-decomposed waste causes health and environment impacts including aesthetic nuisance, organic pollution, uncontrolled methane emission, and various water-borne diseases (Jimoh, 2005).

Cattle waste that is found in large quantities in farms where cows are confined, along the grazing parts and in abattoirs where it constitutes the main waste generated, in addition to waste waters, etc (Kjeldsen, *et al*, 2002; Abdulkareem, 2005; Okonko, 2012).

This potential for environmental pollution is gaining importance in Nigeria as the country's livestock industry expands (Ojolo *et al.,* 2007). Federal Ministry of Agriculture and Natural Resources, FMANR (1997) estimated the population of Nigeria's cattle, sheep, goat, pigs and poultry to be 18, 33.2, 53.8, 8.3 and 97.3 millions, respectively. These livestocks generate huge quantities of wastes daily, which constitute a threat of polluting the environment, unless they are managed and treated in an environmentally safe and economically useful manner.

The main odourants in livestock wastes include ammonia, hydrogen sulphide, amines, and phenols among others (Curtis, 1993). There has been considerable interest in recent years in slurry treatment technologies, and in particular anaerobic digestion (Adelekan and Bamgboye, 2009).

Anaerobic digestion is the degradation of organic waste in the presence of anaerobic microorganisms (Chen, 2008). Edward *et al*., (2012) also reported that anaerobic digestion process enables us to do away with organic wastes whose accumulation in the environment would otherwise lead to numerous health related problems.
The purpose of this study was to examine the use of anaerobic digestion to manage cattle and poultry wastes, using AD in treating both wastes in order to reduce their environmental impacts.

MATERIALS AND METHODS

Raw Materials Collection and Equipment

Sources and collection of manure

Freshly voided poultry and cattle wastes were collected from livestock farms at the Teaching and Research Farm, of the University of Ibadan, Ibadan, Nigeria. Four thousand (4000) litres continuous flow Chinese-type anaerobic digesters were used in this experiment.

Experimental Set-up

Prior to loading into the digester, leaves, waste feed, sticks, stones and other foreign materials were carefully hand-picked from the waste, which was then properly stirred to break the lumps into finer particles.

The ratios of water mixing with slurry were 1:1 and 3:1 by mass for cattle and poultry waste respectively, i.e. 700kg of cattle wastes were measured and mixed with 700L of water in a mixing tank; and it was stirred thoroughly for about 25 minutes to homogenize the mixture prior to loading into the digester, so as to ensure sufficient dispersal of the waste particles. Also, 2100 kg of poultry waste was measured and mixed with 700 L of water in a mixing tank, and the same procedure was used to load the waste into the digester.

The two experiments were subjected to a retention period of 25 days each, and exposed to ambient temperatures, which ranges from 20-39°C.The contents of the digester were vigorously shaken twice daily in the morning at 10:00am and 6:00pm in the evening throughout the retention period. The loading of the digesters was done with a loading corresponding to 35% of the size of the digester. Three replicates were used for each experiment.

Measurement Procedure

The same parameters were determined according to American Public Health Association (APHA) Standard Methods (2005) from the effluents of the digested waste after 5 days, 10 days, 15 days, 20 days and 25 days for the two experiments.

Undigested samples were taken to the laboratory for analysis using standard laboratory procedures according to American Public Health Association (APHA) Standard Methods (2005). The parameters analyzed were hydrogen sulphide (H_2S), Ammonium nitrogen (NH_4^+), Phenols, Amines, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Coliform count and Escherichia coli (E. *coli*).

The pH value was measured using a digital pH meter (Seven Multi SK40, Switzerland).

The results obtained were analyzed using Microsoft excel package to determine the percent reduction of the parameters.

RESULTS AND DISCUSSION

The figures below show percentage reductions in odour parameters of fresh and digested cattle and poultry wastes.

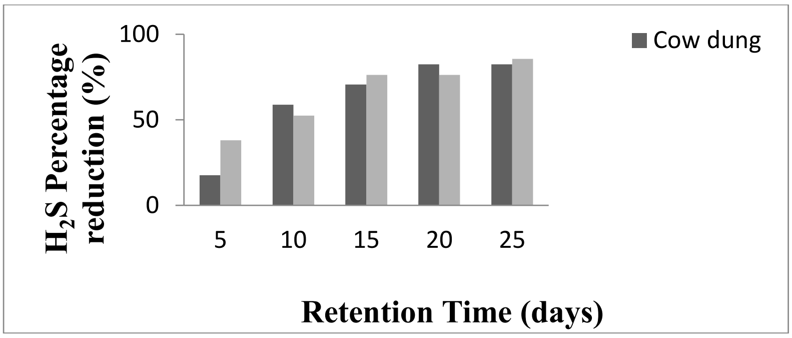

Figure 1: Percentage Reduction in H_2S with Retention Period

Fig. 1, depicts the percentage reduction of H_2S for both cattle and poultry waste during the retention period. The above Figure 1 reveals that H_2S attained 82.4% and 85.7% reduction for both cattle and poultry waste at 25 day retention time respectively.

This significant reduction in H_2S was probably due to the fact that the sulphate is reduced to sulphide by sulphate reducing bacteria such as desulfobacterales and corrosionpedia among others. Higher reduction of H_2S indicated a good reduction in odour intensity. Besides, its unpleasant smell and corrosive nature could reduce the lifespan of pipework and other different installations in biogas industry. According to the observation made by Charlier *et al.*, (2007), who reported that formation of gaseous sulphur-containing compounds such as hydrogen sulphide may cause unpleasant odour due to predomination of anaerobic conditions.

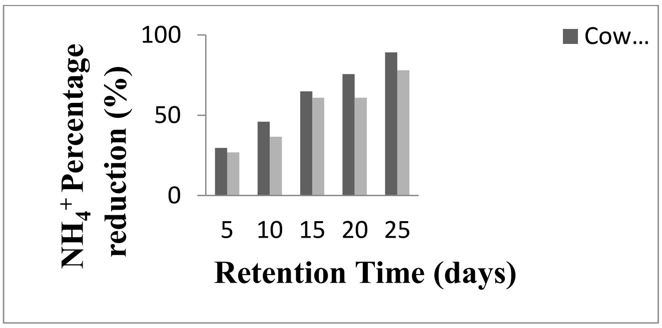

Figure 2: Percentage Reduction in $NH4^+$ with Retention Period

Fig. 2, shows the percentage reduction of $NH4^+$ for both cattle and poultry waste within the 25 days retention period. It was observed from Figure 2, that the percentage reduction of $NH4^+$ within the 25 days retention period is 89.2% and 78.1% respectively. The percentage reduction in ammonia-nitrogen for both wastes occurred due to the fact that the increase in the specific activity of methanogenic bacteria was found to be responsible for decreasing concentrations of ammonia-nitrogen (Chen *et al*., 2008). Therefore, high concentration of ammonia nitrogen should be avoided because it is toxic to anaerobes, which will decrease the efficiency of the digestion and upset the process.

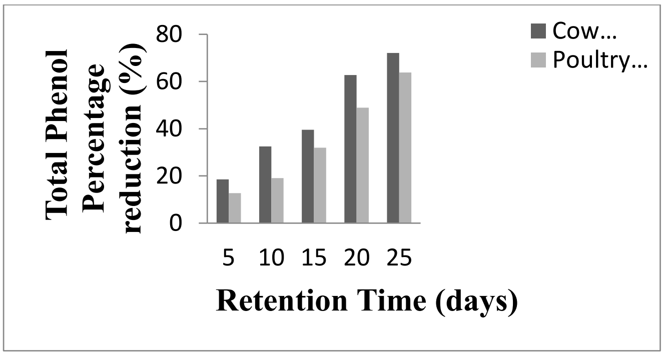

Figure 3: Percentage Reduction in Total phenol with Retention Period

The percentages of reduction of total phenols were 72.1% and 63.8% for cattle and poultry waste respectively (fig. 3). This reduction is very close to 75% final percentage reductions reported by Semih and Selek (2012), during anaerobic digestion process of phenols in the up-flow digester, and 45% reduction of phenol in fixed-bed digester. The percentage reduction observed in this experiment may be due to the nature of the substrates. However, a very good reduction in concentration of phenols was observed by other researchers (Karlsson *et al.,* 1999; Fang *et al*., 2006).

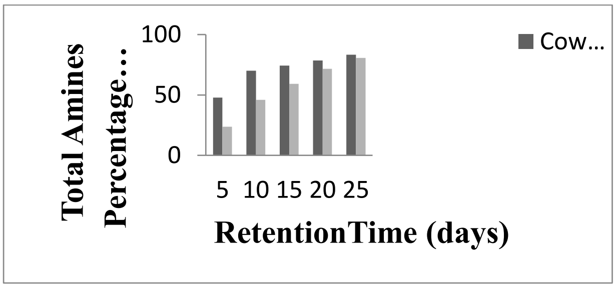

Figure 4: Percentage Reduction in Total amine with Retention Period

From fig 4, the research showed percentage reduction of 83.2% and 80.6% for total amines within 25 days retention period for cattle and poultry waste respectively. This reduction is probably attributed to the nature of the substrates.

Therefore, the observed percentage reduction of H_2S, NH_4^+, total phenols and total amines in anaerobic treatment indicates a significant reduction in odour associated with undigested cattle and poultry waste.

Pollutants Removal during Anaerobic Digestion Treatment

The percentage reduction of pollutants: biological oxygen demand (BOD), chemical oxygen demand (COD), total coliforms and E. *coli* during anaerobic digestion of cattle and poultry wastes for a 25 day retention time are shown in figures 5, 6, 7, and 8 respectively.

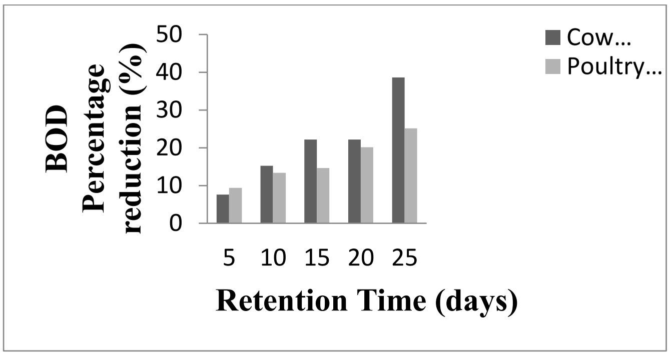

Figure 5: Percentage Reduction in BOD with Retention Period

Figure 5 above, shows percentage BOD removal of 38.6% and 25.2% for cattle and poultry wastes respectively. This shows a slight variation in the percentage reduction of the two waste. This finding is supported by earlier work done by Morris (1976), who reported 37.6% BOD reduction at a hydraulic retention period of 30 days in a bench-scale anaerobic digester.

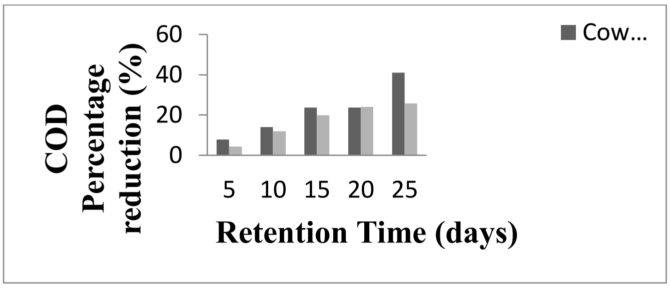

Figure 6: Percentage Reduction in COD with Retention Period

As shown in fig. 6 above, the COD percentage removal were 41.1% and 25.9% for cattle and poultry waste respectively. However, this percent reduction is very close to 45% COD removal reported by by Semih and Selek, (2012) in an anaerobic reactor. Furthermore, Baba and Nasir (2012) also reported 48.5% COD removal in anaerobic digestion of cattle waste for biogas production.

From Figure-6, it can be seen that the COD removal efficiency were 41.1% and 25.9%, which is comparatively lower than the commonly obtained COD removal from cattle manure (51-79%) (Castrillon, *et al*., 2002).

The amount of BOD and COD was found to be reduced by 38.6%, 25.2% and 41.1%, 25.9% for 25 days retention period at mesophilic temperature respectively.This reduction in BOD and COD in the digestates could be traced to the biodegradation of the organic matter in the substrate due to the activities of mesophilic microorganisms and the high initial C/N ratio of the feedstock (Yun, *et al*., 2000).

Also, Zeeman, *et al*. (1988) stated that the reduction in COD and BOD in anaerobic digestion may be due to the consumption of fermenting and methanogenic bacteria. The reduction in BOD and COD in the digested cattle and poultry waste will thereby improve the environmental condition and this reduction increases throughout the retention period.

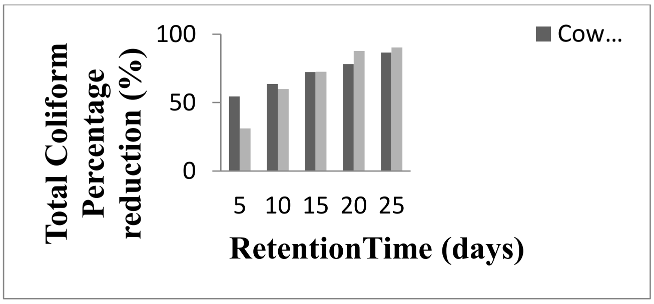

Figure7: Percentage Reduction in Total coliform with Retention Period

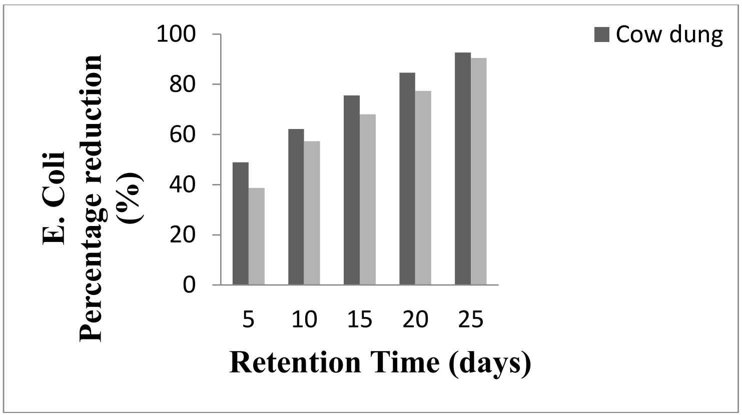

Figure 8: Percentage Reduction in E.*coli* with Retention Period

It could be deduced from figure 7 and 8, that the total coliform and Escherichia coli were reduced from (54.6% - 86.7%), (31.3% - 90.3%) and (48.9% - 92.7%), (38.7% - 90.5%) for cattle waste and poultry wastes respectively. However, it is interesting to note that significant percentage reduction was observed in total coliform and E. *coli* with maximum percentage reduction of 90.5% and 92.7% respectively (see figure 7&8). Kumar *et al*., (1999) observed a faster elimination of Escherichia coli and Salmonella at 35°C than at room temperature during anaerobic digestion of cattle slurry.

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ANTHROPOMETRIC DATA COMPARISON BETWEEN BENUE AGRICULTURAL WORKERS AND OTHER ETHNIC POPULATIONS

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ABSTRACT

An anthropometric study of a sample population of four hundred and seventy (470) Benue agricultural workers of Nigeria comprising of 235 males and females each, were investigated. Thirty (30) anthropometric parameters were studied; thirteen (13) measurements were taken in standing position (including body weight) while seventeen (17) measurements were taken in seated position. This was used to develop a database for the user group. A traditional anthropometer and a digital weighing machine incorporated with a standiometer was used for taking lateral, body weight and height measurements respectively. Results from this study were compared with those of South-East Nigerian, Indian, Indonesian, Filipinos, Chinese, Japanese, Brazilian, Turkish and USA populations. Differences were observed in most of the parameters compared. The differences in anthropometric data between the Benue population and those from other countries underscore the usefulness of this study in the context of designing and introducing agricultural tools, equipment and machinery into the State.

***Keywords*:** Agricultural tools, Anthropometric, Benue, Data, Ethnic population

INTRODUCTION

Benue State derives its name from River Benue, the second largest River in Nigeria. The State is located in the middle Belt region of Nigeria, approximately between latitudes 6½° and 8½° N and longitude 7½° and 10° E. The State has a total land area of about 36,023 square kilometers and administratively it is divided into 23 Local Government Areas (BNSG, 2002). Benue State has a total land area of 310 million hectares, and agricultural land is estimated to be about 180 million hectares representing about 58% of the total land area (BMANR, 2003). Agricultural workers are significantly involved in various agricultural activities where they use different types of farm tools, machinery and equipment. These farm machinery and equipment are oftentimes imported and are not comfortable for use which have a negative impact on the user and consequently results in low farm output. This is as a result of differences in body anthropometry between countries developing these farm machinery and the end users like Nigeria.

Anthropometry involves the systematic study and measurement of the physical properties of the human body, mass and strength properties. The use of anthropometry and ergonomics in design systems has reduced human error in system performance, minimized hazards to individuals in the work environment, reduced adverse health effects and improved system efficiency (Anema *et al*., 2004). Sen *et al.* (1977) reported that anthropometric dimensions of unorganized workers, including agricultural workers, were similar to those of industrial workers.

Research has shown that there are anthropometric differences between different populations in almost every dimension of the human body (Liu *et al*., 1999; Lin *et al*., 2004; Agrawal *et al*., 2010; Onuoha *et al*., 2012; Onuoha *et al*., 2013; Khadem and Islam, 2014; Sadeghi *et al*., 2014, Syuiab, 2015). Ethnic diversity is always a significant factor that may affect the anthropometric data and the scope of its applications. Dixit and Namgial (2012) in their study established that there is a considerable difference between the anthropometric data of Indian and Western population emphasizing the need for generating anthropometric database for agricultural workers in India. Yadav (2012) found that anthropometric measurements of other states of India could not be applied in north-east India and recommended an anthropometric survey of the entire region. In a comparison of Nigerian Farm workers with those of USA, Korea and India carried out by Onuoha *et al.,* (2013), the authors concluded that most of the dimensions determined were smaller for both male and female farm workers than their foreign counterparts. This study is therefore aimed at comparing the anthropometric data of Benue agricultural workers and workers from different ethnic populations of the world. The usefulness of this study is to provide information in the design and introduction of agricultural tools, equipment and machinery into the State.

MATERIALS AND METHODS

Benue State known as the 'food basket of the nation' is located in central Nigeria and has 23 Local Government Areas. Anthropometric dimensions of four hundred and seventy (470) Benue agricultural workers comprising of 235 males and females each were taken. Thirty (30) anthropometric body dimensions considered useful for farm equipment/machinery design were studied. Thirteen measurements were taken in a standing position (including body mass) and 17 measurements were taken in a seated position. A digital weighing machine incorporated with standio-meter was used for the body weight and vertical measurements respectively. Lateral measurements were taken using an anthropometer, while the foot and hand dimensions were determined using a measuring tape. Literature materials containing the anthropometric dimensions of South-East Nigeria, Indonesia, India, Filipin, Japan, China, Brazil, Turkey, Britain and USA were reviewed and used for the anthropometric data comparison with Benue Agricultural workers.

RESULTS AND DISCUSSIONS

The anthropometric dimensions measured for Benue agricultural workers are presented in Table 1. The comparison of Benue workers with different ethnic populations (from reviewed literatures) are presented in Tables 2 and 3. Bar charts (Figures 1-6) were drawn to depict the results.

Comparison between Benue Male and female Agricultural Workers

Table 1 show that female agricultural workers are smaller than their male counterparts in all body dimensions except body weight, hand breadth, hip breadth and chest (bust) depth. Onuoha *et al*., (2012) reported that female South- Eastern Nigerian agricultural workers are smaller than their male counterparts in all body dimensions except waist circumference, hand breadth and hip breadth. Khan (2014) reported no significant difference in parameters such as sitting height, sitting eye height, forward grip reach, shoulder breadth, hip breadth, elbow span and foot breadth for Bangladeshis living in three different areas. Khanal *et. al*., (2015) observed no significant difference in grip diameter, foot breadth and Buttock popliteal length for Eastern Region of Nepal.

Table 1: Anthropometric Data for Benue Male and Female Agricultural Workers Respectively

S/N	Anthropometric Measures	Min.	Max.	Mean	Percentile		Min.	Max.	Mean	Percentile	
				(50th)	5th	95th			(50th)	5th	95th
1	Body weight[1]	55.60	87.50	69.65	52.94	86.36	56.40	87.50	72.41	60.83	83.99
2	Stature	146.30	179.60	163.30	154.19	172.41	138.50	173.50	154.46	143.73	165.19
3	Eye height	137.00	169.70	152.89	141.80	163.98	120.60	158.50	140.00	129.36	150.64
4	Shoulder height	121.10	153.80	137.06	125.94	148.18	111.10	146.20	127.04	116.61	137.47
5	Elbow height	85.60	118.00	101.51	90.37	112.65	79.70	114.70	95.62	85.09	106.15
6	Waist height	81.40	114.10	97.29	86.22	108.36	75.30	110.00	91.04	80.46	101.62
7	Knuckle height	53.90	85.50	69.85	58.78	80.92	51.30	86.40	67.22	56.56	77.88
8	Fingertip height	43.20	75.00	59.04	47.90	70.18	41.00	76.50	57.29	47.21	67.37
9	Arm span	152.50	185.60	168.75	157.66	179.84	140.70	175.40	156.89	146.46	167.32
10	Elbow span	71.00	102.80	87.70	76.69	98.71	65.00	97.80	81.51	71.06	91.96
11	Vertical grip reach	179.40	212.80	195.22	184.07	206.37	167.50	197.80	183.39	173.08	193.70
12	Forward grip reach	54.00	86.70	70.06	58.99	81.13	50.30	85.50	66.48	55.71	77.25
13	Forward fingertip reach	65.00	98.50	81.74	70.64	92.84	63.00	94.20	77.27	67.02	87.52
14	sitting height	69.10	100.00	85.04	74.10	95.98	54.50	85.60	72.39	61.58	83.20
15	Sitting eye height	57.50	90.40	73.62	62.61	84.63	56.00	77.30	65.74	57.10	74.38
16	Sitting shoulder height	40.90	73.40	56.68	45.66	67.70	39.90	63.50	51.29	42.79	59.79

17	Sitting elbow height	16.60	39.50	22.69	11.88	33.50	11.90	32.60	20.72	14.65	26.79
18	Knee height	35.50	69.60	52.65	41.48	63.82	32.30	67.30	48.26	37.53	58.99
19	Buttock-knee length	41.40	74.10	57.27	46.22	68.32	45.40	59.00	52.68	47.02	58.33
20	Buttock popliteal length	31.80	64.50	47.73	36.82	58.64	35.10	53.80	44.83	38.13	51.53
21	Chest(bust) depth	12.30	28.80	20.78	16.21	25.35	18.00	31.50	23.99	19.30	28.68
22	Shoulder breadth	26.80	59.50	42.71	31.66	53.76	34.60	47.60	41.09	36.23	45.94
23	Hip breadth	15.70	46.30	30.08	19.12	41.04	24.90	52.00	39.73	29.98	49.48
24	Upper- arm length	16.10	48.70	32.04	20.92	43.16	24.00	37.50	30.63	26.45	34.81
25	Fore-arm hand length	31.20	64.00	47.20	36.01	58.39	33.00	51.80	42.92	36.24	49.60
26	Hand length	12.30	37.50	19.04	8.02	30.06	14.20	23.50	17.48	14.52	20.44
27	Hand breadth	4.50	9.60	7.44	5.73	9.15	5.10	14.40	8.36	5.43	11.29
28	Grip diameter(internal)	3.20	5.30	4.16	3.49	4.83	0.80	8.70	4.06	1.13	6.99
29	Foot length	16.50	34.70	24.00	17.39	30.61	16.80	23.70	20.27	17.57	22.97
30	Foot breadth	9.70	24.20	13.81	7.28	20.34	6.00	13.80	9.51	6.68	12.34

Body weight is in Kilograms, while all other parameters are in centimeters

Table 2: Comparison of Male Anthropometric Data of Present Study with Other Ethnic Population of the World

DIMENSIONS	BEN	SE(NIG)	INDO	INDIA	FILI	JAPAN	CHN	BRA	TUR	BRIT	USA
Body weight	69.65	57.7	57.1	53.7	NA	66	67	66	77	75	77.8
Stature	163.30	163.4	162	162.5	167	168.8	170.5	170	170.8	174	175.5
Eye height	152.89	153.1	151.2	151	155	157.7	NA	159.5	160.5	163	170.9
Shoulder height	137.06	138.4	135.8	134.5	137.5	137	139.6	141	141.6	142.5	144
Elbow height	101.51	101.2	101.2	102.5	104.1	103.5	105.9	104.5	107.6	109	110.5
Waist height	97.29	68.2	95	98.9	97.3	NA	NA	NA	NA	NA	NA
Knuckle height	69.85	NA	70.2	68.5	72.5	74.	75.7	72	74.6	75.5	76.5
Fingertip height	59.04	NA	59.8	58.5	NA	64.4	65.9	62.5	64.2	65.5	66
Arm span	168.75	NA	168.9	170.5	167.9	169	173.8	175.5	172.7	179	181.1
Elbow span	87.70	NA	85.9	88	NA	87.5	89.4	92.5	92.7	94.5	95.5
Vertical grip reach	195.22	NA	195.1	199.5	193.4	194	200.2	202	217.5	206	208
Forward grip reach	70.06	72.8	69.9	72.5	NA	69	71	76.5	75.1	78	78.5
Sitting height	85.04	83.7	82.9	84	84.8	91	91	88	89.2	91	91.4
Sitting eye height	73.62	74.6	71.4	74	73.4	79	79.1	77.5	78.5	79	80
Sitting shoulder height	56.68	54.2	56.4	55.5	NA	59.1	60.2	59.5	60.6	59.5	59.9
Sitting elbow height	22.69	NA	21.8	20.5	22.2	25.4	26.4	23	23.4	24.5	24.4
Knee length	52.65	52.80	52.10	51.00	50.00	50.90	52.10	53.00	51.50	54.50	55.10
Buttock-knee length	57.27	58	55.3	55.5	54.8	56.7	55.8	59.5	NA	59.5	59.9
Buttock popliteal length	47.73	48.2	46.8	46.5	46.4	47	NA	48	NA	49.5	50
Chest(bust) depth	20.78	NA	20	20.5	NA	21.7	21.7	23.5	22.4	25	25.4

Shoulder breadth	42.71	43.1	41.9	41	44.7	44	46	44.5	47.5	46.5	47
Hip breadth	30.08	29	30.1	31	35.6	34.9	36	34	33.3	36	36.1
Upper-arm length	32.04	NA	31.8	35.5	NA	33.7	33.8	36.5	35.7	36.5	36.6
Forearm hand length	47.20	48.4	45.6	46	44.1	44.8	42.7	47.5	46.6	47.5	48
Hand length	19.04	18.6	18.3	18.5	NA	NA	18.3	18.5	18.9	19	19.1
Hand breadth	7.44	8.2	8.3	8.5	NA	8.5	8.6	8.5	8.7	8.5	8.9
Grip diameter(inside)	4.16	4.3	4.3	4	NA	NA	NA	NA	NA	NA	NA
Foot length	24.00	24.9	24.2	25	NA	25.1	NA	26	26.1	26.5	26.4
Foot breadth	13.81	NA	10.1	9.5	NA	10.4	NA	10	10.4	9.5	9.9

BEN= Benue Present study (2016); **SE (NIG) =South East Nigeria** by Onuoha *et al*., (2012); **INDO=Indonesia** by Syuaib (2015); **India** by Agrawal *et al*., (2010); **FILI=Filipin** by Prado-Lu (2007); **Japan**, **BRA**=**Brazil** and **BRIT**= **Britain** by MacLeod (2000); CHN=**China** and **TUR=Turkey** by Marras and Kawowski (2006); NA=Not Available.

Table 3: Comparison of Female Anthropometric Data of Present Study with Other Ethnic Population of the World

DIMENSIONS	BEN	SE(NIG)	INDO	INDIA	FILI	JAPAN	CHN	TUR	BRIT	USA
Body weight	72.41	51.3	52.3	48	NA	54	52.1	65	63	64.9
Stature	154.46	156.8	152.5	153.2	153.9	158.4	157.2	159.8	161	162.6
Eye height	140.00	147.2	139.4	141.8	143.1	142.5	NA	149.2	150.5	152.4
Shoulder height	127.04	129.1	125	127.1	127.2	127.9	128.5	130.7	131	132.6
Elbow height	95.62	98.4	94.9	96.2	96.3	96.7	97.8	100.3	100.5	102.1
waist height	91.04	NA	91.9	94.1	95.5	NA	NA	NA	NA	NA
Knuckle height	67.22	65.5	65.1	66.4	67.8	70.5	70.8	72.4	72	72.9
Fingertip height	57.29	NA	56.3	NA	NA	60.8	61.8	62.8	62.5	63
Arm span	156.89	NA	156.3	153.1	153.2	157.9	157.1	159.3	160.5	162.6
Elbow span	81.51	NA	78.2	78.4	NA	78	NA	84.2	85	86.1
Vertical grip reach	183.39	NA	180	184.4	190.2	179.5	183.1	188.1	190.5	192.5
Forward grip reach	66.48	67.7	66.7	66.6	NA	62	65.1	69.5	70.5	71.1
Sitting height	72.39	74.8	77.4	80.3	79.9	85.5	84.6	84.8	85	86.1
Sitting eye height	65.74	66.3	66.6	68.7	68.4	73.3	73.2	73.7	74	74.9
Sitting shoulder height	51.29	48.1	50.6	54.6	NA	55.1	56.1	55.8	55.5	56.4
Sitting elbow height	20.72	NA	20.5	23.4	21.9	23.6	25.2	23.2	23.5	23.6
Knee length	48.26	46.8	49	45.3	47	47.5	47.2	49.4	50	50.5
Buttock-knee length	52.68	51	52.7	50.5	52.7	55	53	NA	57	57.4
Buttock popliteal length	44.83	43.2	45.1	38.2	45.1	45	NA	NA	48	49
Chest(bust) depth	23.99	NA	21.7	20.3	NA	21.5	21.3	25.9	25	25.4
Shoulder breadth	41.09	41.7	40.5	36.5	40.2	39.5	40.6	36.6	39.5	39.9
Hip breadth	39.73	29.6	29.9	31.1	36.4	35.8	35.3	30.8	37	37.6
Upper-arm length	30.63	NA	30.8	NA	NA	31.5	30.9	27.3	33	33.5
Forearm hand length	42.92	42.3	43.8	40.7	40.5	41.6	38.4	42.7	43	43.4
Hand length	17.48	17.4	17.3	16.5	NA	16.5	16.7	16.7	17.5	17.5
Hand breadth	8.36	8.4	7.6	6.5	NA	7.5	7.5	7.5	7.5	7.6
Grip diameter(inside)	4.06	3.6	3.8	4.3	NA	NA	NA	NA	NA	NA

Foot length	20.27	21.4	22.3	22.7	NA	NA	NA	23.2	23.5	23.9
Foot breadth	9.51	NA	9.7	8.9	NA	NA	NA	8.8	9	8.9

BEN= Benue Present study (2016); **SE (NIG) =South East Nigeria** by Onuoha *et al*., (2012); **INDO=Indonesia** by Syuaib (2015); **India** by Agrawal *et al*., (2010); **FILI=Filipin** by Prado-Lu (2007); **Japan** and **BRIT= Britain** by MacLeod (2000); **CHN=China** and **TUR=Turkey** by Marras and Kawowski (2006); NA=Not Available.

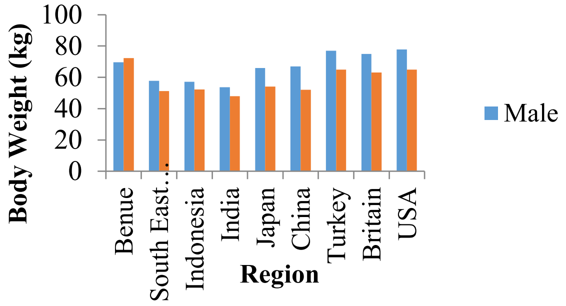

Figure 1: Comparison of Body Weight between Benue Population and Other Countries

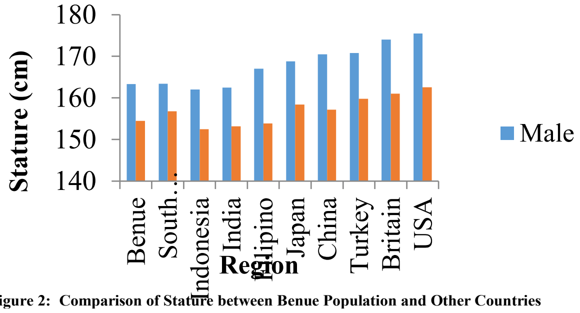

Figure 2: Comparison of Stature between Benue Population and Other Countries

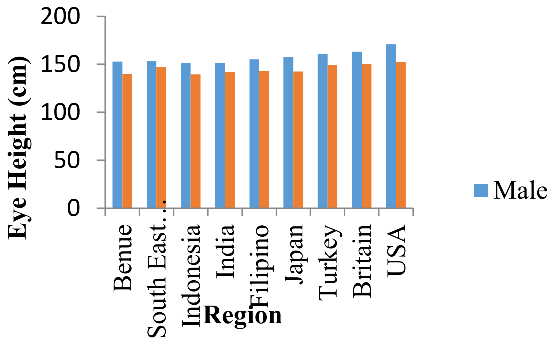

Figure 3: Comparison of Eye Height between Benue Population and Other Countries

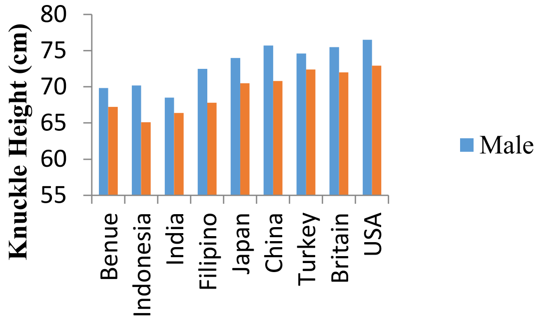

Fig. 4: Comparison of Knuckle Height between Benue Population and other Countries

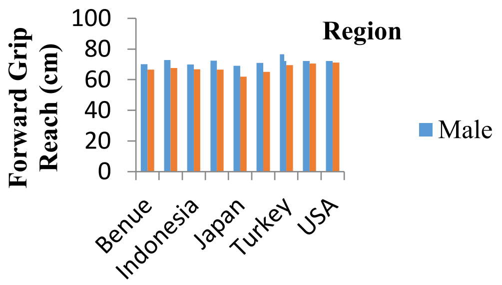

Fig. 5: Comparison of Forward Grip Reach between Benue Population and other Countries

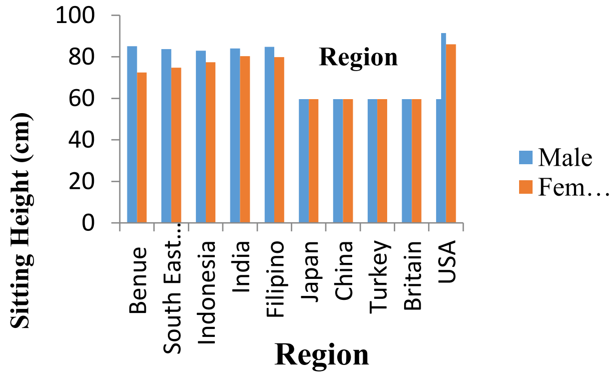

Figure 6: Comparison of Sitting Height between Benue P

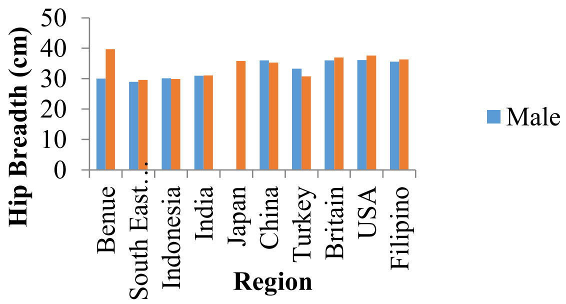

Fig. 7: Comparison of Hip Breadth between Benue Population and Other Countries

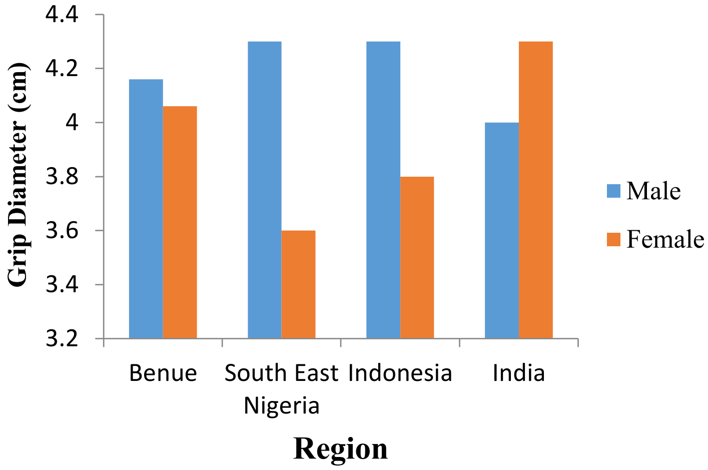

Fig.8: Comparison of Grip Diameter between Benue Population and other Countries

This result reveals that the mean body dimensions of Benue male and female agricultural workers are different and that the body dimensions of the males are comparatively larger than those of the females in most body dimensions. The difference in values suggests that the design parameters for both males and females on the affected dimensions must be different in order not to exceed data range obtained for each gender.

Comparison between Benue Male Farmers and other Ethnic Populations

Figure 1 compares the body weight in the present study with male population of different countries from literature. The Benue male population with a mean weight of 69.65kg weighs more than the South–Eastern Nigerian (57.7kg), Indonesian (57.1kg), Indian (53.7kg), Japanese (66kg), and Chinese (67kg). However, their weight is smaller than that of the Turkish (77kg), British (75kg) and American (77.8kg) male populations. Figure 2 show that the Benue male population's stature (163.3cm) is shorter than all ethnic populations, except Indonesian (162cm) and Indian (162.5cm) populations. Similarly, for eye height (Figure 3), for Benue male population of 152.89cm was found to be shorter than all ethnic populations except the Indonesian (151.2cm) and Indian (151cm) populations. Benue male population have shoulder height of 137.06 cm (Table 2) which is higher than that of Indonesian (135.8 cm), Indian (134.5 cm), and Japanese (137 cm) but lower than South-Eastern Nigerian (138.4 cm), Filipino (137.5 cm), Chinese (139.6 cm), Brazilian (141 cm), Turkish (141.6 cm), Briton (142.5 cm) and American (144 cm). The elbow height for Benue male was almost the same with other ethnic populations studies (Table 2). Knuckle height (69.85cm) of the Benue male was found to be smaller than all countries studied except the Indian population (68.5cm) as shown in Figure 4. Vertical grip reach (195.22 cm) for Benue male population was less than other countries except Indonesia, Filipino and Japan.

Figure 5 shows that Indonesian and Japanese are the only population with a forward grip reach of 69.9cm and 69 cm respectively lower than that of the Benue population of 70.06 cm. Benue farmers showed a sitting height (85.04cm) that is greater than the South–Eastern Nigerian (83.7cm), Indonesian (82.9cm), Indian (84cm), Filipino (84.8cm) but lower than the Japanese (91cm), Chinese (91cm), Brazilian (88cm), Turkish (89.2cm), British (91cm), and American (91.4cm) populations (Figure 6). Sitting eye height of the Benue male (73.62 cm) is less than other countries except Indonesia (71.4 cm) and Filipino (73.4 cm). The knee length (52.65 cm) was less than other countries except for Indonesia (52.10 cm), India (51 cm), Filipino (50 cm), Japan (50.9 cm), china (5.1 cm) and Turkey (51.5 cm). The shoulder breadth for the benue male is only greater than Indonesia and India. For hip breadth (30.08cm), it is observed that of Benue population is greater than that of their South-Eastern Nigerian (29 cm) counterpart. However, it is observed to be lower than the rest of the populations studied (Figure 7). The grip diameter of 4.16cm was observed to be lower than the South-Eastern Nigerian (4.30cm) and Indonesian (4.30cm) populations but greater than that of the Indian (4.00cm) population (Figure 8). For foot length and foot breadth the Benue male (24 cm) is greater than all other countries compared with.

Comparison between Benue Female Farmers and other Ethnic Populations

Figure 1 shows a comparison between the body weights of Benue female population with that of other female ethnic population. Results show the body weight of Benue female population (72.4 kg) is greater than all the countries compared with. The Benue female with a stature (standing height) of 154.46 cm was found to be taller than the Indonesian (152.5 cm), Indian (153.2 cm), and Filipino (153.9 cm) populations but shorter than their Turkish (159.8 cm), British (161 cm), and American (162.6 cm) counterparts (Figure 2). Their eye height (140

cm) and shoulder height (127.04 cm) are shorter than all the populations studied except that of the Indonesian (139.4 cm and 125cm respectively) population (Figure 3).
The knuckle height of the Benue female (67.22 cm) is lower than that of all populations except Indonesian (65.1 cm), Indian (66.4 cm), and South-Eastern Nigerian (65.5 cm) populations as can be seen in Figure 4. Their arm span (156.89 cm) is smaller than other countries except Indonesia (156.3 cm), India (9153.1 cm) and Filipino (153.2 cm). The forward grip reach of Benue female (66.4 cm) population is less than that of other nations except Japan (62 cm) and China (65.1 cm) (Figure 5). The sitting height (72.39 cm) of the Benue female population is lower than all countries compared with (Figure 6), while the sitting shoulder height (65.74 cm) is lower than other countries except South-Eastern Nigeria and Indonesia. The hip breadth (39.73) of the Benue female population is greater than that of all the other nations studied while their grip diameter (4.06 cm) is lower than that of Indians but higher than those of the Indonesian and South-Eastern Nigerian populations (Figures 7 and 8). Their foot length of 20.27 cm is less than other countries.

CONCLUSION

The survey reveals that the mean body dimensions of Benue male and female are different and that the body dimensions of the male are comparatively larger than those of the females in most body dimensions. The difference in values suggests that the design parameters for both males and females on the affected dimensions must be different in order not to exceed data range obtained for each gender. Variations in anthropometric dimensions among different ethnic populations of the world were discovered to be quite marked, which is in line with the studies by Yadav *et al* (1996); Agrawal *et al* (2010); Onuoha *et al*. (2012) and Syuaib (2015). The differences in anthropometric dimensions between the Benue population and population groups from other countries emphasize the usefulness of this study in the context of designing and introducing agricultural tools, equipment and machinery into the State.

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THE USE OF GEOGRAPHICAL/GLOBAL POSITIONING SYSTEM (GPS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN EVALUATING TILLAGE PARAMETERS

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ABSTRACT `
In this paper, Geographical Positioning System (GPS) and Geographical Information System (GIS) are used in assessing some tillage parameters such as; soil moisture content, depth of work, speed of work, penetration resistance, pull force, pull power, wheel slip and fuel consumption. The current analogue method used in the data collection of tillage research can be said to be limiting and cumbersome in many ways. In this research, the GIS equipment such as Nomad/Trimble GPS receiver, Eijkelkamp penetrologger and the tractor work stand were used. Apart from the ability of collecting fast and large quantity of data for analysis, this system enables the identification of spatial soil variability on the farm which allows soil variable treatments. Nomad/Trimble GPS receiver was used to mark out the experimental plot, Eijkelkamp penetrologger equipped with GPS receiver was used to take the soil penetration resistance and soil moisture content along with TDR Multimeter (Time-Domain Reflectometry (TDR)) while the tractor mobile stand was used for the tillage and the recording of data. The results show that portion of plots with low soil moisture content corresponded largely to the portion of high soil resistance, high power requirement and high fuel consumption. Portions of plots with high moisture content were characterised with higher wheel slip.
keywords: Geographical Positioning System (GPS), Geographical Information System (GIS), Penetrologger, Precision Agriculture, Site Specific Farming

INTRODUCTION

The uses of Geographical Positioning System and Geographical Information System in farming operations known as precision agriculture or site specific farming have over the past two decades become more popular. The popularity of this new farming technology stern out of the fact that it has been found to cut down farming operation cost thereby making farming more profitable Shitu *et al.*, (2015). Fulton *et al*, (1996) stated that the analysis of site-specific tillage reveals the potential use of this management technique to save farmers money by only tilling those areas where dry density and cone index problems exist. Shitu *et al.*, (2015) confirmed that over the years specific profitability of any technologies has been identified as the underlining drive for such technology adoption. Precision agriculture (PA) is one of such innovative way of farming through application of technology which has gained a reputable ground in the developed countries as well as developing ones due to its economic and environmental profitability. Batte and Arnholt, (2003) in their studies on the adoption of precision farming (PF) and its use in Ohio, USA reported that profitability was the biggest motivating factor in using precision agriculture tools. Benefits such as onfarm experimentation, improved information to support decisions, risk reduction potential, resource use efficiency, reduction in cost of production, saving inputs, precise pest and stress management, conservative farm management as well as environmental sustainability has been reported by several literature as reasons for using precision agriculture technologies (Patil and Shanwad, 2009; Yu *et al*., 2000; Bongiovanni and Lowenberg-DeBoer, 1998; Snyder, 1996). However, Aschmann et, al (2003) in being cautious reported that Precision agriculture is usually associated with sophisticated technologies that vary in price. The common technologies associated with precision farming include computer hardware and software, GPS and yield monitoring equipment, and equipment for variable rate applications. The cost for these technologies may range from several thousands of dollars to tens-of-thousands of dollars, plus $10+ per acre for an initial soil grid soil sampling with a 2.5-acre grid size. Annual fees for weather information, variable-rate application, and related services may cost as much as $12 per acre (Batte and Arnholt, 2003). The authors concluded that despite these costs, precision farming can sometimes pay off if it results in more efficient use of resources and inputs.
Anazodo *et al.* (1987) revealed that tillage operating parameters such as depth of work, speed of work, penetration resistance soil moisture content are very important to both tillage operations and crop development. These parameters to a great extent influence the forces working on both the tractor and the machine system. Culpin (1986), stated that the draught of ploughs vary according to construction of implement type and condition of the ploughed soil. Kamal and Onwualu (1996) stated that with ploughs of good design and construction, the resistance of the soil per unit area of furrow section varies from about 34kN/m^2 on light, loose, sandy soil to about

110.5kN/m^2 on hard heavy clays. Thus, a light tractor, which can easily pull three furrows on a light soil, may be unable to pull two furrows at the same speed on a heavy soil.

Kamal and Onwualu (1996) also stated that many factors have been identified as affecting draught of tractor – mounted tillage implements. These include soil factors (soil type, moisture content, bulk density, resistance to penetrometer pressure, shear strength), tool factors (type of tool/implement, tool angle, tool speed, tool depth, tool width), soil interface factors and operator performance. They also compared the draught of a disc plough at two different moisture contents on Bangkok clay. It was found that as moisture content increases specific draught decreases. Anazodo *et al.* (1987) revealed that the reduced tillage methods of disc ploughing alone over the years produced soil condition that required more draught than conventional tillage of discing and harrowing.

These tillage parameters contribute to stress of the working system as well as fuel consumption. All together they negatively influence the cost of crop production. It is therefore important to isolate areas on the farm land that could have negative impacts on the system economy and give those areas separate treatments with the aid of spatial variation mapping.

Objective

The objective of this research is to evaluate the soil spatial variability on the farm using GPS and GIS equipment as well as the effect of this variability on tillage parameters such as; penetration resistance, pulling force, pulling power, wheel slip and fuel consumption. This is to enable the farmer take decision on areas to isolate for specific treatments on the farm for economical tillage.

MATERIAL AND METHODS

The study was carried out on a two hectare of light loamy sand research plot of the Faculty of Production and Power Engineering at the University of Agriculture, Krakow-Poland. To investigate the effect of speed, depth of work, soil moisture content and penetration resistance on wheel slip, pull force, pull power and fuel consumption, four replications are chosen. The width of work for the chosen plough is 1.5m. For four replications/passes, the width of one plot will therefore be 6m. Using three (3) speeds and three (3) depths of work, nine(9) plots are obtained. Table 1 shows the experimental layout.

Table 1 Experiment layout

Depth h1= 10-12 cm	Plot 3 **Variant h1v1** Speed v1=4,5 km/h	Plot 5 **Variant h1v3** Speed v3= 7,2 km/h	Plot 8 **Variant h1v2** Speed v2=5,3 km/h
Depth h2=18-20 cm	Plot 1 **Variant h2v3** Speed v3=6,17 km/h	Plot 6 **Variant h2v2** Speed v2=5,16 km/h	Plot 9 **Variant h2v1** Speed v1=4,72 km/h
Depth h3=25-27 cm	Plot 2 **Variant h3v1** Speed v1=4,44 km/h	Plot 4 **Variant h3v2** Speed v2=5,5 km/h	Plot 7 **Variant h3v3** Speed v3=7,0 km/h

The Nomad/Trimble GPS instrument (Fig. 1) was used to map out an area of 60 X 108m out of the two hectare portion of the experimental plot. This instrument was complimented with measuring tapes. Pegs were used to demarcate this portion of land. Fig. 1 shows the marking out of the experimental plots.

Fig.1. Marking out the Experimental Plot with Nomad/Trimble GPS Receiver

The study was carried out on a light loamy soil. The initial soil parameter readings was taking using the Nomad/Trimble GPS to get information on the initial soil physical state especially the soil resistance at the current moisture content.

Measurements of Soil Moisture Contents and Soil Penetration Resistance

Five out of the nine plots were selected for random determination of moisture content and soil penetration resistance. The measurements were taken at fifteen (15) different locations at ten (10m) metres interval using both the penetrologger (fig. 2), soil auger and the TDR Soil Multimeter (fig. 3) The soil auger was used to help the TDR Soil Multimeter take the reading of the soil moisture content at three levels of the soil depth; 10cm, 20cm and 30cm. The penetrologger was programmed according to the manual and used to take soil penetration resistance to the depth of 30cm while it measured the moisture content to the depth of 5cm of the soil. Fifteen measurements points were selected for each plot of 6 X 60m.

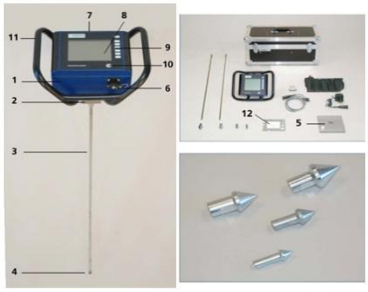


Fig.2. Penetrologger: 1-water-resistant housing 2- impact absorber, 3- bipartite probing rod 4- cone, 5-depth reference plate, 6-communication port, 7- GPS antenna, 8- LCD screen, 9- control panel, 10-level, 11- electrically insulated grips, 12- cone check

The Eijkelkamp penetrologger is available as a complete set suitable for measurements up to a depth of 80 cm. It has as a soil moisture sensor and various cones.

For moisture measurement, TDR probe was used (Fig.3)

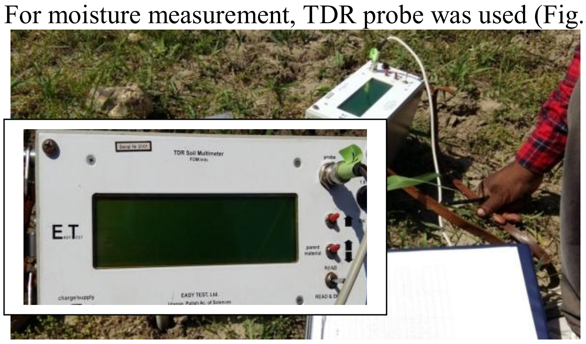


Fig.3.Soil Moisture Measurement with TDR probe Multimeter

After the experimental design and the marking out of the plots, the Mobile Stand (figs.4 and 5) for Measurement of the tillage working parameters was prepared for the measurements. This stand comprises of an industrial laptop, measuring cardIOtechDaqBook 2000A, Gretzbridge, fuel consumption meter (MPM-96), wheel sensor for measuring wheel slips, depth sensor for measuring depth of work, Speed sensor, strain gauge frame and the GPS antenna. All these were connected together on the tractor, MF 235. The preparation for the measurements involved the calibration of the strain guage, leveling of the soil engagement tool and weighing the tillage tool using a digital weighing machine. The standard method of strain gauge calibration as contained in the manual was used.

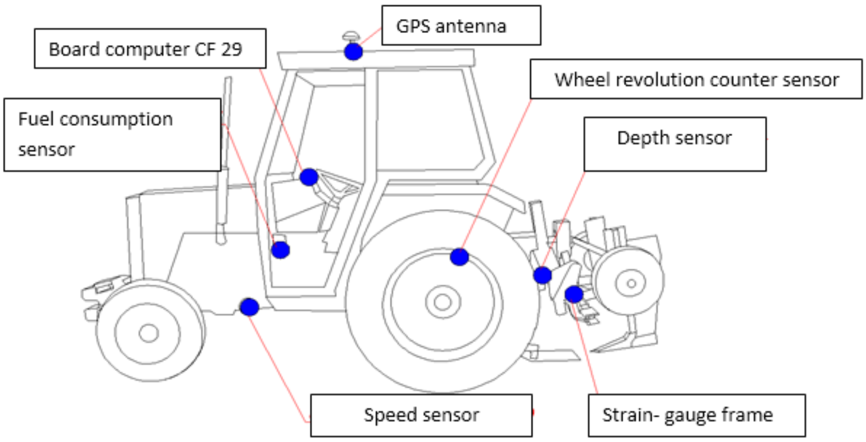


Fig.4 Diagrammatic Representation of the Tractor Mobile Workstand

The strain gauge frame was mounted on the 3-point linkage. The depths were chosen with the help of the adjustment handle on the plough. Working depth was measured by means of contactless distance sensor H – CE (H7) that is commonly used in traction measurements of cars. The change in the distance of the radiated rays indicates the depth of work. This equipment was calibrated to standard according to the manuals instruction. The tillage equipment was leveled on a flat pavement to ensure accurate reading of the depth of work. The depths of work and the speeds investigated are as shown on Table 1. The speeds were chosen using gear selector and the engine revolution of the tractor. After these settings, the obtained speeds were confirmed by driving the tractor with the equipment engaged in the tillage operation for a known distance and time. In starting the operation in each plot, this process is repeated and a pass is done without recording any measurements.

The slip measurement

Slip was calculated from theoretical speed determined on the tractor wheels and working speed measured by the CORREVIT L-400 sensor. 24 magnets were fixed on the steel hoop in at the distance of 0,105 m from each other (Fig. 5).

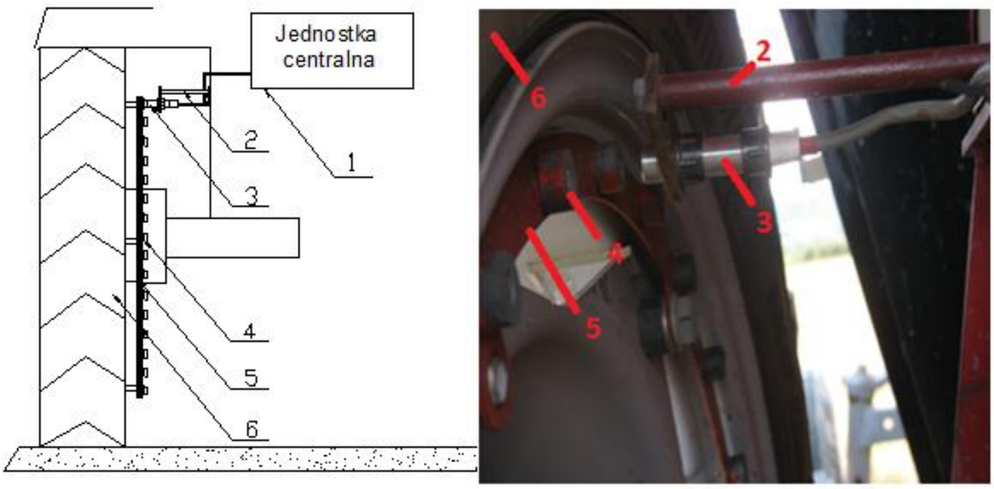


Fig. 5. Measurement of theoretical speed on the tractor wheels; 1- computer, 2- handle, 3- inductive sensor, 4- magnets, 5- hoop, 6- drive wheel

Contraction sensors when passed by a magnet generated a pulse that made possible calculation of the speed according to the below quoted equations:

$$v_t = \frac{n_{rz} \cdot 2\pi \cdot r_d}{t} \qquad (1)$$

where:

v_t – theoretical tractor speed [m·s^{-1}],
r_d – dynamic radius [m],

t – time [s].
n_{rz} – number of wheel revolutions

$$n_{rz} = \frac{l_i}{l_m} \qquad \text{.....} \qquad (2)$$

where:

l_i – number of pulses in time [s^{-1}],
l_m – number of magnets
n_{rz} – circumferential speed of the wheel [$rev \cdot s^{-1}$].

The slip was calculated according to the equation:

$$\delta = \left(\frac{v_t - v_{rz}}{v_t} \right) \cdot 100 \qquad \text{.....} \qquad (3)$$

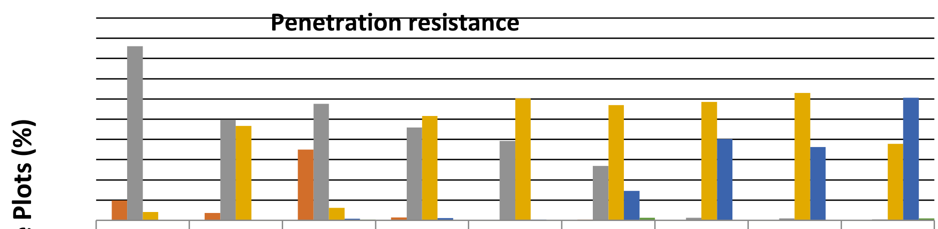
where:

δ - slip [%],
v_{rz} – working speed measured by the optical sensor [$m \cdot s^{-1}$].

With the tractor mobile stand ready for taking measurements, it was driven to the designed experimental plot. Four passes of measurements are recorded in each of the plots. The readings were recorded by the on board laptop (part of the mobile work stand). The following readings were taken simultaneously: speed of work (m/s), depth of work (cm), horizontal forces (Fx) and vertical forces (Fy) on implement, wheel slip and fuel consumption (Ql/h). The readings were taken in every 2seconds of the measurements. Means, Standard deviations and Coefficient of variations (CV %) were calculated with the aid of excel.

RESULTS AND DISCUSSION

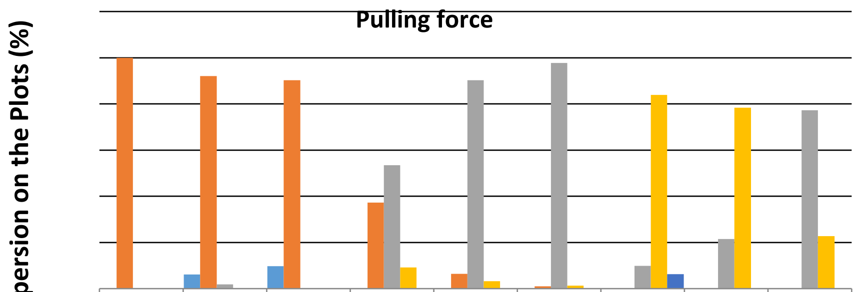
A general overview of Fig.6 shows that Plots, P6, P7, P8 and P9 are characterised with lower penetration resistance than other plots.. This is in agreement with the general principle that soil penertation resistance decreases with increase in soil moisture content(Summers *et al*., 1986; Oskoui and Witnwy, 1982;). However, there are some little deviations from the norm about this relationship (as seen here) between soil moisture content and soil penetration resistance could be explained as a result of the existing coefficient of variations (CV%) as observed in the analysis.



	h1v1	h1v2	h1v3	h2v1	h2v2	h2v3	h3v1	h3v2	h3v3
<0,5	0.05		0.2						
0,5-1	9.76	3.67	35	1.36	0.17	0.3			
1-1,5	86.1	49.69	57.52	45.93	39.26	26.94	1.27	0.87	0.54
1,5-2	4.06	46.64	6.17	51.53	60.23	57.01	58.51	62.92	37.89
2-2,5	0.03		0.82	1.18	0.34	14.51	40.2	36.21	60.6
>2,5			0.29			1.24	0.02		0.97

Fig. 6 Spatial Dispersion of Penetration Resistance (Mpa) on the Plots

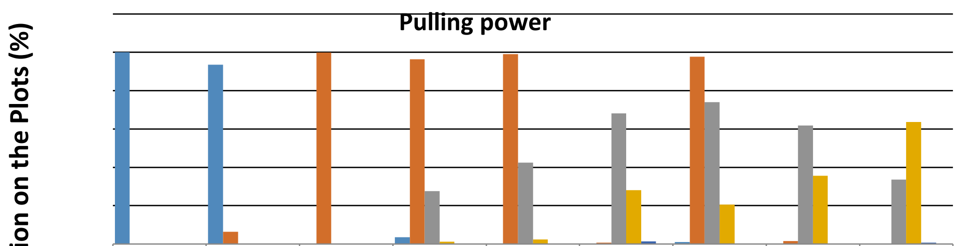
The most important factor that influence the tractor puling force is the soil resisistance and depth of tillage (Kuczewski, 1982). Puling resistance is also a factor of speed and depth of tillage operation. The established existing relationship shows that pulling force increases with increase in soil resistance (Al-Suhahaibani and Al-Janobi, 1997; Collins and Fowler; 1996, Kuczewski, 1982) as well as the depth and speed of operation. Comparing fig. 6 showing the spartial dispersion of penetration resistance (Mpa) on the plots and fig.7 showing the spartial dispersion of the Tractor Puling Force (kN), it is seen that the lowest pulling force existing on Plots P1, P2, P3, and P4 as indicated on fig.7 corresponds to the lowest penetration resistance on fig.6 while the average pulling force between 3-6kN existing on plots, P4, P5 and P6 on fig.7 coresponds to the average values of the penetration resistance on the same plots on fig.6. Similarly, the highest pulling force between 6-12kN existing on plots, P7, P8 and P9 on fig.7 coresponds to the same plots with highest soil resistance on fig.6. The existence of high pulling force on plots, P6 to P9 can be attributed to higher speed and depth of plowing even though these plots show higher soil moisture content.



	h1v1	h1v2	h1v3	h2v1	h2v2	h2v3	h3v1	h3v2	h3v3
<1		6.09	9.68		0.04				
1-3	100	92.11	90.29	37.29	6.4	1.01	0.05	0.05	
3-6		1.81	0.03	53.39	90.27	97.7	9.85	21.49	77.26
6-9				9.16	3.28	1.29	83.84	78.4	22.74
9-12				0.12	0.01		6.26	0.05	

Fig.7 Spatial Dispersion of the Tractor Puling Force (kN) on the Plots

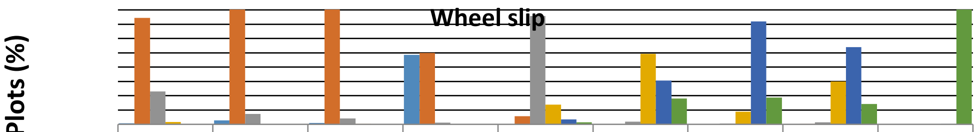
In soil tillage operation, it is generally known that the higher the tractor pull force, the higher the tractor power required(Al-Suhahaibani and Al-Janobi, 1997; Collins and Fowler, 1996; Oskoui and Witney, 1982) In fig.8, the lowest pulling power, lower than 3kW is seen on plots P1 and P2 which happen to be the same plots with lowest values of pulling force on fig.7. The highest value of pulling power greater than 15kW exists on plot P6 on fig.8. However, the portion of the plot this occupies being 0.04% can be said to be insignificant. Average values of pulling power between 6-9kW on plots, P4 to P9 and lower values of 3-6kW on plots, P3, P4, P5 and P7 on fig. 8 similarly confirm the relationship between the tractor pulling force and power.The factors such as soil moisture content, penetration resistance, speed and depth of plowing that influenced the tractor pulling force also have direct influence on tractor pulling power (Summers *et al*, 1986; Reaves and Schafer, 1975).



	h1v1	h1v2	h1v3	h2v1	h2v2	h2v3	h3v1	h3v2	h3v3
<3	100	93.58		3.6			0.98		
3-6		6.42	99.93	96.4	98.99	0.76	97.8	1.54	
6-9			0.07	27.66	42.51	68.22	74.09	61.78	33.64
9-12			0.03	1.23	2.42	28.08	20.66	35.56	63.58
12-15				0.02	0.04	1.33	0.01	0.07	0.73
>15						0.04			

Fig. 8 Spatial Dispersion of the Tractor Pulling Power (kW) on the Plots

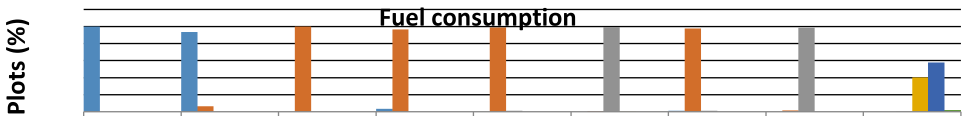
One of the most important factors affecting tractor wheel slip in operation is the soil moisture content: the higher the soil moisture content, the higher the wheel slip (Lando, 1990; Kuczewski, 1982) This relationship is confirmed comparing on fig.9. On fig. 9, the highest wheel slip greater than 25% is seen to occupy over 99% of plot P9 while the rest smaller portion has wheel slip of the range between 20 and 25%. Plot P9 has the highest soil moisture content of between 10.1 to 14.5%. Other high wheel slip values are seen on plots, P6 to P9 on fig. 6 corresponding to where these same plots or the adjacents/neighbouring plots have high soil moisture content. Plots, P1 to P4 have lower values of wheel slip ranging from les than 5% to 10% and average values of between 10 and 15% wheel slip on plot, P5 as shown on fig.9. These wheel slips values confirm as well the relationship between soil moisture content and wheel slip.



	h1v1	h1v2	h1v3	h2v1	h2v2	h2v3	h3v1	h3v2	h3v3
<5	0.69	2.68	0.94	48.64	0.14				
5-10	74.52	90.03	94.78	49.88	5.62	0.21		0.34	
10-15	22.95	7.17	4.05	1.3	75.78	1.85	0.44	1.42	
15-20	1.73	0.12	0.24	0.18	13.67	49.21	8.83	30.05	
20-25	0.12				3.36	30.65	71.98	54.02	0.26
>25					1.43	18.07	18.75	14.17	99.74

Fig.9 Spatial Dispersion of Tractor Wheel Slip (%) on the Plots

Low soil moisture content, high soil resistance, high speed and depth of work, high pulling force and high power usage; all contribute to high fuel consumption (Perfect *et al*, 1997; Anazodo *et al.* 1987). On fig. 10, all the above factors come to play to show the picture or pattern of fuel cosumption on the plots investigated. On Fig. 10, the low value of fuel consumption(l/hr) as shown on plots, P1 and P2 is as a result of corresponding low values of low soil moisture content, low soil resistance, low speed and depth work, low pulling force and low power usage (fig.6, fig.7, fig.8 and fig.9). The highest fuel consumption (l/hr) as seen on plot, P9 is however due to high wheel slip as a result of high soil moisture content (fig. 9), high speed and depth work, high pulling force and high power usage (fig.7 and fig. 8).



	h1v1	h1v2	h1v3	h2v1	h2v2	h2v3	h3v1	h3v2	h3v3
<3	100	93.58		3.6			0.98		
3-4		6.42	99.93	96.4	98.99	0.76	97.8	1.54	
4-5			0.07	0	1.01	98.82	1.22	98.46	0.4
5-6						0.42			40.11
6-7									57.41
>7									2.08

Fig. 10 Spatial Dispersion of the Tractor Fuel Consumption (l/hr) on the Plots

CONCLUSION AND RECOMMENDATION

Even though the use of this 'new technology' has not revealed anything new from what is already known, it has been used to confirm already existing knowledge. With the use of this method, collection of accurate and large quantity of data is made easier. No doubt, the size and accurate data collection is fundamental to obtaining dependable results. However, processing of large quantity of data can be cumbersome as is the case with the use of GIS technology. It is therefore recommended that as we are still in the process of perfecting the use of GIS technology, that efforts be partly directed on the evolution of technologies that will both record and process data ready for farmers/farm managers.

It is saddening to say the least that decades after the emergence of precision agriculture, Nigeria is yet to embrace this technology at a reasonable level. It is more saddening that no tertiary institution in Nigeria is offering any course in this field as at now despite all the advantages this technology has got to offer. President Muhammad Buhari has said, 'Oil won't be sufficient as Nigeria's revenue earner. We need to go back to agriculture'. Precision agriculture is 'our' chance. This paper is therefore making a passionate call to all the stake holders in Nigeria (practising farmers, Politicians, agricultural engineers, researchers and academic institutions) to rise up to this challenge and improve our agricultural practices through the introduction of Precision Agriculture as it is practiced in the developed countries.. Tertiary education can begin immediately by the introduction of 'Precision Agriculture' in our institutions.

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THERMAL LAG PERFORMANCE OF A MOBILE DOUBLE WALLED SAWDUST INSULATED METALLIC SILO

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ABSTRACT

A 1000 kg double walled insulated mobile metallic silo was designed and constructed with two mild sheets of 1mm thickness using sawdust as an insulating material between the metal sheets. The silo has a total height of 1.2m above the ground level with an internal and external diameter of 0.64 m and 0.68 m respectively and resting on a platform which has four wheels attached to it for mobility. A preloading assessment was conducted on the silo to determine the possibility of using sawdust as an insulator in the silo. Comparison was also made between the single walled aluminium sheet silo placed on a platform and the double walled insulated mobile metallic silo to determine thermal performance. Temperature readings were taken 3 times for each time interval for 10 days using a therma waterproof K thermocouple model 232-101. The result showed that the temperature reading was usually low by 8:30am within the double walled silo having a least temperature of 23.9^{0}C, while the highest temperature for double walled silo was at 12:30pm with 33.6^{0}C and the result also showed that the temperature reading was usually low by 8:30am within the single walled silo having a least temperature of 25.2^{0}C while highest temperature for single walled silo was at 12:30pm having a range of 36.6^{0}C. The double walled mobile metallic silo moved smoothly on a flat untilled road by pushing without a jolting action and undulating movement. In conclusion, the double walled mobile metallic silo performed better than the single walled silo and has a good thermal property which is suitable for the storage of grains in tropical region for low income farmer.

Keywords: *Double walled, temperature, thermal time lag, metallic, silo, mobile and Nigeria*.

INTRODUCTION

It was predicted that the world's population will increase to about 9.1 billion people by the year 2050 and most of this increase will occur in developing countries (FAO, 2009). This increase translates into 33% more human mouths to feed, with the greatest demand growth in the developing communities of the world,
food supplies would need to increase by 60% in order to meet the food demand in 2050. Food availability and accessibility can be increased by increasing production, improving distribution, and reducing the losses. Thus, reduction of post-harvest food losses is a critical component of ensuring future global food security (Jaspreet and Anita, 2015). Hence, the need of investing much into the agricultural sector is necessary in order to produce more food to feed the world. Furthermore, increasing agricultural productivity must go hand-in-hand with improved storage in order to reduce post-harvest losses. Promoting small scale agriculture is the key to achieving food security in developing countries Metal silo technology for small and medium scale farming are developed for more comfortable and effective grains protection. The vast majority of silo structures in existence in Nigeria are made from single walled metal sheets which a lot of researchers have studied and reported that they are majorly affected by moisture build up within the silo wall as a result of high thermal conductivity between the ambient environment and the silo wall which then transfers heat to the stored grains in the silo thereby reducing the quality (Alonge *et al*, 2011 ; Alonge and Ayeni , 2014). The prospect of utilizing sawdust as an insulator in silo was investigated by Adejumo *et al*, (2010) when he developed a 350kg double-walled metallic silo using galvanized iron sheet with sawdust as insulating material between the walls. Temperature differences between the silo and the ambient as well as along the height were monitored for a period of thirty days. The result showed the double-walled sawdust insulated metallic silo demonstrated some prospects for use in grain storage especially in the reduction of temperature fluctuations within the silo. In a related research, Yusuf and He, (2011) developed a single walled mobile metallic silo that could be hitched to any class of vehicle with the aim of providing a mobile storage platform for grains in developing countries.
Sawdust is the main by product of wood timber processing. Types of sawdust depend on the varieties of wood from which it is obtained. Hence their thermal properties will differ from one to another. Ogunleye and Awogbemi, (2007) investigated the thermal and physical properties of eight varieties of sawdust and found that they had different thermal conductivity values. Although many outlets are available for the utilization of this waste, economical disposal of sawdust remains a problem of growing concern to the wood industry. Sawdust

particles have proven to be an effective thermal conductor over other alternative and non expensive insulators as reported by (Ogedengbe, *et al*, 2013; Tokan *et al*, 2014).
There is a need to find a suitable material of construction or a construction method that would mitigate against the rising temperature between the silo walls and the ambient environment by acting as a retardant which would slow down the flow of heat into the grains from the outside environment. In addition to this, there is a challenge of moving the grains from the harvest field to the farm house and eventually to the local market. Therefore it is imperative to construct a mobile silo for easy accessibility.

MATERIALS AND METHODS

The materials and methods were divided into three parts: design, construction and testing of the silo prototype.

Design of Deep Silo

For the purpose of this research, a double walled mobile silo made of mild metal sheet was designed and constructed with sawdust as an insulating material between walls of silo. The silo consists of four major sections which include the roof, the wall, conical hopper and the accessories. The accessories include the cover, inspection hole, the platform, wheels, handle, cover opening mechanism and the silo unloading outlet. Inspection hole were incorporated into the design to facilitate proper monitoring of the grains during storage.

Design Consideration

In the design of the silo, a number of factors aimed at ensuring effective utilization, ease of construction and management, considering the level of technology available in the rural communities and accessibility to the intended beneficiaries were taken into account. a cylindrical shape was chosen and for the estimated capacity of 1 tonnes using shelled corn of a density 720kg/m^3 and angle of repose of 27° , an internal and external diameter of 0.64m and 0.68m respectively and height of 1.2m were considered adequate for the silo.

Design Calculations for Silo

The following parameters were calculated and designed for before the silo was fabricated:

i. Plane of rupture method was used to obtain a deep silo because a silo is shallow, if its depth is less than the least lateral dimension while in a deep silo; the depth is greater than the maximum lateral dimension.

ii. Total lateral pressure per unit of wall perimeter

i. Lateral wall pressure L

ii. Vertical wall load, W_l

iii. Vertical floor pressure F_P

iv. Designs against wind load using the modified formula of Barret and Sammet (1966). The isometric view of the mobile double walled silo is shown in Figure 1.

Figure 1: Isometric view of silo

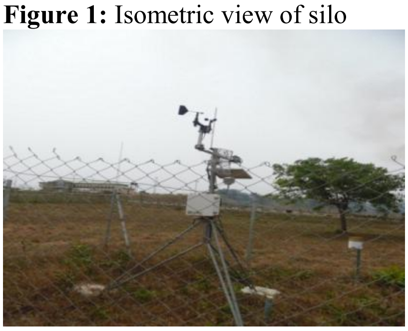

Figure 2: Automatic Weather Station

The materials used were obtained locally at various markets in Omuaran Town, Kwara State, the materials were critically considered based on strength, availability, durability and corrosiveness to prevent ease in construction work and maintenance. The materials used include 2 metal sheets of 1mm thickness, angle iron 50*50, 20mm ball bearing, 20mm shaft, flat bar, pipe, bolt and nut, sawdust, electrode, filler wire, cutting disc, filling disc, twisted rod, smoothing paper, paint, therma waterproof K thermocouple 232-101 model and Automatic Weather Station (Figure 2).

Construction Procedures

1. Marking-out, Cutting and Rolling: The silo comprised of two open cylinders, two complete cones, two frustum cones and a host of other small parts. The two cylinders (outer and inner) were marked out on two different galvanized sheets such that when rolled between two parallel cylinders rotating in opposite direction, it forms the cylindrical shape desired for the structure. All the members were cut-out using a manual shear cutter immediately after the marking out stage and they were rolled into their respective shapes (Figures 3 and 4 below).

Figure 3: Cutting out the frustum

Figure 4: Folded frustum

2 Assembling of Members: After the rolling stage, the inner and outer cylinders and the lower cones were joined by welding them one to another. The inner cylinder was centrally placed in the bigger/outer cylinder and supported by guides made of small metal chips to allow for a uniform spacing 5 cm along the circumference of the two cylinders. With the two lower cones attached to the two cylinders, the small cylinders that form the discharge outlet were fixed on the outer cone by drilling the cones to facilitate easy attachment and discharge of grains from the silo.

3. Incorporation of the Insulation Material: the choice of the insulating material was sawdust due to its low thermal conductivity of 0.06W/ (mK). The sawdust was placed in the spacing of 5 cm between the inner and outer cylinder and the lower and upper conical sections for the purpose of reducing temperature influx into the structure.

4. Incorporation of Accessories: the silo accessories include the inspection holes, the platform, wheels, the cover opening mechanism and the silo unloading outlet. Holes of diameter 20 mm were drilled from the external cylinder through the inner cylinder to serve as a means of inspecting the storage conditions in the structure. A hole was made at the top side of the silo in which the probe of the thermocouple was inserted to measure the temperature in the silo. The platform was constructed and a handle attached to it, the welded circular wheels were constructed and attached to the platform. To further improve the appearance of the structure, it was painted with green paint.

Figure 5: Temperature reading using therma probe for double walled insulated metallic silo

Figure 6: Temperature reading for single walled aluminium sheet silo

Testing of the silo

Pre-storage temperature measurements were carried out to establish the efficiency of the silo before grains are stored in the structure. Measurements were taken through each of the inspection hole located on the silo wall and outside the silo for a period of 10 days. Temperature readings were taken three times daily at 8:30 am, 12:30 pm and 3:30 pm. The inspection hole was opened slightly to avoid exchange of air with the ambient environment which might reduce the internal temperature readings, the k thermocouple was inserted and the lid closed for about 2 minutes (Figure 5). The readings were recorded and this step was repeated two more times at the pre-determined time of the day. The average of these readings were calculated and recorded as a single value in the final table. To assess the thermal performance of the double walled silo over the single walled silo, an already fabricated single walled silo made from aluinium sheet located in the Storage and Processing Laboratory, Landmark University was used for the test. The silo was transferred to the field, placed beside the double walled silo and the same procedure stated earlier was used for the measurement (Figure 6). The temperature difference between the ambient environment and both silos were also measured using the same procedure while the Automatic Weather Station measured the ambient climatic readings.

RESULTS AND DISCUSSION

The results show that there were differences between the temperature within the double walled and single walled silo. This is an indication that there is resistance to heat influx into the double walled silo from the ambient environment. The low temperature within the silo was also found to be dependent on the time of the day at which readings were taken. Naturally lower temperatures were recorded in the mornings than in the afternoon; this also has direct effect on the temperature within the silo. It could be observed that the thermal insulation property of the sawdust has reduced the heat transfer into the silo.

Double walled silo temperature reading

The Highest Temperature (H.T) of 28.2^{0}C for 8:30 am in the double walled silo (DWS) was obtained on Day 2, the H.T of 42.5^{0}C for 12:30 pm in the DWS was obtained on Day 7, the H.T. of40.9^{0}C for 3:30 pm in the DWS was obtained on Day10, the Lowest Temperature (L.T) of 21.2^{0}C for 8:30 am in the DWS was obtained on Day 6, The L.T of 32.6^{0}C for 12:30 pm in the DWS was obtained on Day 4, and the L.T of 24.9^{0}C for 3:30 pm in the DWS was obtained on Day 1. The analysis shows that the temperature increases with the time of the day, with the lowest at 8:30 am and the highest at 12:30 pm and 3:30 pm respectively (Figure 7)

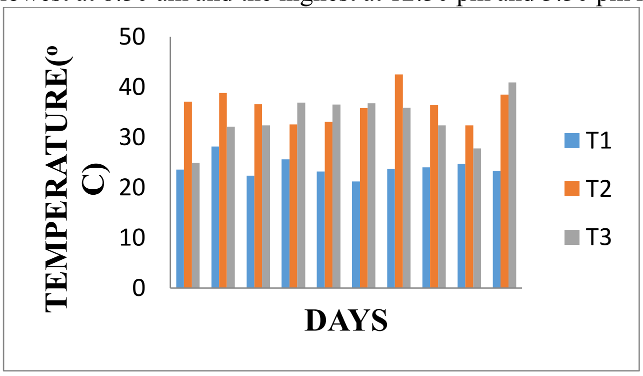

Figure 7: Average temperature variation within DW silo at different time of the day (15th to 24th May, 2015) where T1(blue) is 8:30 am, T2 (red) is 12:30pm and T3(green) is 3:30pm.

Single walled silo temperature readings

The H.T. of 29.4⁰C for 8:30 am in the single walled silo (SWS) was obtained on Day 2, H.T. of 42.8⁰C for 12:30 pm in the SWS was obtained on Day 7, The H.T. of 42.8⁰C for 3:30 pm in the SW was obtained on Day10, The L.T. of 21.3⁰C for 8:30 am in the SWS was obtained on Day 6, The L.T. of 30.4⁰C for 12:30 pm in the SWS was obtained on Day 5, and the L.T. of 27.9⁰C for 3:30 pm in the SWS was obtained on Day 9. The statistical analysis shows that the temperature increases with the time of the day, with the lowest at 8:30 am and gradually increased at 12:30 pm and highest at 3:30 pm (Figure 8).

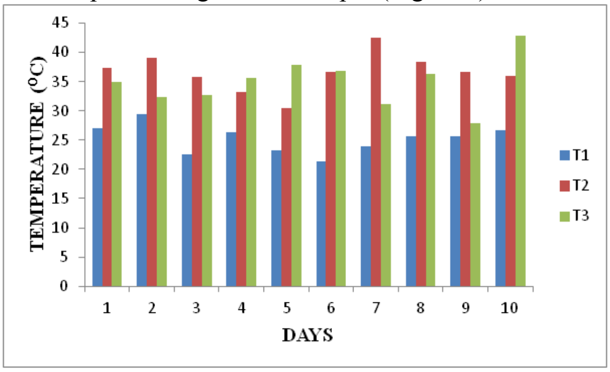

Figure 8: Average temperature variation within silo at different time of the day (15th to 24th May, 2015. Where T1(blue) is 8:30 am, T2 (red) is 12:30pm and T3(green) is 3:30pm.

Comparison between different silos at the same time.

Temperature differences at 8:30am between DWS and SWS

The H.T of 29.4⁰C at 8:30 am in the SWS was obtained on Day 2, the H.T of 28.2⁰C at 8:30 am in the DWS was obtained on Day 2.The L.T of 21.2⁰C at 8:30 am in the SWS was obtained on Day 6, the L.T of 21.3⁰C at 8:30 am in the DWS was obtained on Day 6.

The statistical analysis showed that temperature readings gotten at 8:30 am in the SWS increased but at the DWS, temperature readings gotten at 8:30 am decreased (Figure 9).

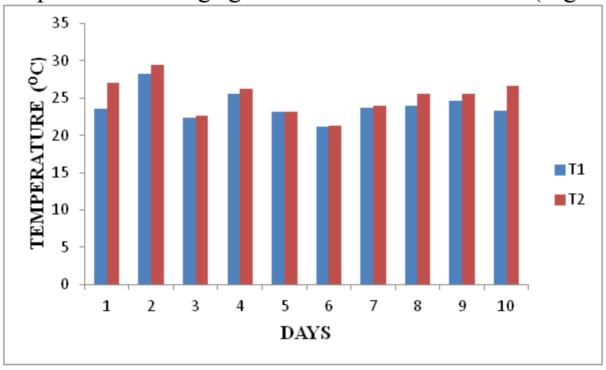

Figure 9: Average temperature variation within the two silos at 8:30am (15th to 24th May, 2015). Where T1(blue) represents DWS and T2(red) represents SWS.

Temperature differences at 12:30pm between DWS and SWS.

The H.T of 42.8⁰C at 12:30 pm in the SWS was obtained on Day7; the H.T of 42.5⁰C at 12:30 pm in the SWS was obtained on Day 7.The L.T of 30.4⁰C at 12:30 pm in the SWS was obtained on Day 5, the L.T of 32.4⁰C at 12:30 pm in the DWS was on Day 9. The statistical analysis showed that temperature reading gotten at 12:30 pm in the single walled silo; increased but at the DWS, temperature reading gotten at 12:30 pm decreased (Figure 10)

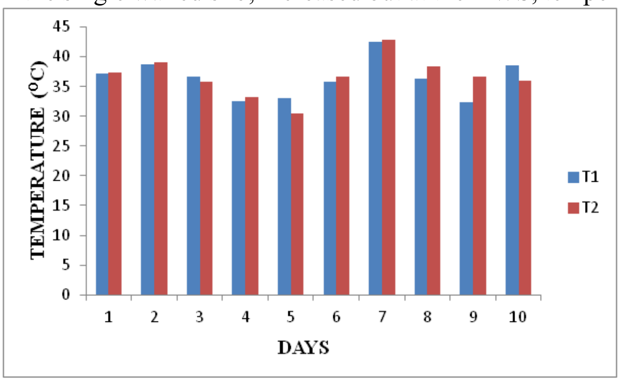

Figure 10: Average temperature variation within the two silos at 12:30pm (15th to 24th May, 2015). Where T1(blue) represents DWS and T2(red) represents SWS.

Temperature differences at 3:30pm between DWS and SWS.

The H.T. of 42.8⁰C at 3:30 pm in the SWS was obtained on Day10, The H.T of 40.9⁰C at 3:30 pm in the DWS was obtained on Day 10, The L.T of 27.9⁰C at 3:30 pm in the SWS was obtained on Day 9, The L.T. of 24.9⁰C at 3:30 pm in the DWS was obtained on Day 1.

The statistical analysis showed that temperature reading gotten at 3:30 pm in the SWS increased but at the DWS temperature readings gotten at 3:30 pm decreased (Figure 11).

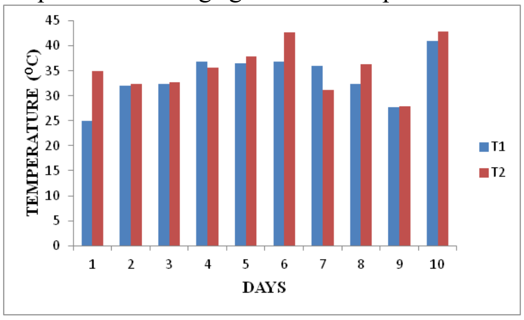

Figure 11: Average temperature variation within the two silos at 3:30pm (15th of 24th May, 2015). Where T1(blue) represents DWS and T2(red) represents SWS.

Comparison with environmental condition

Thermal time lag difference at 8:30am between DWS and ambient condition

The statistical analyses show that there are significant differences between the temperature within the DWS silo and the ambient environment (Figure 12).The H.T. of 28.2⁰C in the DWS at 8:30 pm was obtained on Day 2 due to an heavy rainfall on the that day, the ambient temperature of 23.7⁰C at 8:30 pm was obtained on Day 2, the temperature gotten from DWS was high due to the effect of rainfall when compared to the ambient temperature, this difference is largely due to the lagging effect of the sawdust in between the walls which did not allow heat flow from the interior into the ambient environment which had a lower temperature reading. This effect is termed the thermal time lag difference.

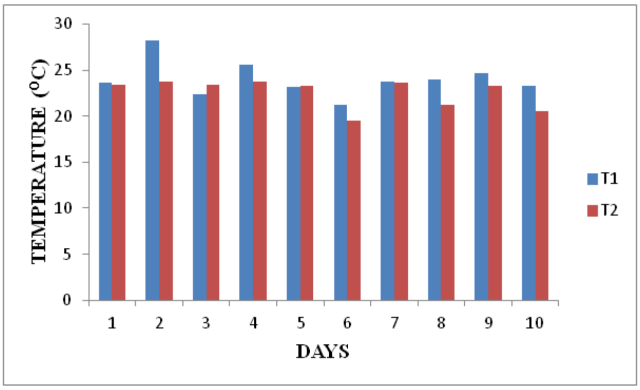

Figure 12: Average temperature within the Double walled silo and ambient condition at 8:30am (15th to 24th May, 2015). Where T1 represents DWS and T2 represents the ambient temperature.

Thermal time lag difference at 12:30pm between DWS and ambient condition

The statistical analyses showed that there were significant differences between the temperature within the double walled silo (DWS) and the ambient (Figure 13). The H.T of 42.5⁰C in the DWS at 12:30 pm was obtained on Day 7; the ambient temperature (A.T) of 30.6⁰C at 12:30 pm was obtained on Day 2.

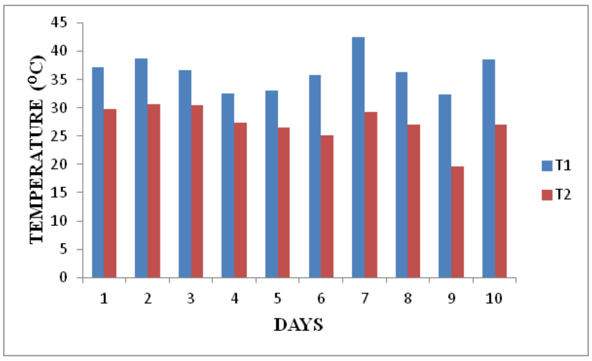

Figure 13: Average temperature within the Double walled silo and ambient condition at 12:30pm (15th to 24th May, 2015). Where T1 represents DWS and T2 represents the ambient environment temperature.

Thermal time lag difference at 3:30pm between DWS and ambient condition

The statistical analyses showed that there were significant time lag differences between the temperatures within the DW silo and the ambient (Figure 14). The H.T of 40.9^{0}C in the DWS at 3:30 pm was obtained on Day 10; the A.T. of 30.3^{0}C at 3:30 pm was obtained on Day 2.

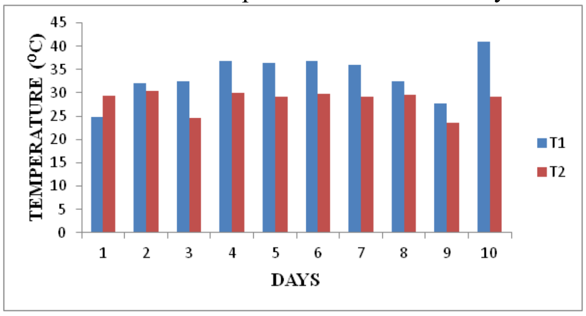

Figure 14: Average temperature within the Double walled silo and ambient condition at 3:30pm (15th to 24th May, 2015). Where T1 represents DWS and T2 represents the ambient environment temperature.

CONCLUSION

The sawdust insulated double-walled metallic silo demonstrated some prospects for use in grain storage; especially in the reduction of temperature fluctuations within the silo due to the low thermal conductivity of the sawdust. This is an indication that there is resistance to temperature influx into the silo from the ambient environment which shows that the low thermal conductivity of the sawdust has reduced the heat transfer into the silo. The silo was tested for ease of movement on a typical farm road by pushing and pulling and it easily moved from one place to another during evaluation period without jolting and undulating on the ground. The silo makes efficient use of space as compared to other locally constructed storage structures.

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EFFECT OF SEGREGATION ON THE STRENGTH OF CONCRETE USED IN FARM STORAGE STRUCTURES

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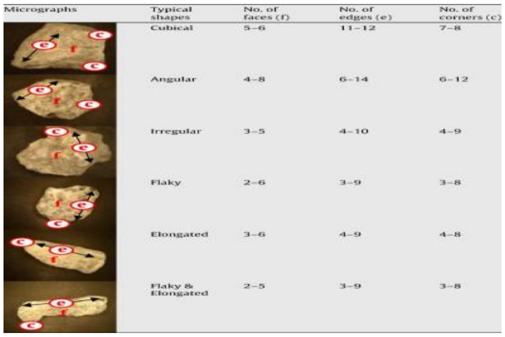
ABSTRACT
Segregation of solid module significantly affects the quality of concrete. Which can be measured through compressive quality test, to decide the limit of the heap that a solid can convey which is connected unswervingly and the devastating burden per unit surface region of the connected burden to the solid. The accompanying states of total was utilized; Angular, Elongated, Smooth rounded, Flaky total, Control total to cast 60 cubes of concrete. The trial blend proportion utilized was 1:3:6 with a water/concrete proportion of 0.5. The threw solid shapes were cured for7,14,21,and28 days and their normal compressive quality and normal thickness was ascertaine d,the compressive quality are for Angular(9.4818.28N/mm2), Elongated(9.08-16.36N/mm2),Smooth rounded(9.0-16.98N/mm2), Flaky(10.01-8.16N/mm2) and Control aggregate is (17.56-26.01N/mm2). Arrangement of this outcome shows that angular aggregate has the most elevated quality esteem; it is advisable to obtain angular aggregate even from the local quarry.

Keywords: Absorption, Aggregate, Durability, Mortar, Strength,

INTRODUCTION
Concrete and its cementations (volcanic) constituents, such as pozzolanic ash, have been used since the days of the Greeks, the Romans, and possibly earlier ancient civilizations. However, the early part of the Nineteenth Century marks the start of more intensive use of the material. Garber,(2006). Published his statement of principles of construction, recognizing the weakness of the material in tension. Also according to Nawy, (2005) a Plain concrete is formed from a hardened mixture of cement, water, fine aggregate, coarse aggregate (crushed stone or gravel), air, and often other admixtures. The plastic mix is placed and consolidated in the formwork and, then cured to facilitate the acceleration of the chemical hydration reaction of the cement-water mix, resulting in hardened concrete. Concrete is a stone like material obtained by permitting proportioned mixture of cement, sand and gravel or other aggregate, and water to harden in forms of the shape and dimensions of the desired structure (Arthur, H. N., David, D. and Charsles, W. D., 2004).Concrete is an assemblage of cement, aggregate and water. The most commonly used fine aggregate is Sand derived from river banks (Lohani, T.K., Padhi M., Dash, K.P. and Jena, S., 2012).
Concrete is one of the most widely manufactured materials in the world and over recent decades technical innovations, especially in the use of admixtures have improved not only the quality but also the range of potential applications for this versatile construction product. Today's concrete has to fulfil a wide range of requirements in both the fresh and hardened state. In most cases the properties of fresh concrete also affect the quality of the hardened concrete and ultimately its durability. This means that concrete has to be correctly proportioned and must remain homogeneous during placing and after compaction in order to avoid effects such as bleeding, segregation, honey combing, laitance, settlement and plastic cracking over the top bar. These effects would all lead to reduced quality and durability of the hardened concrete. European Federation for Specialist Construction Chemicals and Concrete Systems and European Federation of Concrete Admixture Associations, (2006). Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements or roads, bridges/overpasses, motorways/roads, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Famous concrete structures include the Burj Khalifa (World's Tallest Building), The Hoover Dam, The Panama Canal and The Roman Pantheon (Matthias, 2010).



Micrographs	Typical shapes	No. of faces (f)	No. of edges (e)	No. of corners (c)
	Cubical	5–6	11–12	7–8
	Angular	4–8	6–14	6–12
	Irregular	3–5	4–10	4–9
	Flaky	2–6	3–9	3–8
	Elongated	3–6	4–9	4–8
	Flaky & Elongated	2–5	3–9	3–8

Plate 1: Different Typical Shapes of Aggregate.
[www.sciencedirect.com/science/article/pii/s0301751609000428 (image Google search)]

As surface smoothness increases, contact area decreases, hence a highly polished particles will have less bonding area with the matrix than a rough particles of the same volume (Shetty, 2005).

Materials and Methods

The coarse aggregate material obtained from Tungan Mallam (Soject Quarry), Mai-Tunbi Minna and Rabah Sokoto South, was used in this research. Aggregate shapes considered during sorting of aggregate according to shapes in Plate 1, were as Follows Elongated, Flaky, Angular and Smooth Rounded. Elongated, and Flaky, were obtained from Soject Quarry at Tungan Mallam Niger State, angular was gotten from Mai-tunbi local quarry, Minna Niger state and Smooth rounded was obtained from Sokoto South at Sokoto State. Their physical property was determined and recorded. And their sizes range from 10 to 20mm.

Physical Properties

The physical properties of the aggregate were determined in accordance with BS 1377-9 (1990). These include; Moisture Content, Bulk Density (compacted and Un-Compacted), Porosity, Void Ratio, Specific Gravity, Impact value, Water Absorption, Sphericity, Roundness Ratio.

Sieve Analyses.

Some set of standard sieves was weighed and arranged in ascending order of the sizes from base to top. Some part of the samples was then taken and weigh by the use of a weighting balance, and the value obtained was recorded.

Weight of aggregate retained = (weight of sieve + aggregate sample) - (weight of sieve)

% Weight retained = $\frac{\text{Weight of aggregate retained}}{\text{Total weight of aggregate retained}}$ x 1OO

Fineness modulus (FM) = $\frac{total\ commulative\ \%\ retained}{100}$

Coefficient of uniformity (Cu) = $\frac{D60}{D10}$

Coefficient of curvature (Cc) = $\frac{D30}{D60 \times D10}$

Sorting coefficient (So) = $(\frac{D75}{D25})^{1/2} = \sqrt{(\frac{D75}{D25})}$

Coefficient of uniformity (Cu); - This indicate the range or spread of the sand grain size, also known as coefficient of concavity.

Coefficient of curvature (Cc); - This is the major of shape of the curve between diameter D60 and D10.

Compressive Strength Test of Concrete Cubes.

The cubes of concrete were removed from the curing tank, dried for 3 minute and weight immediately on a weighing balance to determine the weight of each cube. The cube was carefully placed in the compressive testing machine with it smooth side in contact with the plates of the machine. The machine power was switch on, the gear of the machine turn clockwise, and ready to crush the cube. At the loading the dial start reading clockwise, at failure, the dial stops and the gear turned anti-clockwise. The load at each failure was obtained and recorded. Three cubes were crushed for each shape of each sample on 7th, 14th, 21st, and 28th days of curing. The following equation was applied:

$$\text{strength} = \frac{\text{crushed load}}{\text{surface area of concrete cube}} \times 100$$

RESULTS AND DISCUSSIONS

Moisture Content (M.C)

The Moisture Content of experiment samples (Control, Flaky, Angular, Elongated, Smooth and Fine Aggregate) are given in table 1 as 0.19, 0.18, 0.19, 0.16, and 1.13 respectively. Since the Moisture content reveal the quantity of water present in each aggregates, the result shows that the aggregate contain certain amount of water which will result to low absorption capacity.

Bulk Density

The Bulk Density test result of the aggregates of different shapes are given in Table 1 for Compacted and Un-compacted respectively. The statistical analysis shows result there was significant difference in the samples for both Compacted and Un-compacted, the Elongated Aggregate as the leased compacted Bulk Density (1473.79±0.2 Kg/m^3) while Smooth Aggregate as the highest compacted Bulk Density (1605.40±0.13Kg/m^3) and Un-compacted Bulk Density shows no significant different between angular and Elongated Aggregate. These value are within the range of 1440kg/m^3 to 1850kg/m^3 as reported by Abdullahi (2005).

Specific Gravity

The results of specific gravity of the aggregates (Control, Flaky, Angular, Elongated, Smooth and Fine Aggregate) are given in Table 1 as 2.52, 2.67, 2.62, 2.55, 3.04, and 2.55 respectively. The results are within the specification of specific gravity of rock group that lies between 2.5 and 3.0 for natural aggregate. The Smooth Round aggregate have highest specific gravity. The mix design of a concrete is relative of specific gravity.

Porosity and Void ratio

Concrete durability is a subject to the level of porosity and void ratio of aggregates. Result of porosity given in Table 1 with the following value 6.68, 3.03, 6.17, 3.50, 5.96, 5.53% respectively and the void ratio obtained in the result lies between the (0-50%) percent specified

Table 1: Physical Properties result of Different Aggregates

	MC	Compacted bulk density	Un-compacted Bulk D	Porosity	Void Ratio	SG	Impact Value	Water ABS
Control Agg	0.19^c	1595.44^e	1488.9^c	6.68^f	0.94	2.52^a	9.92^e	0.65^b
Flaky Agg	0.18^b	1552.49^c	1505.4^d	3.03^a	0.94	2.67^d	5.18^a	0.63^a
Angular Agg	0.19^c	1515.63^b	1422.1^a	6.17^e	0.94	2.62^c	7.83^c	0.72^c
Elongated Agg	0.19^c	1473.79^a	1422.1^a	3.50^b	0.94	2.55^b	6.35^b	0.84^d
Smooth Agg	0.16^a	1606.40^f	1509.7^e	5.96^d	0.95	3.04^e	8.52^d	1.04^f
Fine Agg	1.13^d	1588.074^d	1487.4^b	5.53^c	0.94	2.55^b	7.94^c	0.94^e

*Value followed by same superscript alphabet are not significantly different at ($P<0.05$) along the column. Values are Mean of triplicate determination. (Agg)Aggregate.

Sieve Analysis

Table 2: Sieve Analysis of Aggregate.

	fineness modulus	Coefficient Uniformity	Coefficient of Curvature	Sorting Coefficient
Control Agg	6.366	1.642	1.006	1.212
Flaky Ags	5.869	1.5	1.041	1.164

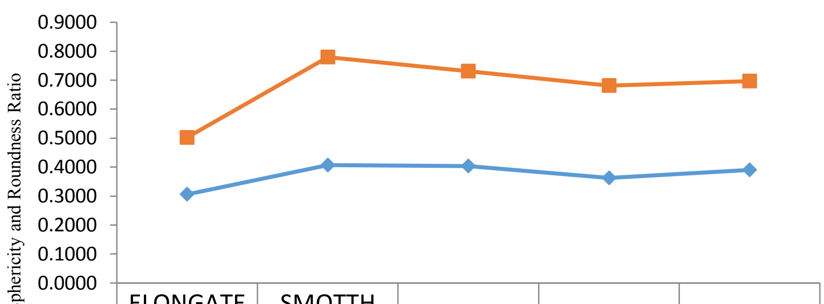
Angular Agg	6.608	1.6	1.1	1.69
Elongated Agg	6.196	1.5	1.009	1.264
Smooth Rounded Agg	6.432	1.833	1.094	1.274
Fine Agg	4.213	2.714	1.371	1.618

Grading of Aggregate (Agg) was done by sieve analysis. The properties of aggregate used for the research are summarized in Table 1.0 while shows their particles size distribution.From the Table, it shows the sieve analysis of the sand used as fine aggregate in the experiment and it distribution into fine, medium, and coarse aggregate of tiny particle distributions. The sand fractions were more of medium fraction of the sieve analysis, than coarse and fine fractions. Followed by some coarse nature of the sand particles and some little fine fraction of its content the particle size distribution curve for the Elongated, Flaky, Angular, and Smooth Rounded and Control Coarse Aggregates. From the Table, it was observed that, there was more of coarse size gravel fraction in appearance than the medium and fine size gravel fraction. The Fineness modulus (FM) for fine Aggregate (sand), and Coarse Aggregate (Elongated Aggregate, Flaky Aggregate, Angular Aggregate, Smooth Rounded Aggregate, and Control Aggregate) are as follows; 4.2130 and (6.1965, 5.8696, 6.6086, 6.4328, and 6.3663).Comparing the fineness modulus calculated of all the aggregate used for this experiment, it was observed that the sand can be used as fine aggregate more than the order aggregates which were used as the coarse aggregates.

Comparing all the coarse aggregate, it was observed that Angular aggregate possess the highest fineness modulus which makes it to be the coarsest in nature, followed by the Smooth Rounded Aggregate, Control Aggregate, Elongated Aggregate, and lastly the Flaky Aggregate. Coefficient of uniformity (Cu) for Fine Aggregate (sand), and Coarse Aggregate (Elongated Aggregate, Flaky Aggregate, Angular Aggregate, Smooth Rounded Aggregate, and Control Aggregate) are as follows 2.7143, and (1.5000, 1.5000, 1.6000, 1.8333, and 1.6429).The fine aggregate which was the sand shows a great uniformity in nature; according to the value obtain from the calculated Coefficient of Uniformity of aggregate, and when it was compared with the rest of the coarse aggregate.

This result gives the blending nature of the fine and coarse aggregates use for this experiment in the nature. Coefficient of Curvature (Cc) for fine Aggregate (sand), and Coarse Aggregate (Elongated Aggregate, Flaky Aggregate, Angular Aggregate, Smooth Rounded Aggregate, and Control Aggregate) are as follows 1.3714, and (1.0099, 1.0417, 1.1000, 1.0947, and 1.0062).

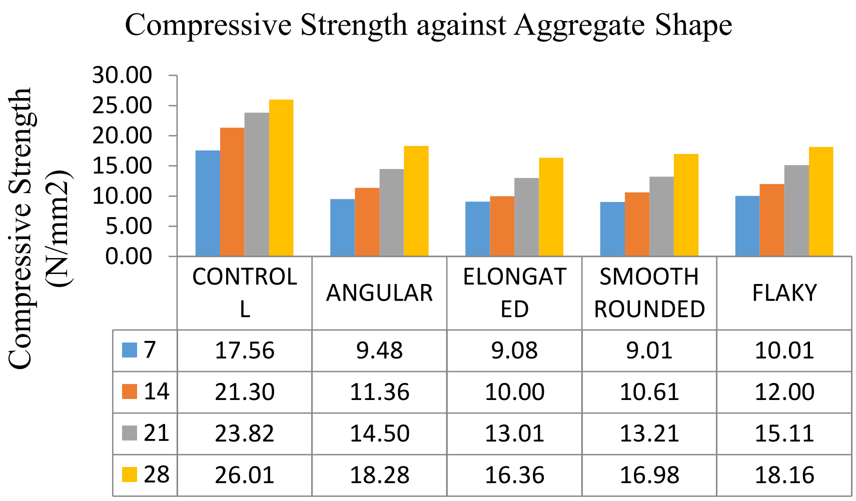
The Angular aggregate shows the highest curving nature when it was compared with the order Coarse aggregate, this was because of its Angular nature. Smooth rounded was the second in terms of arrangement from highest to lowest, and this was because of it physical nature as smooth and roundness. Flaky aggregate was the third but has much greater curviness than the Elongated and Control. Sorting coefficient (So) for fine Aggregate (sand), and coarse Aggregate (Elongated Aggregate, Flaky Aggregate, Angular Aggregate, Smooth Rounded Aggregate, and Control Aggregate) are as follows 1.6183, and (1.2649, 1.1649, 1.1698, 1.2748, and 1.2127).



	ELONGATED	SMOTTH ROUNDED	FLAKY	ANGULAR	CONTROL
AVE SPH	0.5025	0.7796	0.7309	0.6809	0.6973
AVE RR	0.3060	0.4070	0.4036	0.3628	0.3900

Figure 1: Sphericity and Roundness Ratio against Aggregate Shape

The Coarse Aggregate were arranged in according to their increase in strength from the lowest to the highest in terms of strength, and the graph in Figure 1 indicate that there was an increase in the sphericity and roundness ratio as the strength moves or increases from left to right which later decreases in terms of the Aggregate shape. This also shows the Sphericity and Roundness Ratio of the Coarse Aggregate Shapes. The Weight of Aggregate used was between 600g to 1000g of each sample of this experiment. At the highest compressive strength (control) the roundness ratio and sphericity was at an average when compared to the rest of the shapes, because it constitute of aggregate with different shapes, number of edges , faces, and corners. This result indicated that considering the arrangement of aggregate from left to right in terms of their increase in strength, in relation to concrete segregation to the effect of the concrete strength it was relies that the control aggregate has an average to high resistance of segregation to the strength of concrete casted with it as a sample.
Smooth Rounded Aggregate shows a high sphericity and roundness ratio, which contributed mostly to it failure due to the occurrences of segregation to the concrete casted



	CONTROL L	ANGULAR	ELONGAT ED	SMOOTH ROUNDED	FLAKY
7	17.56	9.48	9.08	9.01	10.01
14	21.30	11.36	10.00	10.61	12.00
21	23.82	14.50	13.01	13.21	15.11
28	26.01	18.28	16.36	16.98	18.16

Figure 2: Compressive strength (N/mm^2) versus Aggregate shapes (Control, Angular, Elongated, Smooth Rounded and Flaky Aggregate).

Compacting Factor Test are shown in Figure 2, for Aggregate such as Angular, Elongated, Smooth rounded, Flaky Aggregate, and Control aggregate it was 42.00mm, 39.00mm, 41.00mm, 37.00mm, and 41.00mm. For the compacting factor test aggregate such as Angular, Elongated, Smooth rounded, Flaky Aggregate, and Control aggregate it was 0.94, 0.97, 0.93, 0.88, and 0.91 The result of the average Compressive strength (N/mm^2) for 7, 14, 21, and 28 days for each aggregate such as Angular, Elongated, Smooth rounded, Flaky Aggregate, and Control aggregate. For Angular it has the following result 9.48 N/mm^2, 11.36 N/mm^2, 14.50 N/mm^2, and 18.28 N/mm^2, The result indicated that there was an increase in the compressive strength of the concrete with respect to the ageing of the concrete after curing for 7, 14, 21, and 28 days.
The result of the average density of cubes (kg/m^3) for 7, 14, 21, and 28 days for each Aggregate such as Angular, Elongated, Smooth Rounded, Flaky Aggregate, and Control aggregate. For Angular it has the following result 2202.47 kg/m^3, 2141.23 kg/m^3, 2307.16 kg/m^3, and 2322.96 kg/m^3, for Elongated it has the following result 2099.75 kg/m^3, 2105.68 kg/m^3, 2334.81 kg/m^3, and 2431.60 kg/m^3, for Smooth rounded it has the following result 2206.42 kg/m^3, 2202.47 kg/m^3, 2269.63 kg/m^3, and 2382.22 kg/m^3, The results of the average bulk density indicate that there was an increase in the average bulk density of the concrete cubes from 7 days to 28 days of curing for some of the coarse Aggregate shapes. However, the significant differences of the average compressive strength of the different aggregate used during the experiment indicates how the concrete strength varies with respect to time or days of curing.

CONCLUSION

The experimental work carried out on the effect of concrete segregation on the strength of concrete used in farm storage structures was successfully carried out, and the result shows that the theory behind effective segregation is dependent on the specific gravity, bulk density, shapes (i.e. Angular, Flaky, Elongated, and Smooth Rounded), and number of edges (e), faces (f), & corners (c) and also sphericity and roundness ratio of some aggregate which make up the shapes of the aggregate.

The mean compressive strength of the concrete which was produce using the different shapes but the same trial mixture, and which under goes 28 days curing period (hydration with water) are as follows for the following shapes Angular, Elongated, Smooth rounded, Flaky aggregate, and Control aggregate are 18.28 N/mm^2, 16.36 N/mm^2, 16.98 N/mm^2, 18.16 N/mm^2, and 26.01 N/mm^2, From this result, it can be concluded that Angular aggregate has the highest strength there by showing a good resistance to segregation during the time of settling of the concrete fresh mixture i.e after the concrete have been placed in kit formwork or mould, and before the cement hydration is completed to bind both the fine and coarse aggregate together in the presence of water for curing, however the control aggregate shows the highest strength when compared with the rest of the shape.

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RESPONSE SURFACE OPTIMIZATION OF AVOCADO PEAR (*PERSEA AMERICANA*) SEED OIL EXTRACTION AND CHARACTERIZATION AS A POTENTIAL INDUSTRIAL FEEDSTOCK

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ABSTRACT

The present work is concerned with the study of the effect of temperature, time and their combined interactive effects on oil extraction yield from Avocado Pear seed using response surface methodology (RSM) in a soxhlet extraction apparatus with petroleum ether as solvent. The extracted avocado oil was also characterized to determine its suitability for relevant industrial application. The optimum extraction conditions were temperature of 60 ^{0}C, time of 5 hr with a corresponding oil yield of 17.9 wt%. Model validation using coefficient of determination (R^2) gave a value of 0.9211. Physicochemical properties of the oil such as acid value (6.89 mg KOH/g), peroxide value (3.7 meq/kg), saponification value (189 mg KOH/g), iodine value (62.18 g I_2/100g) establishes the potential of the oil for paint making, soap production and a potential feedstock for biodiesel production.

***Keywords**: Avocado pear, extraction, response surface, optimization, model*

INTRODUCTION

Vegetable oil of plant and animal origins has been known to be an important feedstock for renewable energy production. It is used mainly as a viable feedstock for biodiesel production. Vegetable oil is also playing noteworthy role in the agro-industrial activities globally. The oils are used in the production of cosmetics, drugs and food substance. These oils are known to be potential source of energy in human and safeguard of internal organs. Most developing countries of the world are presently in short supply of edible oils and fats which is putting a heavy strain on the foreign exchange position of most African countries. This situation, therefore, calls for concerted research effort to increase edible oil production in Africa. In order to overcome this challenge, new sources of oil bearing crops are been exploited (Musa *et al.,* 2015).

The Avocado pear (*Persea Americana*) is a nutritious and valuable fruit tree found in the tropics. The species belongs to the family *Lauraceae. Persea Americana* is well known in many parts of the tropical world including Nigeria (Akachukwu, 2006). Avocado oil is the major avocado product, although it is rarely been explored in Nigeria. Only a few countries are actually involved in the production of oil namely Mexico (34 %), USA (8 %), Israel (4 %), South Africa (<2 %) and New Zealand (<1 %) and these are also the countries involved in growing, trading of the fruit to the cosmetics and pharmaceutical industry and as a lubricant. The emerging market for avocado should be acknowledged and taken advantage of as it presents many opportunities for relevant exploration of the surplus fruits for the production of value added product (Kuinimeri, 2011). Avocado's oil is mostly composed of monounsaturated fat. The oil is rich in Vitamin B, E and K. Avocado oil is well known for its anti-bacterial, anti-wrinkle and healing properties. The multiple properties of avocado oil such as excellent stability, emollient, effective skin penetration, softening and moisturizing ability which facilitate its broad application for cosmetic products synthesis (http://www.olivado.com/avocado_cosmetics.htm).

Solvent extraction is a viable means of extracting oil from the plant seeds. The process leaves a residue of less than 1% oil. It is one of the most efficient method uses for oil extraction from its precursor. This unit operation produces high quality oil at relatively low cost (Ochigbo and Paiko, 2011). Several studies have been documented on the extraction of oil from avocado pear (Botha, 2004; Ikhuoria and Maliki, 2007; Mostert, 2007; Akpabio *et al.,* 2011; Adama and Edoga, 2011; Gatbonton *et al*., 2013; Costagli and Betti, 2015).

Studies of the effects of process variables on the extraction of Nigeria avocado pears using Response surface methodology are rarely reported in literature. Response surface methodology (RSM) is a statistical technique used for the design of experiments and optimization of complex systems. RSM is an efficient and effective way to optimize the parameters that affect the process. This technique is used in order to find the optimize conditions when a number of factors are involved in process. It is characterize with several advantages such as it reduces process cost and process time through a reduction in the number of experimental runs. RSM is used to identify the response by using given process variables and fit an empαirical model (Bokhari *et al.,* 2012). The aim of this work is to study the optimization of the Avocado oil seed extraction using Response Surface Methodology (RSM) studying the effect of temperature and time on oil yield.

METHODOLOGY

Materials

Avocado pear, petroleum ether, Acetic acid, Chloroform, Phenolphthalein indicator, Potassium, hydroxide, Starch solution, Sodium thiosulphate, Potassium Iodide were all of analytical grade.

Methods

Raw material preparation
The avocado seed were distilled washed manually with water and sun dried for 5 days followed by oven drying. It was then ground to fine powdered particle. The powdered/ crushed seeds were sieved to a particle size of 500 micrometer sample and was stored in a polythene bag and kept in a cool place for further analysis.

Experimental design
A 2^2 RSM experimental design was used to determine the optimum yield, two variables (time and temperature of extraction) was studied at both high and low levels. The upper and lower levels were chosen considering the range commonly employed in literature.

Table 3.2: Matrix of Experimental Design

	Level				
Code	- α	-1	**0**	**1**	+ α
Time (hr)	2.59	3	4	5	5.41
Temp (C)	47.93	50	55	60	62.07

Oil extraction from seed
Ten (10) g of dried seeds was placed onto a thimble and the thimble was put into the sohxlet apparatus. The solvent (Petroleum ether) was poured into three-neck- round bottom flask that is connected to the extractor and flask along with the condenser on the top to avoid any solvent losses due to evaporation. The entire experimental set up was then placed on the temperature controller heater to provide the required temperature. The temperature was measured by a thermometer that was inserted in one of the necks of the round bottom flask. After certain interval of the time the experiment was stopped and the oil extracted by the solvent was separated using rotary evaporator under vacuum at temperature of 65 ^oC. The oil obtained after evaporation was weighed. The yield was calculated using equation (1).

Oil yield (%) = Mass of oil extracted/ mass of seed (1)

Characterization of Avocado seed Oil
The crude oil samples were subjected to various physicochemical analyses accordingly to determine its properties such as saponification value, iodine value, peroxide value, free fatty acid value, acid value, specific gravity, refractive index and viscosity using AOACS standard.

RESULTS AND DISCUSSION

Table 2: RSM Oil Extraction

Run	Tempt(^{o}C)	Time (hr)	Yield (%)
1	-	-	8.75
2	+	-	13.5
3	_	+	16.5
4	+	+	17.9
5	-α	0	10.6
6	+ α	0	12.5

7	0	- α	9.45
8	0	+ α	17.4
9	0	0	15.5
10	0	0	15.23
11	0	0	16.89
12	0	0	15.7
13	0	0	15.67

Table 3: Analysis of Variance for Petroleum Ether

Source	**SS**	**DF**	**MS**	**F-Value**	**Prob > F**
Model	103.3	5	20.66	16.35	0.001
A-temp	9.76	1	9.76	7.73	0.0273
B-time	68.4	1	68.4	54.15	0.0002
AB	2.81	1	2.81	2.22	0.1798
A^2	20.23	1	20.23	16.01	0.0052
B^2	4.1	1	4.1	3.25	0.1146
Lack of Fit	7.21	3	2.4	5.9	0.0596

Where SS=Sum of Squares, DF=Degree of Freedom, MS=Mean Squares

The experimental result for the optimization of oil extraction using a 2^2 RSM design is shown in Table 2. The result of statistical analysis of variance (ANOVA) carried out for the response evaluated to obtain the quadratic model is also depicted in Table 3. The response surface quadratic model equation for the weight percentage of oil yield as a function of temperature and time for coded factors and with actual factors is shown in the equation 2 and 3 respectively below .For coded factors

$$Y\ (\%) = 15.80 + 1.10\,A + 2.92\,B - 0.84\,AB - 1.71\,A^2 - 0.77\,B^2 \qquad (2)$$

For actual factors

$$Y\ (\%) = -263.51863 + 8.39403\,temp + 18.27862\,time - 0.16750\,temp * time - 0.068210\,temp^2 - 0.76775\,time^2 \qquad (3)$$

From the coded factors, it can be seen that only A and B has positive coefficients, which indicates that they affect the yield of oil positively. That is, the factors A and B are directly proportional to the oil yield. However, the factors, such as A^2, B^2 and AB all have negative coefficients; therefore will have an inverse effect on the oil yield. From Table 3 the model F and p- value of 16.35 and 0.001 respectively is an indication that the model is very significant. When the values of probability >F is less than 0.0500 it is an indication that model terms are significant. In this case A, B and A^2 are significant model terms while if the values are greater than 0.100 it is an indication that the model terms are not significant in this case AB and B^2 are not significant model terms. The result revealed that both temperature and time shows a significant influence on the oil yield from extraction.

Table 4: Model Response

Parameter	Values
Std. Dev.	1.12
Mean	14.28
R-Squared	0.9211
Adj R-Squared	0.8648
Adeq Precision	13.016

The Analysis of Variance shows that the model was sufficient to express the actual relationship between the yield and the significant value, with a satisfactory coefficient of determination, $R^2 = 0.9211$ which indicates 92 % of variability can be adequately explained by the model. It is also important to state that there is a quantitative agreement between R- squared and the adjusted R-squared value.

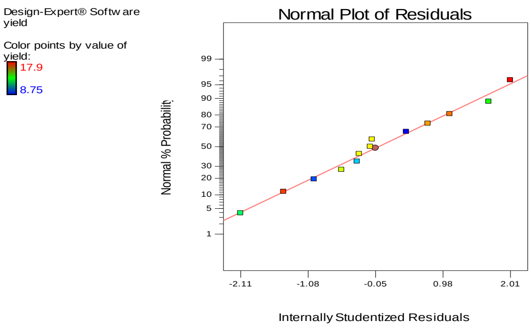

Figure 1: Model diagnostic plot

The central composite design normal probability plot of the residuals is usually an indication of the level normality of the response surface model developed. From Figure 1 shown above the approximately linear data points shows the normality of the model. According to Bokhari *et al.* 2012 when non-linear pattern are observed its signifies abnormality in the error term which may be corrected by transformation. The result obtained in this study shows no sign of any abnormality in this model.

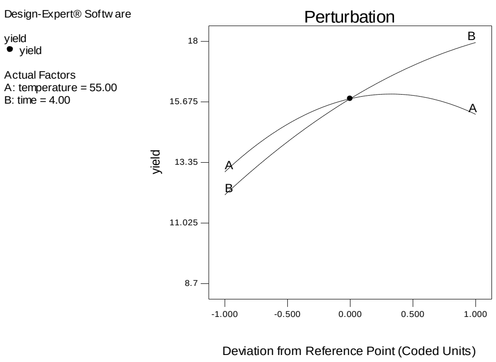

Fig 2: Perturbation Plot

Perturbation provides the outline views of the response. Perturbation plot shows how the response changes as any of the parameters moves from the reference point, with all other factors held constant at the reference value (Bokhari *et al.*, 2012). Figure 2 show that extraction time has the most pronounced effect of oil yield from the extraction process than temperature. This can be explained from the steep nature of slope when compared to slope of temperature. The yield decreases after a yield of 15 % and begins to reduce again.

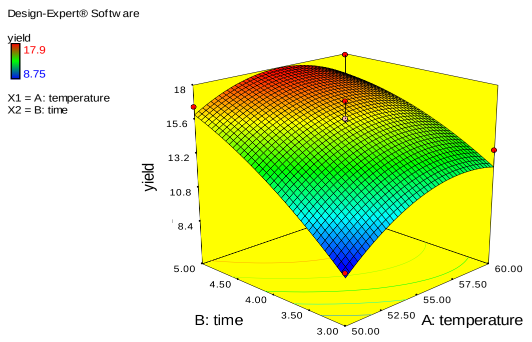

Fig. 3: 3-D plot of yield with respect to extraction time and temperature

Figure 3 shows the 3D plot of the factors with respect to the yield. From the result the extraction time is shown to be the most important factor that affects the oil yield. The oil yield increases as times increases from low to high as higher extraction time results in more oil yield. Also an increase in temperature also leads to an increase in oil yield. However, when the temperature was increased beyond the boiling point of the solvent used a reduction in oil yield was experienced due to possible loss of the solvent. It is important to note simultaneous increases in both temperature and time will simultaneously inversely affect the yield of oil.

3.2.5 Properties of Avocado Seed Oil

Table 5: Properties of from Avocado pear oil

Properties	Value
Saponification value (mg KOH/g)	198
Iodine value (gl$_2$/100g)	62.18
Peroxide value (Meq/kg)	3.07
Free fatty acid value (%)	5.4
Acid value (mgKOH/g)	6.8943
Specific gravity (@ 25^{0}C)	0.9162
Refractive index	1.465
Viscosity (mm^{2}s^{-1})	7.1

The oil content of the avocado seed was 17.9 wt%. This shows that only a slight fraction of the fruit is made up of oil. The saponification value obtained for this work is 198 mg KOH/g. Musa *et al* (2015) reported that oil with saponification value of 200 mg KOH/g indicates a high value of fatty acids with low molecular weights. This kind of oil will be good for the production of soap, shampoos and shaving cream.

The iodine value of avocado seed oil is 62.8 gI$_2$/100g. This value signifies high level of unsaturation. The oil could be classified as non-drying oil, since its iodine value is less than 100 gI$_2$/100g (Musa and Aberuagba, 2012). According to Akintunde *et al.* (2015) the European standard recommended a maximum iodine value of 120g I2/100g oil for feedstock to be used for biodiesel production. The value obtained for this study indicates that avocado oil is a viable raw material for biodiesel synthesis. This iodine value also establishes its potential for paint making (Akpabio *et al*., 2011)

The Free Fatty Acid (FFA) value of avocado seed oil is 5.4 %. The FFA of the oil is higher compared with 2.4 % for native pear oil (Akpabio *et al.*, 2011). The free fatty acid is important in determining the suitability of oil as edible oil. The lower the free fatty acid content, the more appealing the oil (Ikhuoria and Maliki 2007). The low free fatty acids of the oils (<5 %) makes them suitable as edible oils. Although, the value was slightly higher than 5 % it could also be used as edible with further refining. The free fatty acids value is low when compared to Jatropha oil and other conventional oil. The low free fatty acids content is an obvious indication of low enzymatic hydrolysis. According to Mahale and Goswami-Giri, (2012) oil with high free fatty acids develops off flavour during storage due rancidity. The oil from this study can be used for cooking and for the production of biodiesel and biodegradable lubricating oil.

Peroxide value is a valuable measure of oil quality and an indication of the ability oil to resist oxidation. The peroxide value obtained for the oil was 3.07 Meq/kg. The value obtained in the analysis is less than those reported by Akpabio *et al.*, 2012. The value is lower than 10 meq/kg set for edible vegetable oil by the Codex Alimentarius Commission. The low peroxide value obtained in this study depicts high oxidation stability and its ability to resist microbial degradation.

Viscosity is an important propertiy that measures the resistance of flow of liquids (Musa and Aberuagba, 2012). The viscosity of oil is 7.1. The low viscosity of oil bears close similarity to the viscosity of biodiesel thereby establishing the ease of by which the oil can be effectively converted into biodiesel.
Refractive index is used to check purity. The avocado pear oil had a slightly higher refractive index of 1.421. Other physical properties such as viscosity, density and moisture content were 7.1 mm^2s^{-1}, 0.9kg/m^3 and 20 % respectively.

CONCLUSION

RSM was successfully used to study the effect of temperature and time on oil extraction from avocado pear seed using the soxhlet apparatus. An empirical equation was developed for oil yield as a function of variables investigated. The optimal condition for the extraction of oil from avocado seed was at the temperature of 60 ºC and time of 5 hours, particle size of 500 µm. Oil yield in the soxhlet apparatus was 17.9 wt % The oil can be used for paint making due to its low iodine value. However, the free fatty acid value and peroxide value makes the oil a good candidate for domestic use as edible oil and also commercially for soap making, lubricant and biodiesel production.

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THE DEVELOPMENT OF A MOTORIZED CITRUS JUICE EXTRACTOR

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ABSTRACT

Juice extraction from fruits has been a worrisome problem to local farmers in Nigeria due to their perishable nature. The inability of local farmers to afford the high cost of imported juice extractor has worsen the problem. Hence, the need to look for an alternative juice extractor from locally available materials in order to reduce or eliminate the difficulty encountered in extracting juice by local means from citrus fruits like orange, red grape, tangerine e.t.c. A small scale motorized red grape and orange citrus juice extractor was developed and fabricated using locally available construction materials. the essential components of the machine includes feeding hopper, top cover, auger welded shaft, juice sieve, juice outlet, shaft outlet, gear box, main frame, pulley and bearing. In operation the auger welded shaft conveys, crushes, presses and squeezes the fruit to extract the juice. The juice extracted is filtered through the juice sieve out through the juice outlet and is collected while the residue waste (shaft) is discharge through the waste outlet. Result shows that the average juice extraction efficiency were 85% *and* 86.30% *respectively for red grape and orange. Powered by* $2H_p$ *electric motor, the machine has a juice extraction capacity of 1.27 and 1.32kg / hr for red grape and orange respectively with a machine cost of about 1300, it is affordable for small scale citrus farmers in the rural communities.*

Keywords*: red grapes, juice extractor, testing, juice extraction capacity, machine cost, and extraction efficiency.*

INTRODUCTION

Production of fruits in Nigeria can be estimated at hundreds of thousands of metric tons per year. Unfortunately over 40% are lost due to perishable nature of fruit occasioned by high moisture content and poor post-harvest handing and marketing availability (Badmus, 2004), this means that processing theses fruits to fruit juice is the next best thing to fresh fruits and the packaging can be in a septic, easily transported containers like cans that are less susceptible to damage and have a relatively long storage life. Juice extraction and separation therefore, open up new market opportunities for tailoring fruits products to modern consumer. The problem of hygiene due to local methods of handling and preservation , also with reduced rate of time wastage or drudgery in manual extraction and processing will be something of the past as this machine which is been sold at an affordable price to enable average orchard farmer or small scale industrialist is made available.

Principle of extraction

In the citrus juice processing industry there are two major ways to extract juice from fruits like grapes, orange tangerine e.t.c. one is to cut the fruit in half and remove the juice by means of a reamer which is called the Brown method. The other is hole fruit extraction which involved crushing and crushing and squeezing the peeled fruit inside the extracting chamber of the machine, this method is known as the inline method (Shigely and Mitchell, 1983). The juice extractor is made up of a power unit comprising the (electric motor gear box, belt, pulley and bearing) the feeding unit made up of the hopper with top cover through which the fruit will be introduced to the machine, the extracting unit or housing which comprises the worm shaft (auger), incorporated which presses, squeezing and conveys the pulp waste outside the unit, it is covered or housed inside a cylindrical perforated which is meant to sieve off pulp, seeds and skin, a separate juice receiver outlet and an incorporated pulp waste exit where the fruit (orange) waste will be evacuated. Fruit juices are categorized as those with and without pulp. Other classification includes natural juice (product obtainable from fresh fruits) and mixed juice (obtained from the mixing of two or more fruits of different species or by adding sugar). Juice obtained by removal of a major part of their waste content by vacuum evaporator or fractional freezing are defined as concentrated juice (Wills *et al* 1998). Juice is the fluid extracted from the cells of mature fruits, the cell wall is made of cellulose, hemicellular peptic substance and proteins (Ashurt 1999). Fruit juice extractor is an agricultural technology implement that involves the pressing of whole fruit in order to obtain the juice and reduce the bulkiness of the fruit to liquid and pulp. The advantages of using machine for extraction are time saving, improved efficiency, increase production capacity and reduction in spoilage and waste (Nidhi and Mathew 2006). Rultaceae is a large family of trees and occasional herbs, which are of great economic importance yielding the citrus fruits (lemon, grape, orange, tangerine and lime) as well. The family name is called Ruteceae while the botanical name is called citrus spp

(Otterloo, 1997). Although there are wide variation in size and shape of different citrus fruit, there is little difference in types of extraction operation used to remove juice from them,below is a flow chart showing the process through which extraction is been carried out;

$$sorting\ and\ grading$$
$$\downarrow$$
$$washing$$
$$\downarrow$$
$$peeling\ and\ cutting$$
$$\downarrow$$
$$sizereduction$$
$$\downarrow$$
$$juice\ extraction$$
$$\downarrow$$
$$sievingand\ \ clearification$$
$$\downarrow$$
$$packaging$$
$$\downarrow$$
$$storage/freezing$$

Fig1: flow chart of processing of juice Lawal(2005)

Extraction variables such as heat treatment and duration of treatment were reported to affect the color acidity and vitamin C content of grape fruit juice, however soluble solids, pHp and specific gravity of the juice are not affected by heat treatment (Akinale *et al*, 2001), smooth and Naggy reported that temperature and duration affects the total vitamin content of the grape fruit and orange juice. Miguel *et al* (2004) also inv*estigated* the effect of two extraction methods of pomegranate (punica granatum) juice on its quality and stability during storage at 4^0c was evaluated.

MATERIALS AND METHODS

Material collection: the construction and evaluation of the juice extractor materials were selected based on their availability, durability, cost and corrosion resistant properties, stainless steel were used as construction materials for the hopper and cylindrical because of the corrosiveness of grape fruit (Citrus peradisi). Stainless steel was used as construction material. For the screen (sieve) and the auger owing to its durability, strength availability and traditional use for domestic purposes.

Operation of the machine:

The component parts of the machine are: the hopper, cylinder screen (sieve), auger, frame, and shaft. Etc. the hopper was mounted on the cylinder that houses the screen (that is the sieve) which is supported by a rigid frame of angle iron. The extractor was connected electrically to the electric motor through the gear box which is connected to the electric motor via a pulley and au-belt when the 20hp electric motor is switched on, rotational motion is transferred through the pulley to the gear box and then to the shaft which in turn rotates the auger enclosed in the screen (sieve) and the squeezing, pressing, crushing as well as conveying operation on t he peeled fruits in the chamber and shaft is let out through the waste outlet while the juice obtain is let out through the juice outlet simultaneously. Hence the extracted juice is collected using a clean bucket or pan as the case may be. The juice needed to be filtered again by a 0.002mm sieve in order to remove some cloudy pulp from the fruit that may appear in the juice and it is the packaged and stored by refrigeration.

Experimental run: oranges and grape fruits 5kg each were washed and peeled using a knife poured into the clean machine. The electric motor was turned on and speed was transferred from the motor to the geer box and then the shaft which rotates the auger which in turn presses, squeezes and compress and conveys the peeled oranges against the perforated cylinder for 10mins. The juice then passed through the perforated holes of the sieve into the collector (fruit outlet) at the base of the extracting chamber and the pulp (shaft) was discharged simultaneously through the waste (shaft) outlet at the adjacent side of the juice outlet which is been collected also for appropriate disposal.

Calculations of parameters:

$$efficiency\ (\%) = \frac{weight\ of\ juice\ extracted}{weight\ of\ maximum\ extracted} * 100$$

$$efficiency\ (\%) = \frac{weight\ of\ ju\square ce\ extracted}{time\ taken\ (spent) for\ extracted}$$

All the determination were in triplicate and values obtained were statically analyzed using SPSS 10.0 for windows

Table1. Performance evaluation of the citrus juice extractor n = 3

Parameters	Mean	Grape ±SD	CU (%)	Orange Mean	Dotted line $\pm SD$	CU (%)
Mass of fruit loaded (g)	328.00	37.6	10.9	339.50	17.7	5.4
Mass of fruit extraction(g)	164.00	18.8	11.2	172.50	6.9	4.0
Time taken to extract juice in (min)	10.00	0.0	0.0	30.00	0.0	0.0
Mass of extracted juice (g)	196.50	14.0	6.2	198.60	6.1	3.4
Juice extraction capacity kg/hr		0.1	6.8	1.30	0.1	7.9
Juice extraction eff %	85.75	3.9	4.9	87.52	2.0	2.5

RESULTS AND DISCUSSION

The table1 depicts the result obtained during performance evaluation. The mean mass of grapes and oranges loaded were 328.00 and 339.50 respectively was obtained for both citru fruit, this could be attributed to the efficiency of the extractor and the time of harvesting the fruit because the fresh fruits are used.

It is believed that more juice is obtained during the reining seasons because the fruits will be fresh and succulent than the dry seasons.

However, the juice, contained macerated pulp of fruits and cloudy colour Filtration may be required to remove the tissue particles. The auger squeezes the peeled fruits so effectively that the seeds were not crushed which could affect the taste of the juice because the seeds are better when chewed over ripe and green fruits impair colour, taste and flavor and would have significant influence on viscosity and flavor of the processed juice. To provide juice for superior quality that will meet hygienic legal requirement, decay fruits and unripe green fruits should be sorted out before extraction.

The juice extraction capacity of the extractor for grape is 1.32kg/hr which was higher than that of orange which is 1.30kg-1. There was no significant difference as this was attested for by the low standard deviation and coefficient of variation (%) reported for the tow citrus fronts conclusion.

The above result shows that the extractor is effective in the production of orange and grape juices and is more effective than using hand and cup to extract juice. The extracting efficiency of machine for grape is 5.75% and for grape is 81.52%. From the same results, it is observed that this machine would solve problem of producing juices where there is erratic power supply since it has the capacity of extracting higher volume of juice per unit time.

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PERFORMANCE EVALUATION OF A PERFORATED CYLINDER TYPE CASSAVA PEELING MACHINE

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ABSTRACT

Peeling of cassava tuber at all levels is still largely carried out manually; however, this study assessed the performance of a perforated cylinder type cassava peeling machine and developed an empirical model to predict the performance of the machine. The data of physical and mechanical properties of five varieties of cassava tubers grown in Niger State were used in the design of the machine. The machine was evaluated using cassava variety - TSM 82/00661 obtained from Kure – Ultra modern market, Minna, Niger State. The performance of the machine was based on the peeling efficiency and tuber flesh loss using machine speed range of 370, 570 and 770 rpm, applied load of 5, 8, 11, 14 and 17 N. The peeling efficiency increased with increase in speed and load applied on tuber irrespective of the category of tuber diameter used. The highest peeling efficiency of 69.93 % was obtained at speed of 770 rpm, load of 17 N and tuber diameters 11 - 40 mm, 41 - 70 mm and 71 - 100 mm. The percentage of tuber flesh loss was 3.01 – 4.05 %. The developed models are adequate and valid between the predicted and the observed values. The experimental variables (speed and load) fit into the models generated with higher coefficients of determination (R^2 = 81.87 %, R^2_{adj} = 75.77 %, R^2_{pred} = 69.16 %).

Keywords: *Cassava, machine speed, applied load, peeling efficiency, tuber flesh loss, and perforated peeling mechanism*

INTRODUCTION

Cassava (Manihotesculenta) is a tropical plant which has a fibrous root system. Some of these roots develop into root tubers by the process of secondary thickening. These roots develop radially around the base of the plant forming five to ten tubers per plant. These are the main economically useful parts of the plant (Ajibola, 2000). Cassava is a popular, important food energy and commercial crop in tropical countries. There are numerous varieties of cassava in the world today and these are usually differentiated from one another by their botanical characteristic and level of hydrocyanic acid which causes toxicity in the root. This toxicity vary from place to place, for instances, a bitter variety may become sweet or vice versa. This is as a result of environmental factors such as soil type, soil moisture, soil fertility, tillage practice and vegetation of the farm (Grace, 2004). Olukunle and Oguntude (2007) further reported that soil factors would also influence shape and size of the tuber which constitutes major bottleneck in cassava peeling.

Cassava has nutritive and commercial benefits which make it attractive especially to the local farmers. First, it is rich in carbohydrates and could be enriched with other food compositions such as protein. Secondly, it is always available in all seasons, making it preferable to other more seasonal crops such as grains, peas, beans etc for food security. Compared to other crops, cassava is more tolerant to low soil fertility, and more resistance to pest and diseases. More importantly too, it thrives very well on soil so depleted by repeated cultivation that has becomes unsuitable for other crops. It also tolerates environmental stresses such as short period of drought, strong and desiccating winds (Osundahunsi, 2005).

Cassava yield varies from as low as 5 tonnes to more than 60 tonnes per hectare (CBN Newsletter, 1995; RMRDC, 2004). World production of cassava root was estimated to be 184 million tonnes (FAO, 1991). Majority of production is in Africa where 99.1 million tons are grown. Fifty-one and a half (51.5) million tons were grown in Asia and 33.2 million tons in Latin America and the Caribbean. Nigeria is the world's largest producer of cassava. However, based on the statistics from the Food and Agricultural Organization (FAO) of the United Nations, Thailand is the largest exporting country of dried cassava with a total of 77% of world export in 2005. The second largest exporting country is Vietnam, with 13.6% followed by Indonesia (5.8%) and Costa Rica (2.1%). Worldwide cassava production increased by 12.5% between 1988 and 1990 (RMRDC, 2004).

All the unit operations involved in cassava processing such as grating, drying, milling, pressing, sieving, frying and extrusion have been mechanized successfully; however, peeling remains the only unmechanized process which has constituted a serious global challenge in food industries. On the average about 20 to 25 kg of roots can be peeled in an hour. It is reported that 30 kg of fresh weight is lost during the manual peeling because woody tips are removed. The process is slow and labour-intensive, averaging 25 kg per man-hour, but it gives the best result. It is worthy to note that the major problem in cassava peeling arises from the fact that cassava roots exhibit appreciable differences in weight, size and shape (Alade, 2005). There are also differences in the properties of the cassava peel, which varies in thickness, texture and strength of adhesion to the flesh (Agbetoye, 2003). Another major constraint of cassava is that the roots deteriorate rapidly (IITA, 1990). Cassava tubers have a shelf life of 24 - 48 hours after harvest (Akintunde *et al.*, 2010). Fresh roots must be processed within 2 to 3 days from harvest to avoid deteriorating.

Thus because of the difficulties associated with cassava peeling, there is the need to develop a perforated cassava peeling machine to develop models to predict the performance of the machine.

MATERIALS AND METHODS

Material selection

The materials used for the construction of the machine were chosen on the basis of their availability, suitability, economy and viability in service among other considerations (ASAE, 2003; Gupta and Das, 1997; Sahay and Singh, 1994; Mohsenin, 1986; Khurmi and Gupta, 2007). Each component of the machine was designed following standard engineering principles (Balami *et al.*, 2012). The materials used in evaluating the machine was the cassava variety - TSM 82/00661 obtained from Kure – Ultra modern market, Minna, Niger State, Nigeria. The machine was powered by a 1 hp electric motor.

Principles of operation

The developed cassava peeling machine (Fig. 1) basically consists of the perforated peeling cylinder type which is operated by a 1hp electric motor through the pulleys by which the speed was varied. The variation in speed was achieved by varying the pulley on the driven shaft. The concept of this peeling system involves feeding the tubers in the feed tray at predetermined sizes and shapes after sorting out the cassava tubers. The perforations provided on the cylinder give rotary and linear motion on the tuber. As the tuber enters into the peeling chamber, it receives a rotary motion as a result of the rotation of the peeling cylinder which is tilted at 35˚ to the horizontal. The shear force created between the peeling cylinder and the metallic press which give support to the applied load in turn peels the cassava tuber. After that the peeled cassava tuber glides easily out through the outlet chute due to the 35º inclination of the shaft of the peeling cylinder. The peel removed is separated from the desired products into the waste section of the machine.

Figure 1: The developed Cassava Peeling Machine

Performance Evaluation of the Machine

The test was conducted using cassava variety - TSM 82/00661 obtained from Kure – Ultra modern market, Minna, Niger State, Nigeria at an average moisture content of 65 % (wet basis).

Determination of Peeling Efficiency of the Machine

The peeling efficiency *(PE)* of the machine was determined using the expression given in equation 1 (Khurmi and Gupta, 2005).

$$PE = \frac{Q_c}{Q_t} \times 100\% \qquad (1)$$

Where:

Q_c– Mass of unpeeled skin remaining on the tuber after going through the peeling process, g;
Q_t = Mass of peeled skin of the tuber after going through the peeling process, g

Determination of percentage of tuber flesh loss

The percentage of tuber flesh loss ($\%T_{f.loss}$) was determined using equation 4 (Khurmi and Gupta, 2005).

$$\%T_{f.loss} = \frac{M_{pfm} - \mathrm{M}_{ph}}{M_{pt}} \text{ x } 100\% \qquad (4)$$

Where:

M_{pfm} – mass of peel and flesh, g; M_{ph} – mass of peel removed, g; M_{pt} – mass of peeled tuber, g

Experimental Design

A two variable factorial design was used to conduct the experiment for the determination of peeling efficiency and percentage of tuber flesh loss. The parameters considered are the speed of peeling mechanism (370, 570 and 770 rpm) and applied force (5, 8, 11, 14 and 17 N).

Model Development

The assumptions made in Model Development are: cassava tubers are fairly cylindrical (this is feasible where tubers are cut into sizes in order to eliminate pronounced bends); cylinder length is 0.8 m; the applied loads are in two categories, namely 5 - 11 N and 11 - 17 N, tuber weight is between 0.5 kg to 2.0 kg, tuber diameter between 11 to 100 mm and the tubers come into the peeling chamber one at a time.

The statistical method employed is factorial design, having 6 levels of the applied load and 3 levels of the operation speed of the cassava peeling machine. The data obtained were analysed using MATLAB tools.

Quadratic model equation was finally employed after unsatisfactory use of the linear model for predicting the efficiency of the cassava peeling machine as expressed in equation 5.

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_{12} x_1 x_2 + \alpha_{11} x_1^2 + \alpha_{22} x_2^2 + \alpha_{211} x_2 x_1^2 + \alpha_{122} x_1 x_2^2 + \alpha_{1122} x_1^2 x_2^2 \qquad (5)$$

And since $y = \alpha_{211} x_2 x_1^2 + \alpha_{122} x_1 x_2^2 + \alpha_{1122} x_1^2 x_2^2$ terms are insignificant, the equation (5) was reduced to equation (6) as follows:

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \alpha_{12} x_1 x_2 + \alpha_{11} x_1^2 + \alpha_{22} x_2^2 \qquad (6)$$

Where: y = peeling efficiency of the machine (%), x_1 = speed of the machine operation (rpm), x_1 = load applied on the cassava tuber (N), α – a constant

Model Validity and Adequacy Tests

The mean of the replicated data, the individual regression coefficients and the t-values for the individual regression coefficients were evaluated by using statistical software MATLAB R 2011b. Based on the calculated regression coefficients, the model for the perforated cylinder type and diameters (11-40 mm, 41-70 mm and 71-100 mm) were developed. However, the statistical significance of each of these regression coefficients was assessed by constructing confidence interval and testing of hypothesis, using the T-test protocol, about individual regression coefficient (Spiegel and Stephen, 2008; Shangodoyin and Agunbiade, 1999).

Also the regression sum of squares (ANOVA), for individual regression coefficient (including the expunged ones) were evaluated (Owen and Jones, 1994). The adequacy of the fitted model was evaluated by testing hypothesis (F-test) on the individual regression coefficient (Dougherty, 2002; Attwood and Dyer, 1995).

RESULTS AND DISCUSSION

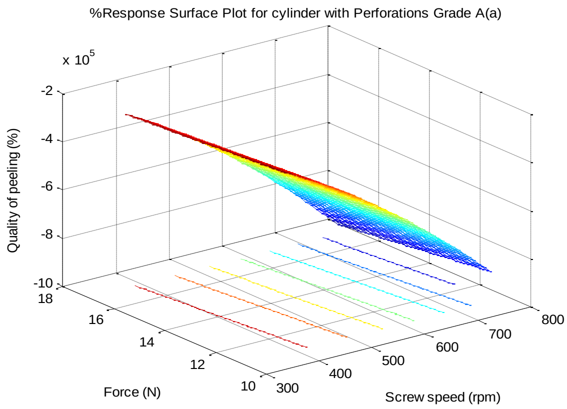
Effect of Operational Speed and Load on Peeling Efficiency

The effects of the speed of operation and applied load on the peeling efficiency of the perforated type cassava peeling machine are shown in Tables 1and 2.The peeling efficiency increased with the individual effect of speed but decreased with the applied load when above 17 N. The increase of peeling efficiency with the associated increase in speed is not unconnected with higher peeling rate of the machine at higher speed, irrespective of the applied load. The combination of speed and load, however, behaves differently as the peeling efficiency tends to increase at some instance and decrease at some instance too. The efficiency of the cassava peeling machine is an important parameter which helps in deciding the performance of the machine operation. Lower peeling efficiency implies that most of the cassava roots processed by the machine are lost in the process, and only very meagre amount of the product is usable, and this is unacceptable in machine design (Adetan*et al.*, 2005).

Effects of Operating Parameters on the percentage of tuber flesh loss

The variations of applied load and speed of operation of the cassava peeling machine on the percentage of tuber flesh loss of the different tuber root diameters, namely 11 - 40 mm, 41 - 70 mm and 71 - 100 mm are shown in form of surface response plot Figures 1 -3. From the figures 1 – 4, it can be seen that the percentage tuber flesh loss increases with increase in machine speed and load applied. It can therefore be concluded that the effect of peeling on tuber flesh loss is dependent on force applied on tuber, speed of operation of the machine, and time the tuber spent inside the machine before it is discharged from the outlet of peeling unit.

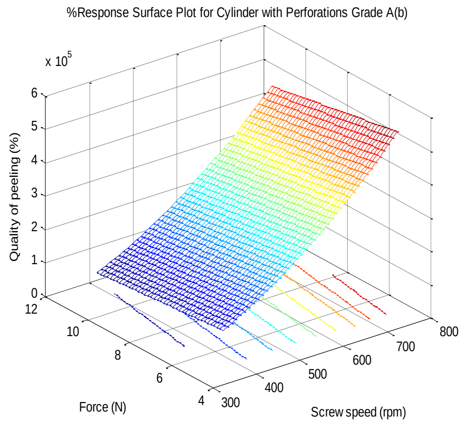
(a)



D = 11–40 mm

X_1 = 570 rpm

(b)

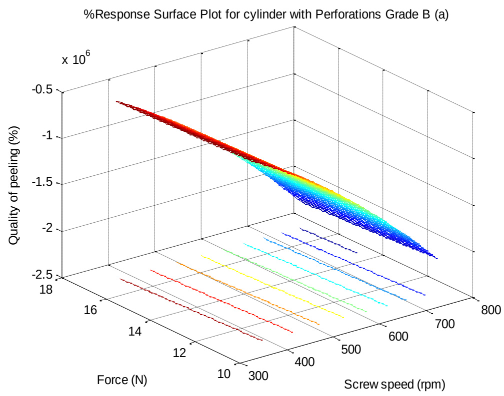


D = 11–40 mm

X_1 = 770 rpm

Figure 1: Variation of Force and Machine Speed on Percentage of tuber flesh loss (11 – 40 mm diameter) a) Load (5 - 11 N) b) Load (11 - 17 N) [D = diameter of tuber, X_1 = speed of operation, X_2 = force applied, FL = % of peel removed]

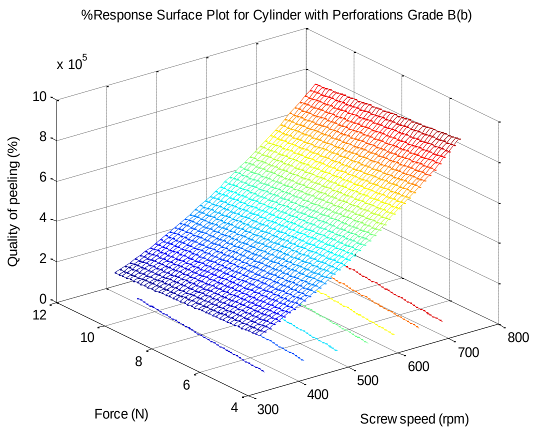
(a)



D = 41–70 mm

X_1 = 570 rpm

(b)

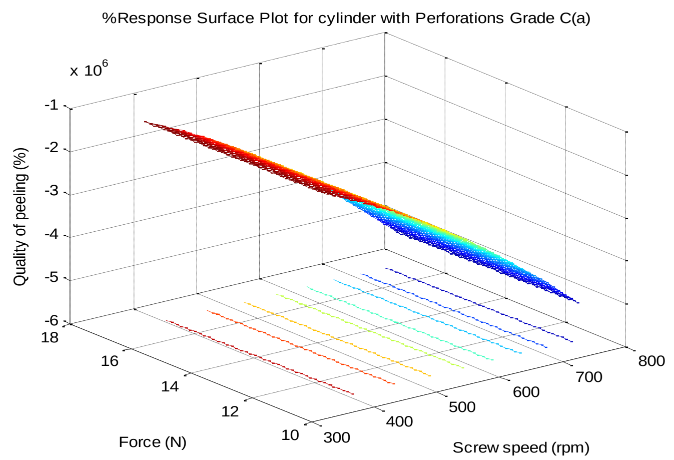


D = 41–70 mm

X_1 = 770 rpm

Figure 2: Variation of Force and Machine Speed on Percentage of tuber flesh loss (41 – 70 mm diameter) a) Load (5 - 11 N) b) Load (11 - 17 N) [D = diameter of tuber, X_1 = speed of operation, X_2 = force applied, FL = % of peel removed]

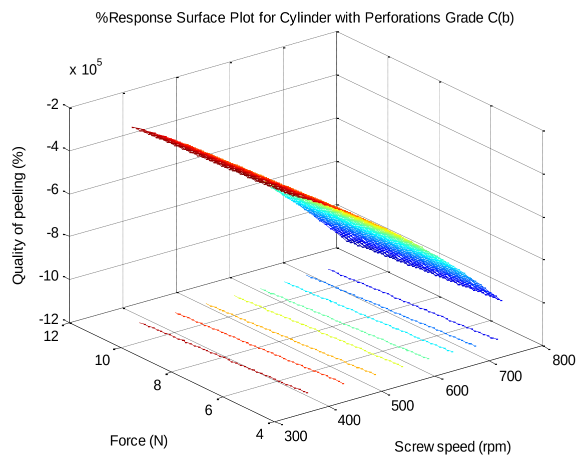
(a)



D = 71–100 mm

X_1 = 770 rpm

(b)



D = 71–100 mm

X_1 = 770 rpm

Figure 3: Variation of Force and Machine Speed on Percentage of tuber flesh loss (71 – 100 mm diameter); a) Load (5 - 11 N) b) Load (11 - 17 N) [D = diameter of tuber, X_1 = speed of operation, X_2 = force applied, FL = % of peel removed]

Model Validation of the Peeling Efficiencies of the Machine

The validation of the models developed for predicting the peeling efficiencies of the machine are shown in Figures 4.

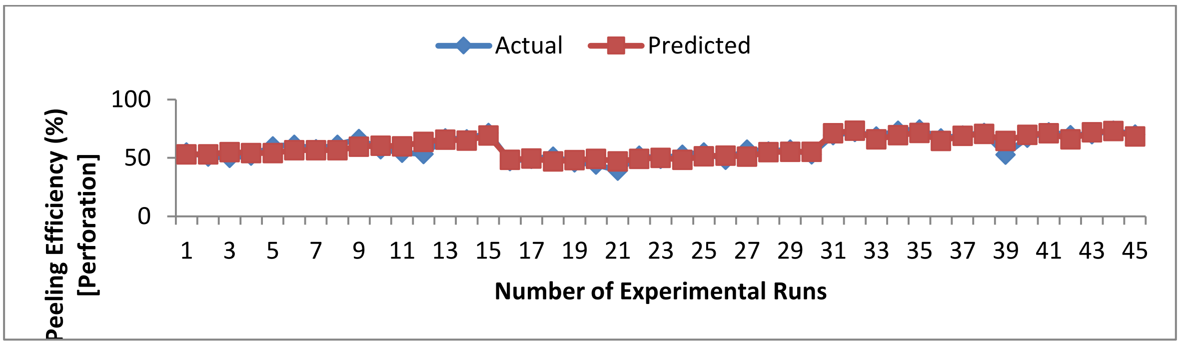


Figure 4: Validation of the Model for Predicting the Peeling Efficiency of the Machine

Model Equations for Predicting Peeling Efficiency of the Machine

The model equations for predicting the peeling efficiency of the cassava peeling machine were developed by assuming that the peeling efficiency varied as a function of the speed and the applied load on the cassava tubers subject to the 370 < speed< 770 rpm and 5 < load < 17 N as constraints. Equation 7 shows the fitted models. Also, the analysis of variance of the model for peeling efficiency prediction is shown in Table 2.

Peeling efficiency:

$$PE\ (\%) \quad = 137.49 - 0.349S + 0.534F - 0.0025SF + 0.00034S^2 + 0.0706F^2 \begin{cases} R^2 = 81.83\% \\ {R_{adj}}^2 = 75.77\% \\ {R_{pre}}^2 = 69.16\% \end{cases}$$

(7)

Where, S = operating speed of the machine (rpm), F = applied load on the tubers (N), $PE\ (\%)$ - the peeling efficiency.

Table 2 shows the analysis of variance of the quadratic model developed. The Model F-value of 13.51 implies the model is significant. There is only a 0.01% chance that a "Model F Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicating model terms are significant. In this case S, F, SF, S^2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), but model reduction may improve the model.

Model Equations for Predicting the Percentage of tuber flesh loss

The model equations for predicting the percentage of tuber flesh loss, were operated under two separate load categories (5 – 11 and 11 – 19) and were fitted in Equations (8 - 13) and results obtained were used in plotting Figures 5 - 7.

Percentage tuber flesh loss (11 – 40 mm diameter)

Machine Operation under 5 – 11 N load category

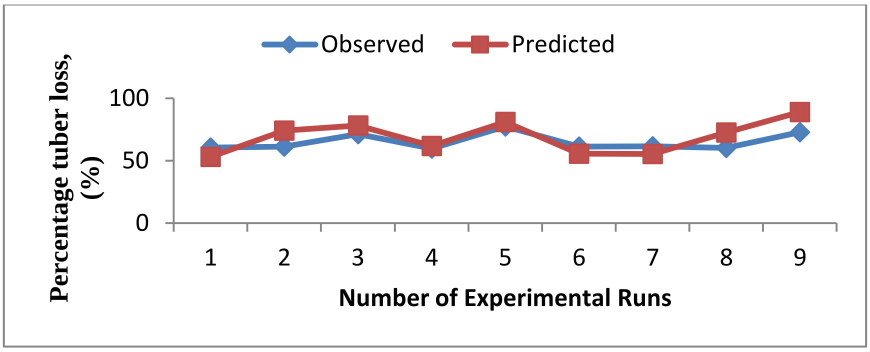
$$\%\mathrm{Tf.loss} = 65.1810 + 2.5922S + 0.1852F - 17.1688SF - 1.2432S^2 - 1.0094F^2 + 0.4859S^2F + 2.1194\,F^2S + 2.5922S^3 + 0.1852F^3 \qquad (8)$$

Machine Operation under 11 – 17 N load category

$$\%\mathrm{Tf.loss} = 58.5946 + 6.0407S + 3.3568F - 15.1153SF + 0.9946S^2 + 1.5376F^2 + 0.3464S^2F + 0.9788\,F^2S + 6.0407S^3 + 3.3568F^3 \qquad (9)$$

Validation of the Models for predicting percentage of tuber flesh loss with 11 - 40 mm diameter under 5 - 11 N and 11 - 17 N loads are shown in Figures 5.

(a)



(b)

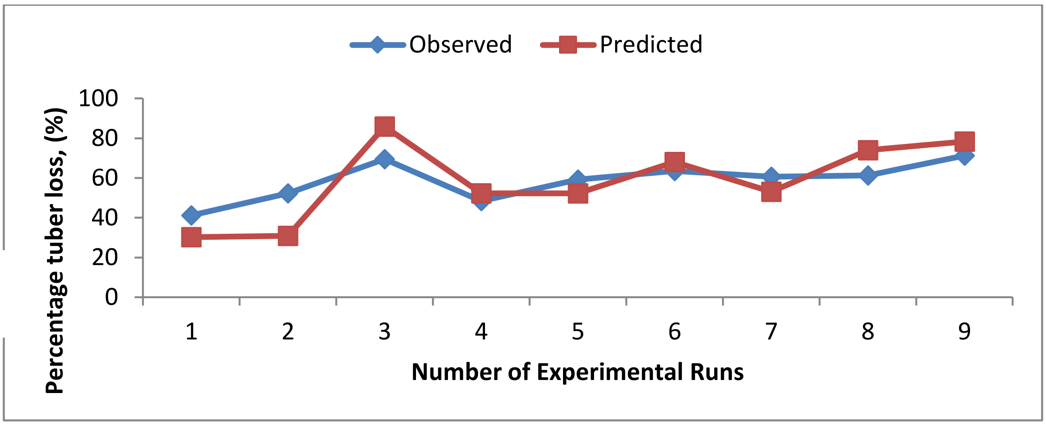


Figure 5: Model Validations of percentage tuber flesh loss with 11 - 40 mm diameter range

a) Under 11 - 17 N loading range b); under 5 - 11 N range

(ii) Percentage tuber flesh loss (41 – 70 mm diameter)

Machine Operation under 5 – 11 N load category

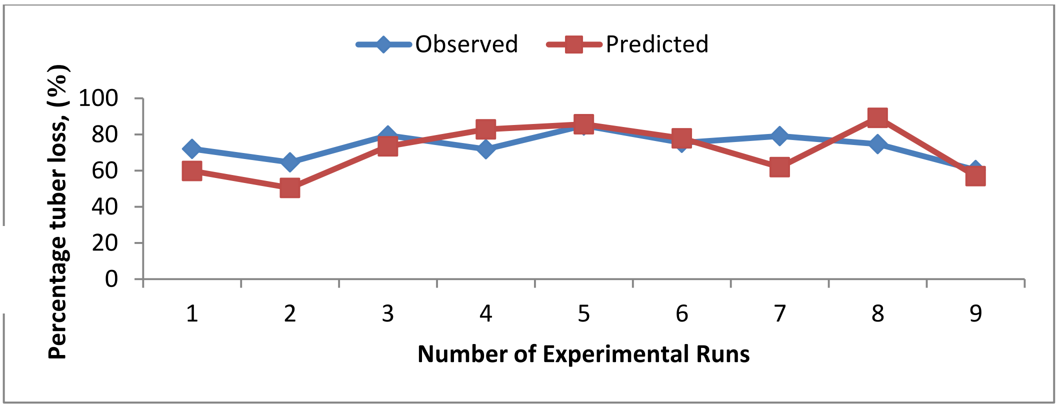
$$\%\text{Tf. loss} = 71.4184 + 1.3785S - 2.4409F - 19.5682SF - 3.3389S^2 - 5.9829F^2 - 5.8270S^2F + 0.1815\,F^2S + 1.3785S^3 - 2.4409F^3 \quad (10)$$

Machine Operation under 11 – 17 N load category

$$\%\text{Tf. loss} = 68.9971 + 2.5642S + 1.7901F - 15.6965SF + 1.5783S^2 + 0.8123F^2 + 3.4407S^2F + 1.5174\,F^2S + 2.5642S^3 + 1.7901F^3 \quad (11)$$

Validation of the Models for predicting percentage tuber flesh loss with 41-70 mm diameter under 5-11 N and 11-17 N loads are shown in Figure 6.

(a)



(b)

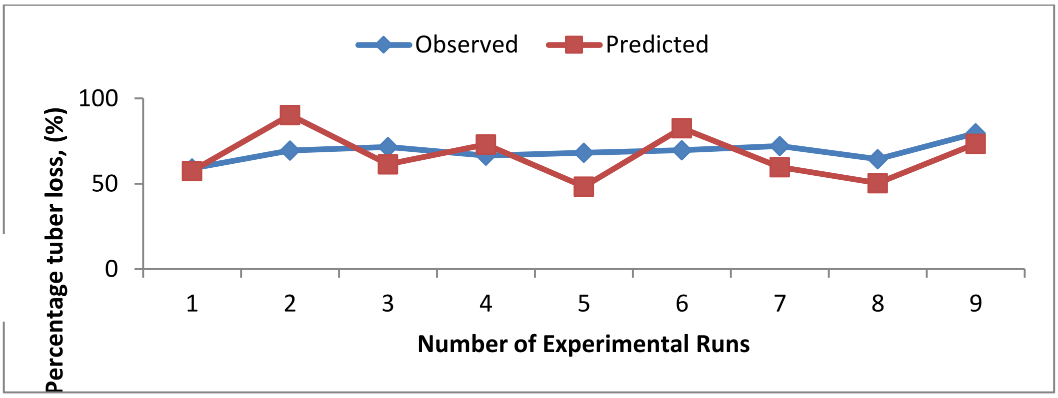


Figure 6: Model Validations of percentage tuber flesh loss with 41-70 mm diameter range

a) Under 11-17 N loading range b) under 5-11 N range

(iii) Percentage tuber flesh loss (71 – 100 mm diameter)

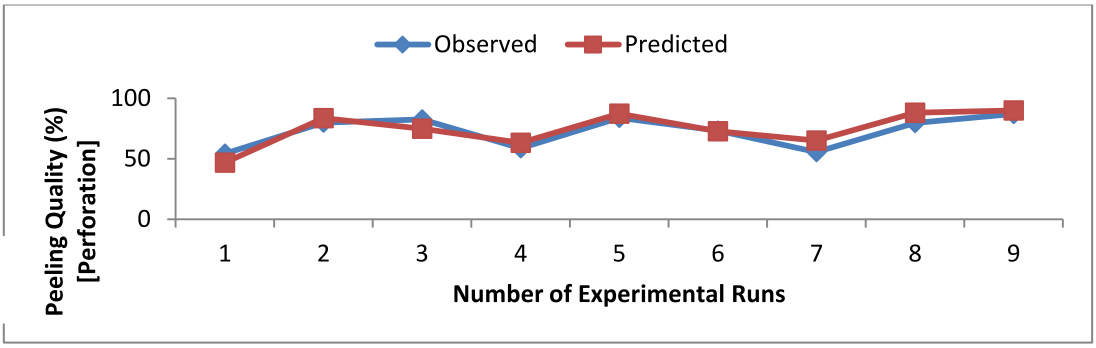
Machine Operation under 5 – 11 N load category

$$\%\text{Tf. loss} = 72.7852 + 8.2829S + 0.6045F - 18.3184\,SF - 8.4213S^2 + 0.7420F^2 + 0.6973S^2F + 3.4493F^2S + 8.2829S^3 + 0.6045F^3 \quad (12)$$

Machine Operation under 11 – 17 N load category

$$\%\text{Tf. loss} = 73.0995 + 7.5336S - 1.5844F - 14.4823SF - 1.6427S^2 + 3.0532F^2 - 3.7725S^2F + 0.1033F^2S + 7.5336S^3 - 1.5844F^3 \quad (13)$$

Validation of the Models for predicting percentage tuber flesh loss with 71 - 100 mm diameter under 5 - 11 N and 11 - 17 N loads are shown in Figure 7.

(a) 

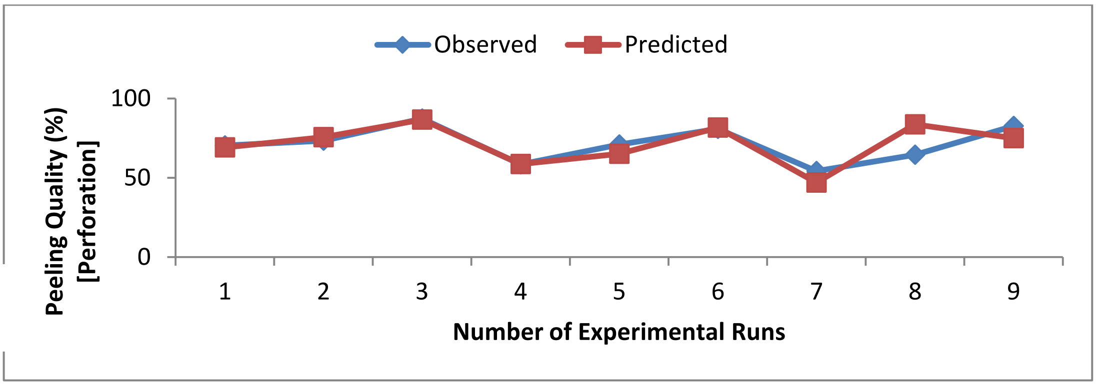
(b) 

Figure 7: Model Validations of percentage tuber flesh loss with 71-100 mm diameter range

a) Under 11-17 N loading range b) under 5-11 N range

CONCLUSION

The performance evaluation of perforated type cassava peeling machine was carried out using cassava variety - TSM 82/00661 grown in Niger State, Nigeria. The machine has 420 kg/h throughput capacity. The percentage of the cassava peel removed increased with the combined effect of the speed of operation of the machine and force applied on tuber irrespective of category of the tuber diameter used. The efficiency of peeling also increases with the individual effect of speed but decreases when the applied load is above 17 N. The models developed for predicting the peeling efficiency and percentage of tuber flesh loss are adequate and valid between the predicted and the observed values.

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Table 1: Efficiency of Cassava Peeling under different Speeds and Loads

Load, N	Speed, rpm		
	370	570	770
	Efficiency, %	Efficiency, %	Efficiency, %
5	54.62	51.22	68.49
8	51.85	39.11	66.67
11	57.41	52.66	52.78
14	57.41	57.12	69.33
17	66.67	53.11	69.93

Table 2: Analysis of variance (ANOVA) of the model for peeling efficiency prediction

Source of Variation	**df**	**SS**	**MS**	**F-Cal**	**P > F**
Model	11	3267.59	297.05	13.51	< 0.0001*
A-Speed	1	825.41	825.41	37.54	< 0.0001
B-Load	1	269.88	269.88	12.27	0.0013
C-Cylinder	2	15.31	7.66	0.35	0.7086
AB	1	129.68	129.68	5.90	0.0208
AC	2	115.34	57.67	2.62	0.0877
BC	2	6.02	3.01	0.14	0.8726
A^2	1	1855.04	1855.04	84.36	< 0.0001
B^2	1	50.91	50.91	2.32	0.1376
Residual	33	725.64	21.99		
Cor Total	44	3993.22			

* Significant at 5 % level.

DEVELOPMENT AND PERFORMANCE EVALUATION OF A PALMYRA PALM SEED CRACKING MACHINE

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ABSTRACT

The most common method of seed cracking which is still widely used in the some parts of Nigeria is by manually breaking the seed one at a time between the palms or using hard objects which is tedious, time consuming and ineffective. In view of the difficulties associated with palmyra palm seed processing, a machine for cracking palmyra palm nut was developed and tested taking into cognisance the engineering properties of the palmyra palm seed. The machine was evaluated using the seeds at three different moisture content levels of 8.09, 7.04 and 5.50 % and machine speeds of 1100, 1200, and 1480 rpm respectively. The test was replicated thrice. Also a model regression equation was also developed to help predict the optimum performance of the machine. The machine had average cracking efficiency of 64.00, 80.00 and 88.00 % at speed of 1100, 1200 and 1480 rpm respectively. However, the highest cracking efficiency of 88.00 % and lowest kernel breaking ratio of 5.50 were observed at speed of 1480 rpm and moisture content of 5.50 %. Analysis of variance results indicate that, the interaction between the speeds and moisture content has significant effect on the cracking efficiency ($P \leq 0.005$). The developed machine has a through put capacity 160 kg per day as against the hand cracker of 4 kg per day, which means that the machine could reduce drudgery, save time and encourage Palmyra palm seeds farmers to go into mass production.

Key words: *Palmyra palm seed, cracking clearance, cracking efficiency, kernel breaking ratio*

INTRODUCTION

Palmyra palm tree *(Borassus aethiopum)* grows in the tropical or sub-tropical climates. Palmyra palm consist of genus of six species of palms that grow in great abundance on fluvial flats and coastal plains, and also occurs in open secondary forest, dense forest borders and in savannah areas where it is restricted to grassland with annual rainfall of 500-1000 mm and high ground water table. It is irregular, widely distributed, typically found at altitudes of up to 400 m, but up to 1200 m in Africa and Asia. Growth of the Palmyra palms depends very much on soil conditions. Palmyra palm tree grows best in sandy and well - drained soil but prefers alluvial soils near watercourses. Prefers PH in the range 5.5- 7. Established plants are draught tolerant (Arbonnier, 2004).

The growth of Palmyra trees have been categorized into three phases. The first phase involves leaf development, the second phase involves rapid growth of the trunk above the ground and takes place from the 8 to 20 year of age. The third phase involves flowering and shedding of leafstalks (Poinar, 2002; Arnold and Mohsenin, 1971). The palmyra tree has slow growing ability and very long life, to over one hundred years (Arbonnier, 2004). A picture of the palmyra palm tree is shown in Plate I.

Plate I. Palmyra palm *(Borassus Aethiopum)* trees

Palmyra palm is common in populated areas where most of its products are used for domestic and industrial raw materials. Almost all its parts are useful in food production, such as: oils, timber, dyes, fibers, wine, and raw materials. The wood of the Palmyra palm tree have high resistant to termites and fungi, and is good in constructions and also for household furniture. The roots is used to treat stomach parasites, bronchitis, asthma sore throats and mouthwash. The leaves are used for thatching, mat, basket, fan, hat, umbrellas and writing materials. The seedlings, fruits are eaten as a food supplement and both the fruit pulp and seeds are edible. The fruit is made into soft drinks (Ogbuagu *et al.,* 2013). The fruits, seeds and kernels of Palmyra palm are shown in plate II (A, B and C).

(A)

(B)

(C)

Plate II. Palmyra palm parts: (A) Fruits, (B) Seeds and (C) Palmyra kernels

The fruit measures about 15.25 cm in diameter, has a black husk, and is borne in clusters. The small fruit are pickled in vinegar while the shell of the fruit can be punctured with a finger and the sweetish liquid sucked out for refreshment like coconut water. The top portion of the fruit must be cut off to reveal the three sweet jelly seeds socket, translucent pale-white. The jelly part of the fruit is covered with a thin, yellowish-brown skin (Sakande *et al.,* 2004). The ripened fibrous outer layer of the palm fruit can also be eaten raw, boiled, or roasted. People have perfected the art of making various sweet dishes with the yellowish viscous fluid substance obtained from a ripe palm fruit. The pulp of mature fruit is reportedly rich in vitamins A and C (Ogbuagu *et al.,* 2013).

The peeled seedling are eaten fresh or sun-dried, raw or cooked in various ways. They also yield starch. It has been proposed for commercial starch production. The top portion of the young fruit has three seeds inside, sometimes two but rarely one, in which the jelly-like seed is found. The jelly like is a famous and delicious summer food (Awal *et al.,* 1995).

Over the years the cracking of Palmyra palm seed to release the kernel is normally done manually which is tedious and time consuming. The minimum force and pressure required to break the seed is about 7.45 kN and 1.46 kN/mm^2 respectively (Eric *et al.,* 2009). Despite the numerous uses of Palmyra palm there is no machine for cracking the seeds. In view of the difficulties associated with processing of palmyra palm seed, a machine for cracking palmyra palm seed become imperative.

MATERIALS AND METHODS

Materials

The materials used were selected based on their availability, cost, suitability and viability in service among other considerations. In the design of this palmyra palm seed cracking machine some properties of palmyra palm seed were considered such as physical properties (shape, size, sphericity, surface area and weight of the palmyra palm seed), mechanical properties (compressive strength of palmyra palm seed when placed on horizontal and vertical) and hardness of the palmyra palm seed were determined as outlined by (Balami *et al.*, 2014).

Methods

Determination of Moisture Content of Palmyra Palm Seed

The moisture content of Palmyra palm seeds was determined by drying the sample in an Air circulating oven (PBS118SF, England) at 105 ^{0}C for 24 hours on wet basis. The drying condition was decided based on preliminary studies and in reference to (ASAE, 2001; Carman, 1996). In order to achieve the desired moisture level for the study, Palmyra seeds in three separate polyethylene bags were conditioned by adding a measured amount of water based on the equation (1).Each test was replicated 3 times and the mean values of moisture content were obtained.

$$Q = W_i \frac{m_f - m_i}{100 - m_f} \quad (1)$$

Where:
Q = mass of water to be added in (g),
W_I = initial mass of the sample in (g),
m_i = initial moisture content of the Palmyra palm seeds in (%) and
m_f = final moisture content, (%).

Determination of the Volume of hopper

The volume of the hopper is similar to that of trapezium and therefore determined using equation 2.

$$V = \frac{1}{2} hl(a_1 + a_2) \quad (2)$$

Where:
a_1 = length of the bottom of the hopper
a_2 = length of the top part of hopper
h = height of the hopper.
l = Length of the hopper

Pulley Diameter

The ratio of the pulley for the electric motor to that of the cracking shaft was calculated as given in equation 3 (Spott 1988).

$$N_1 d_1 = N_2 d_2 \quad (3)$$

Where: N_1 = Speed of the driving pulley, rpm; N_2 = Speed of the cleaning shaft, rpm; d_1 = Diameter of the driving pulley, mm; d_2 = Diameter of the driven pulley, mm

Tensions on belts

The tensions on the belt were determined using Equations 4 and 5 as given by Khurmi and Gupta (2007).

$$\frac{T_1}{T_2} = e^{\mu\theta_1} \quad (4)$$

$$P = (T_1 - T_2)V \quad (5)$$

Where: T_1 = tension of belt on tight side in (N); T_2 = tension of belt on slack side (N); μ = mean coefficient of friction of palmyra palm seed; θ_1 = angle of contact between motor pulley and belt in radian; v = velocity of belt m/s; P = power from electric motor.

Belt Length

The belt length was determined using equation 6 (Khurmi and Gupta 2007).

$$L = \frac{\pi}{2}(d_1 - d_2) + 2C + \left(\frac{d_1 - d_2}{4C}\right)^2 \quad (6)$$

Where: $C = 2d_1$ = centre distance in (m);

d_1, d_2 = diameters of electric motor and blower pulley, mm.

Angle of wrap

The angle of wrap between the belt and electric motor pulley was determined using equation 7 and 8.

$$\theta_1 = 180 - \sin^{-1}\frac{d_1 - d_2}{2C} \quad (7)$$

$$\theta_2 = 180 + \sin^{-1}\frac{d_1 - d_2}{2C} \quad (8)$$

Where:

θ_1 = angle of wrap between belt and motor pulley (degree), θ_2 = angle of wrap between belt and machine pulley (degree), C = centre distance between pulley, m

The approximate length of a belt

The length of the belt was determined using equation 9as expressed by Khurmi and Gupta, (2012).

$$L = 2C + \frac{1.57(D_1 + D_2)}{2} + \frac{(D_1 + D_2)^2}{4C} \quad (9)$$

Where:

L = the length of the belt,

From standard table, a belt designated as A50 was selected based on the power rating of the prime mover, the length of belt, the centre distance and the correction factor for belt and angle of wrap

Determination of force required to crack the palmyra palm seed

The force required to crack the palmyra palm seed is as given in equation 9 by Rajput (2012):

$$F = \frac{T}{r} \quad (10)$$

Where:

F = the force required to break the seed in N

T = the torque in Nm

r = the radius of the cracking mechanism shaft in m

Determination of Total Power Required by the Machine

The total power **(P_T)** required to operate the cracking machine was determined using equation 11as reported by Khurmi and Gupta (2006).

$$P_T = P_S + P_C \quad (11)$$

Where:

P_S – Power to crack the seed, watt

P_C– Power to operate the cracking mechanism, watt

But:

$$P_S = T\omega; T = Fr; F = Mg$$

$$P_C = Fr\omega$$

But:

$T = Fr$
$F = Mg$

Where:
$T = Torque$, Nm
$F =$ force required to crack the seed, N
M = Ms + Mb + Mp - masses of seeds, beaters and pulleys.
$r =$ radius of the cracking mechanism, mm
$\omega =$ angular velocity, rad/sec
g – acceleration due to gravity, m/s^2

Determination of mass of the Beaters

The mass of the beaters was determined using equation 12.

Mass of beaters (M_B) = $\delta_b(NLBT)$ (12)

Where:
$M_{B\,=}$Mass of the beaters (kg)
$\delta_{B\,=}$Density of the beaters (kg/m^3)
N - Number of the beaters
L - Length of the beaters (m)
B - Breadth of the beaters (m)
T - Thickness of the beaters (m)

Determination of the cracking shaft diameter

The diameter of the cracking mechanism shaft was determined using the expression given in equation 13 (Rajput, 2012):

$$d^3 = \frac{16}{\pi Ss}\sqrt{(K_bM_b)^2 + (K_tM_t)^2} \quad (13)$$

Where:
M_t= torsional force, *Nm*
M_b= bending moment, *Nm*
K_b= combine shock and fatigue factor applied to bending moment.
K_t= combine shock and fatigue factor applied to torsional moment.
Ss (allowable) for shaft with keyway is 40MN/m^2 (Khurmi and Gupta, 2012).

Design of the Cracking Unit Clearance

The clearance of the cracking unit is one of most important aspect in the design of a cracking machine and this was determined as reported by Onyechi *et al*. (2014) using equation 14:

$$\text{Cracking Unit Clearance} = \frac{a+b}{2} \quad (14)$$

Where:
$a =$ The major diameter of the seed (mm)
$b =$The minor diameter of the seed (mm)

Technical Characteristics

The technical characteristics of the cracking machine is shown in Table 1.

Machine Description and Principle of Operation

The Palmyra palm seed cracking machine (Figure 1) consists of the following component: hopper with cover, cracking chamber, shaft, cracking mechanism, discharge outlet, frame, adjustable plate and prime mover. The hopper is made from 5 mm gauge mild steel sheet formed into a pyramidal frustum with a top opening of 330 mm x 330 mm and a bottom opening of 250 mm x 330 mm with sides inclined at 60 degree to help the free flow of the Palmyra palm seeds into the cracking chamber. The adjustable plate is meant for controlling the amount of seeds entering into the cracking chamber which consists of a decagonal housing made from 10 mm gauge mild steel plate. There is also a horizontal shaft made from 23 mm mild steel rod attached with 2 beaters made of 15 mm diameter mild steel circular rod arranged at intervals of 180 degrees adjacent to one another. The decagonal housing is 250 mm diameter with an opening of 250 mm x 330 mm at the upper curvature where the seeds are introduced from the hopper while the lower curvature has an opening of 50 mm where the cracked seeds escape into the discharge outlet. The machine is powered by 15 hp electric motor. The frame is made from 80 mm x 80 mm mild steel angle iron to carry and support the machine components.

Operation: As the Palmyra palm seeds are introduced into the machine through the hopper, the seeds are cracked as a result of the impact caused by the fast rotating beaters against the concave. The kernels and the cracked particles are then discharge through the discharge outlet.

Figure 1.Pictorial View of the Palmyra Palm Seed Cracking Machine

Experimental Design

A two-variable (moisture content and speed) factorial design provides the framework for the experiments. The data obtained from the design matrix were fitted into regression equation to give the required model equation.

$$y_c = x_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_{12} + \beta_4 x_1^2 + \beta_5 x_2^2 + \boldsymbol{\epsilon} \quad (15)$$

y_c = Cracking efficiency

Where: $\beta_1,\ \beta_2,\ \beta_3,\ \beta_4\ and\ \beta_5$- the regression coefficient estimates

ϵ - the experimental error.

x_o − dummy variable; x_1 − moisture content; x_2 − cracking speed; $x_1 x_2$ − interactions

The experiment was carried out based on two factors and three levels of speed (1100, 1200, 1480 rpm) and moisture content (8.09, 7.04 and 5.50 %) and replicated thrice

Performance Evaluation

After obtaining some fresh Palmyra palm fruits from Wushishi main market, Niger state, Nigeria, the fruits were sorted out and cleaned before removing the cap to get to the seed. After cleaning the seeds and the fibre threads removed, 60 kg of the seeds at an average moisture of 6.88 % were divided into (10, 20, 30 kg) and fed into the machine for cracking at three machine speeds of (1100, 1200, 1480 rpm). The weight of the kernels collected at the ends of each run were recorded and the cracking efficiency, percentage cracked kernel, percentage of uncracked kernels and kernel breaking ratio were determined using the equations 15 – 18. The experiment was replicated thrice

Cracking Efficiency

The Cracking efficiency (Ɛc) was determined using equation 16.

$$\text{Cracking efficiency } (\mathcal{E}_c) = \frac{C_{udk}}{T_{fs}}\ X\ 100\ \% \quad (16)$$

Where:

C_{udk} = Total mass of cracked seeds recovered

T_{sf} = Total mass of the seeds fed into the machine

Percentage cracked kernel ($\mathcal{E}_{bk}$)

The percentage cracked kernel was determined using equation 17.

$$\varepsilon_{ck} = (100 - total\ \%\ \text{of cracked kernel}) \quad (17)$$

Percentage of uncracked Seeds

The percentage uncracked seeds was determined using equation 18.

$$\varepsilon_{uck} = (\frac{T_{us}}{T_{fs}})100\ (\%) \qquad (18)$$

Where:
T_{us} = total mass of uncracked kernels,
T_{sf} = total mass of fed into the machine

Kernel Breaking Ratio (KBR)
The Kernel breaking ratio was determined using equation 19.

$$\text{Kernel Breaking Ratio (KBR)} = \frac{C_{dk}}{C_{dk} + C_{udk}}\ X\ 100\ \% \qquad (19)$$

Where:
C_{dk} = Mass of broken kernels recovered
C_{udk} = $Mass\ of$ unbroken kernels recovered

RESULTS AND DISCUSSION
The results of the physical and mechanical properties of the palmyra palm seed used in the design of the cracking machine (Balami *et al.*, 2015) are present in Tables 1 – 3. Table 4 presents the technical characteristics of the developed machine while Table 5 presents effect of machine speed and moisture content on the cracking machine performance. At 5.5 % moisture content and operating the machine at speeds of 1100, 1200 and 1480 rpm, cracking efficiencies of 64.00, 80.00 and 88.00 % were obtained. This agreed with the work reported by Ologunagba *et al.* (2010) and Ologunagba (2012). The results also showed that the cracking efficiency increased with decrease in moisture content at constant shaft speed. At a speed of 1480 rpm, the efficiencies were 81.30, 86.67 and 88.00 % for moisture contents of 8.09, 7.04 and 5.50 % respectively. Hence, test results revealed that the optimum performance of the machine was at moisture content of 5.50 % of Palmyra palm seed and 1480 rpm machine shaft speed. The model has a P-value of 0.0202 which is highly significant indicating that both the moisture content and speed are responsible for the cracking efficiency. The interaction between the two factors speed and moisture content has significant effect on the cracking efficiency at ($P \leq 0.05$). The response surface plot (Figure 2) presents the simulated data. The model data predicted follows the pattern of the real data of the experimental data, which shows a good correlation between them. The significant of each term in the model was determined by calculating the t- statistic value and comparing it with the table t- statistic value (t_{cal}> t [$\boldsymbol{\alpha}$, N(r-1)]) at significant of 5 % significance level. Comparing each of the calculated t-statistic ($t_{(0.005,18)}$ = 1.734), the regression coefficient of $x_1$is insignificant on the cracking efficiency. It was also observed from the model equation that the speed as a singular variable (x_2) has a positive effect on the cracking efficiency. It therefore means that the higher the speed of the cracker the better the cracking efficiency.

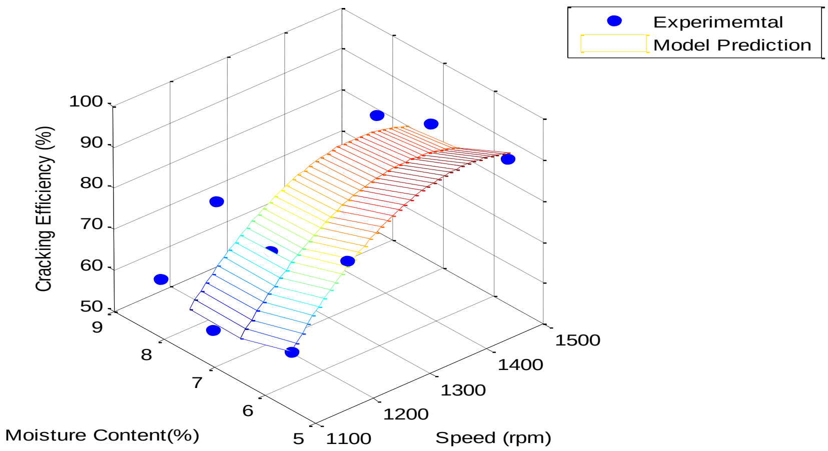

Figure 2: Response Surface Plot for the Cracking Efficiency

CONCLUSIONS
A machine for cracking palmyra palm seed was successfully developed and tested. At machine speed of 1100, 1200 and 1480 rpm and an average moisture content of 5.50 % the machine has cracking efficiency of 64.00, 80.00 and 88.00 %. The kernel breaking ratio decreases with increase in machine speed while uncracked seed percentage decreases as the machine speed increases. The developed machine has a through put capacity 160 kg

per day as against the hand cracker of 4 kg per day, which is believed will surely reduce drudgery save time. The interaction between the two factors has significant effect on the cracking efficiency at P≤0.05.

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Table 1: Technical Characteristics

Designed Parameters	Calculated Values
Shaft Diameter	23 mm
Clearance gap	7.32 cm
Total Power Required (P_T)	15 hp
Mass of the Cracking mechanism(M_D)	8.00 kg
Mass of the pulley	6.78 kg
Total torque (τ_T)	15.64 Nm
Maximum Bending Moment (M_{max})	24.28 Nm
Overall length	980 mm
Overall height	470 mm
Overall width	1130 mm

TABLE 2: Physical Properties of Palmyra Palm Seed at 3 moisture content levels

Parameter	N	Moisture content (%wet basis) 5.50	7.04	8.09
Major Diameter (cm)	20	7.75±0.73	8.65±0.69	10.89±1.66
Intermediate Diameter (cm)	20	7.22±0.79	8.00±0.80	7.76±1.93
Minor Diameter (cm)	20	6.88±0.66	7.77±0.77	9.14±1.84
Geo. Mean Diameter (cm)	20	7.25±0.67	8.16±5.04	9.11±1.53
Surface Area (cm^2)	20	167±30.30	209±79.80	270±95.90
Bulk density (c/cm^2)	20	0.35±0.11	0.24±0.06	0.33±0.14
True density (g/cm^3)	20	0.94±0.13	0.91±0.13	1.55±0.37
Porosity (%)	20	62.32±13.76	73.16±7.42	78.31±8.54
Sphericity (%)	20	0.94±0.04	0.94±0.07	0.85±0.11
Volume (cm^3)	20	134.30±16.9	137.75±16.92	141±20.08
Arithmetic mean diameter (cm)	20	7.28±0.67	8.17±0.59	9.25±1.51

N = Number of sample, Values with ± = standard deviation

Table 3: Coefficients of Friction of Palmyra Palm Seed and its Kernel at 8.09 % M.C

Properties	Mean of Seed	Max. seed	Min. seed	Mean of kernel	Max. kernel	Min. kernel
Plywood	0.36 ±0.06	0.44	0.23	0.44 ±0.03	0.51	0.38
Glass	0.25 ±0.02	0.29	0.22	0.31 ±0.03	0.36	0.26
Metal	0.34 ±0.05	0.39	0.26	0.36 ±0.04	0.43	0.26

Table 4: Mean Values of Mechanical properties of Palmyra palm seed

Parameter	Moisture content (% wb) 5.50	7.04	8.09
F at peak (KN)	6.29±0.49	6.67±0.48	8.03±1.87
δ at peak (KN/mm	0.29±0.05	0.41±0.05	0.46±0.07
F at break (KN)	7.73±0.87	8.80±0.54	10.82±0.23
δ at break (KN/mm	1.16±0.08	1.22±0.14	1.46±0.19
Deformation at peak (mm)	2.82 ±0.20	3.49±0.36	3.98±0.19
Deformation at break (mm)	3.93±0.17	3.61±0.35	4.10±0.16

F = Force, δ = Stress, Value of Standard Deviation

Table 5: Effect of Speed and Moisture Content on the Machine Performance Indices

Machine Performance Indices	Machine Speed 1100 rpm			1200 rpm			1480 rpm		
	At 8.09, % m.c	At 7.04, % m.c	At 5.50, % m.c	At 8.09, % m.c	At 7.04, % m.c	At 5.50, % m.c	At 8.09, % m.c	At 7.04, % m.c	At 5.50, % m.c
Cracking efficiency (%)	64.00	58.67	64.00	77.67	72.00	80.00	81.30	86.30	88.00
% Uncracked (%)	12.00	12,00	6.00	12.00	9.30	8,00	9.30	8.00	5.30
Kernel Breaking Ratio (KBR)	26.67	33.20	29.70	16.67	20.37	13.05	11.00	5.87	5.53

UTILIZATION OF CROP AND ANIMAL WASTES FOR SUSTAINABLE BIOGAS PRODUCTION

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ABSTRACT

Given the finitude and negative impact of fossil fuel on the environment and public health, renewable energy is becoming a favoured emerging alternative. Nigeria generates about 542.5 million tons from crops and animal wastes per annum, which in turn has the potential of yielding about 25.53 billion m³ of biogas (about 169 541.66 MWh) and 88.19 million tons of bio-fertilizer per annum. Both have a combined estimated value of about N 4.54 trillion ($ 29.29 billion). This potential biogas yield will be able to completely displace the use of kerosene and coal for domestic cooking, and reduce the consumption of wood fuel by 66%. This paper presents the potential benefits of crops and livestock wastes generated in Nigeria as a renewable source of biofuel and bio-fertilizer. Research gaps and challenges in biogas production were also presented.

***KEYWORDS:** Renewable energy, crop residue, animal waste, anaerobic digester, bio-fertilizer, biogas.*

INTRODUCTION

The high discharge rate of obnoxious gases such as carbon dioxide (CO_2), nitrogen oxide (N_2O), methane (CH4), chlorofluorocarbons (CFCs) *etc*. in the atmosphere as a result of burning of fossil fuels and other anthropogenic factors have led to increase in global warming resulting in climate change with attendant consequences of flooding, desertification, drought *etc*. The occurrence has necessitated the quest for alternative sources of fuels produced from plants and animal residues. These fuels are clean burning and result in no net increase in the proportion of greenhouse gases in the atmosphere (Ubwa *et al.,* 2013). In evaluating national development and the standard of living of any nation, the supply and consumption of energy are very important (Ukpai and Nnabuchi, 2012). Human energy consumption has been moderate before the industrial revolution in the 17th century. Sustainable resource management of waste and the development of alternative energy source has become one of the major present challenges of most third world countries due to economic growth. The history of waste utilization shows independent developments in various developing and industrialized nations. Nigerian society is today confronted with dwindling sources of fossil fuels and chemical feedstock and their proliferation of waste generated by municipalities and agricultural industries. This has brought great interest in the use of agricultural waste (from crops and animals) as substitute for fossil fuels. But the conversion of renewable sources or waste to chemicals and fuels by microbial fermentation through a biogas reactor represents a challenge in the present day and more so in the nearest future (Adeyemo and Adeyanju, 2008; Ubwa *et al.*, 2013).

However, Nigeria occupies a total land area of 91,077,000 ha with about 70% of the population involved in agricultural production (Simonyan and Fasina, 2013). Its agricultural land constitutes approximately 74,500,000 ha of the total land area. About 33% of the agricultural land is arable land, whilst 44% and 3% are permanent pasture and permanent crop areas respectively, and 12% is under forest and woodland and approximately 0.3 % is under irrigation (Agbro and Ogie, 2012). As shown in Figure 1, there is high potential for production of agricultural residues from crops and animal wastes which are biogas feedstock. It is believed that the agricultural sector is one of the country's potential sources of revenue that is yet under-developed and unexplored. The utilization of waste from plants and animals to produce energy through biogas is perhaps one of the non-exploitable areas in the agricultural sector. The use of animal manure and plants' residues as bioenergy feedstock allows farmers to take advantage of new markets for traditional waste products. In effect, transforming animal waste into bioenergy has the potential to convert the treatment of animal waste from a liability or cost component into a profit centre that can generate annual revenue, moderate the impacts of commodity prices and diversify farm income (Kothari *et al.,* 2010). In the past few decades, the country has witnessed increased level of waste generation due to increased population, agricultural activities, and growth of cottage industries (Ojolo *et al.,* 2007). A huge amount of waste is generated daily from the various agricultural farms, homes, and agro-processing industries in Nigeria. These wastes are usually disposed of either into the sea, river, or on the land, and most times incinerated, thereby releasing toxic fumes which threaten public health and as well support breeding of flies. Other fallouts include: odour emission, breeding ground for disease vectors and pathogens, uncontrolled recycling of contaminated goods and pollution of water resources (Ngumah *et al.,* 2013). What was considered as waste many years ago has now become useful such that it can be inferred in life, nothing is a 'waste'. It can only waste when there is lack of useful technology for its transformation and application.

Consequently, there is intense scrutiny of possible alternative of solid waste utilization through biogas production using organic residues of crops and animals. Governments and industries are constantly on the lookout for technologies that will allow for more efficient and cost-effective farm waste treatment (Guruswamy *et al*., 2003; Alvarez *et al*., 2006). One technology that can successfully treat the organic fraction of wastes is anaerobic digestion (Hill, 1993; Verma, 2002). It has the advantages of producing energy, yielding high quality fertilizer and also preventing transmission of disease (Koberle, 1995). Biogas provides a renewable and environmentally friendly process that supports sustainable agriculture. It refers to a gas produced by the biological breakdown of organic matter in the absence of oxygen. It provides a renewable and environmentally friendly process that supports sustainable agriculture through its generation of clean biofuel produced by micro-organisms or bacteria during anaerobic digestion of organic matter derived from liquid manure from hens, cattle, poultry, pig, sheep, dogs, and organic waste from crop stems, leaves and other residues (IFAD, 2012). Figure 2 shows the significant health, sanitation and environmental benefits that could be obtained by filtering manure into a biogas plant and converting the waste into safe fertilizer.

Biogas primarily composed of methane (which can be used for cooking), carbon dioxide (which can be used for fire extinguishers), and compost products suitable as soil conditioners on farmlands (Ojolo and Bamgboye, 2005). Manure-based biogas digester systems are considered ecological since the technology captures and utilizes methane directly, thereby limiting total greenhouse gas emissions from crops and animal residues. Consequently, its production via anaerobic digestion can be a good resource channel if properly harnessed as in the case of China and India. Moreover, the effluent of this process is a residue rich in essential inorganic elements like nitrogen and phosphorus needed for healthy plant growth known as bio-fertilizer which when applied to the soil, enriches it with no detrimental effects on the environment nor on the soil chemistry as compared to synthetic fertilizers (Bhat *et al*., 2001). This will further make up for the inadequate supply of chemical fertilizers which are somewhat expensive. The huge amount of foreign exchange invested in the importation of synthetic fertilizers can be drastically reduced by using the digestate of anaerobic digester. Harnessed biogas therefore, can either be processed and sold directly or used to generate energy, which can then be sold. Achieving solutions to possible shortage in fossil fuels and environmental problems that the world is facing today requires long-term potential actions for sustainable development. In this regard, biogas renewable energy resource appears to be one of the most efficient and effective solutions to energy problems since the electricity generating sector in Nigeria has been very inefficient with blame always going to insufficient gas supply and reduced water levels at the dams. By using this renewable resource and non-polluting technology, biogas generation serves a triple function: waste removal, environmental management and energy production. Biogas is now widely integrated with animal husbandry and can become a major means of manure treatment in the agricultural sector, thus advancing other environmental goals, namely, habitat preservation, soil restoration and watershed protection (IFAD, 2012).

Generally, exploitation of crop and animal wastes for production of biogas in Nigeria is still at the level of institutional research work and pilot schemes. Its progress being stunted by ignorance; researches at universities frequently considered as being too academic, lack of political will, and inadequate coordinating framework (Ngumah *et al.*, 2013). The objective of this paper is to highlight the amount of organic waste generated from animal and crops residues in Nigeria and the amount of biogas derivable from such generated waste, with a view to providing data required for feasibility studies in setting up a biogas scheme which would in turn proffer a feasible, sustainable, and profitable integrated biodegradable waste management system that will take care of the various endemic environmental issues which have in the past defied various treatments.

RESIDUES OF AGRICULTURAL CROPS

Nigeria has in abundance agricultural crops that have potential as biomass feedstock for biogas production. Agricultural residues are organic materials produced as by-products during the harvesting and processing of agricultural crops. They are classified into crop residues and agricultural industrial by-products (Agbro and Ogie, 2012). Crop residues in Nigeria include straw, leaves and stalk of cereals such as rice, maize/corn, sorghum, and millet, cassava stalk/peelings and cocoa pods. Agro-industrial by-products, on the other hand, are produced mainly after crop processing, they include cocoa husk, coconut shell and husk, rice husk, oil seed cakes, sugarcane bagasse, and oil palm empty fruit bunch (Dominik and Rainer, 2007; Ajueyitsi, 2009).

Agricultural residues which are produced at the time of harvest are referred to as primary or field based residues while those produced along with the product during processing are secondary or processed based residues (Simonyan and Fasina, 2013). Agricultural residues are heterogeneous, with varying bulk density, moisture content, particle size and distribution depending on the mode of handling. They are characterized by their fibrous nature, low nitrogen content and vary with geographical location (Smith, 1989). Some of the field residues are used as fertilizer, for erosion control and as fodder for livestock. According to Cooper and Laing (2007), about 50% of the residue are burnt on cropland before the beginning of the next cropping season. Process residues are known as good energy source; chemical composition of a crop residue varies depending on factors such as variety, age of residue or stage of harvest, physical composition including length of storage and harvesting practices (OECD/IEA, 2010). The production data of some of the major agricultural crops in Nigeria are shown in Table 1.

Cassava has the highest output of residues generated and its estimated value is about 42533 thousand metric tons. Crops like yam, cashew, coffee, and potato have output ranging between 220 and 600 thousand metric tons. The quantity of crop residues available for energy is highly dependent upon special environment and utilization intensity (Agbro and Ogie, 2012). Seasonal variability seriously constrains the use of residues. Estimates of crop residues availability is a function of the effectiveness of harvest methodology, the residual quantities required to protect the soil from erosion and the density and dispersion of the residue relative to the feasibility of collecting the material. In North America, 62 % of all residues occur between October and December while in Nigeria, about 80 % of the residues occur between April and September (Odia, 2006; Agbro and Ogie, 2012). The quantity of crop residues that can be realistically used is considerably less than the total produced. The ratio between main product and residue varies depending on a set of factors such as variety, moisture content, nutrient supply and use of chemical growth regulators among others. In reality, not all existing residues can be used for biogas production due to scattered abundance, technical constraints, ecosystem functions and other uses (animal fodders, fertilizer, domestic heating and cooking). The 2010 production data of some crops were combined with the residue- to-product ratios (RPR) of the different crops to obtain the amount of residues for each annual crop (Table 2) and from perennial plantation crops (Table 3). Analysis made by Simonyan and Fasina (2013) showed that the estimated total amount of crop residue that is potentially available for energy is 150 million tonnes. Using 30% conversion that is typically obtained in biomass to energy conversion systems efficiency and the heating value data, these residues can provide 0.60 EJ of energy, which is about 34% of the current energy consumed in Nigeria.

ANIMAL WASTES

Animal wastes (or manure) are mainly the droppings or excrete of livestock animals and other organic matters as bedding, feed residues *etc.*it is the most used substrate in biogas production around the world. Animal manure contains essential micro-biota for anaerobic fermentation for production of methane-rich biogas. The main constituents of animal wastes are organic material, moisture and ash. When decomposed under aerobic conditions, CO_2 and stabilized organic materials are produced while CH_4, CO_2 and stabilized organic materials are produced in anaerobic conditions. The quantity of manure produced generally depends on the amount of feed consumed, the quality of the feed and the live weight of the animal (Duku *et al.,* 2011; Simonyan and Fasina, 2013). Farm animals generate huge amount of manure daily which can be converted into biogas by anaerobic digestion. Animal wastes particularly ruminants offer potential for both direct and combustible fuel and as input to produce biogas. Figure 3 illustrates that 68% of solid bio-waste generated in Nigeria came from livestock wastes (excreta and abattoir waste), while 15%, 10%, and 7% came from crop wastes, human excreta, and municipal solid waste (MSW) respectively. Ngumah *et al.* (2013) estimated the total tonnage of bio-waste generated per annum at about 542.5 million (Table 4). This bio-waste has the potential of generating 25.53 billion m^3 of biogas, with 66% (16.66 billion m^3) coming from livestock wastes alone, while MSW, human excreta and crop residue contributed the remaining 5%, 10%, and 19% respectively (Figures 3 and 4, and Table 4).

BIOGAS TECHNOLOGY RESEARCH AND POTENTIAL IN NIGERIA

Nigeria is an energy-rich resource country in terms of both fossil fuels such as crude oil, natural gas, coal, and renewable energy resources like solar, wind and bio-mass. The urban poor and the rural households however, still depend on biomass for their energy needs. In Nigeria, identified feedstock substrate for an economically feasible biogas production includes water lettuce, water hyacinth, dung, cassava leaves and processing waste, urban refuse, solid (including industrial) waste, agricultural residues and sewage (Okagbue, 1998; Akinbami *et al.*, 2006; Ubalua, 2008). It has been estimated that Nigeria produces a minimum of 227,500 tons of fresh animal waste daily. Since 1 kg of fresh animal waste produces about 0.03 m^3biogas, then Nigeria can potentially produce about 6.8 million $m^3$of biogas every day from animal waste only. In addition, 20 kg of municipal solid waste (MSW) per capita has been estimated to be generated in the country annually (Mshandete and Parawira, 2009).Going by the 2012 census figure of 170, 123, 749 million inhabitants, the total generated MSW will be at least 2.77 million tonnes every year. With increasing urbanization and industrialization, the annual MSW generated will continue to increase (Akinbami *et al.*, 2006). Biogas production may therefore be a profitable means of reducing or even eliminating the menace and nuisance of urban wastes in many cities in Nigeria.

Although biogas technology is not common in Nigeria, various research works on the science, technology and policy aspects of biogas production have been carried out by various scientists in the country. Some significant researches have been done on reactor design by some Nigerian scientists that would lead to process optimization in the development of anaerobic digesters. For instance, the Usman Danfodiyo University, Sokoto, designed a simple biogas plant (with additional gas storage system) that could produce 425 L of biogas per day which could be sufficient to cook meals for one person (Dangogo and Fernado, 1986). Similarly, an engineering design and economic evaluation of a family-sized plant was carried out at the Technology Planning and Development Unit, Obafemi Awolowo University, Ile-Ife (Adeoti, 1998). Igoni *et al.* (2008) provided a synthesis of the key issues and analyses concerning the design of a high-performance anaerobic digester. Ezekoye and Okeke (2006) designed and constructed a plastic bio-digester and used it to produce biogas from spent grains and rice husk mixed together. The digestion of the slurries was undertaken in a batch operation and good biogas was produced. Many other raw materials available in Nigeria have been critically assessed for their possible use in biogas production by Odeyemi (1993). They include refuse and sewage generated in urban areas, agricultural residues and manure. It was concluded that poultry manure generated in homes and in commercial poultry farms could be economically feasible substrates for biogas production. The potential to utilize poultry, cow and kitchen wastes for biogas production was demonstrated by many other researchers including Lawal *et al.* (1995), Ojolo *et al.* (2007) and Zuru *et al.* (1998).

Plant materials such as crop residues are observed to be more difficult to digest than animal wastes (manures) because of the difficulty in achieving hydrolysis of cellulosic and lignin constituents with attendant acidity in the biogas systems leading to reduction and sometimes cessation of gas flammability/gas production. Flammable gas which helps in reducing forestation and desert encroachment is produced through the conversion of organic matter such as animal and plant wastes into biogas (Jewel, 1996). Ofoefule *et al.* (2010) reported that, paper waste which abounds everywhere including the immediate environment is a very good feedstock for biogas production. This waste can be utilized for energy generation instead of burning them up or having them littered around and invariably constituting a nuisance to the environment. The study has also shown that blending the paper waste with cow dung or any other animal waste will give sustained gas flammability throughout the digestion period of the waste since animal wastes are good starters for poor producing wastes. The studies on Bambara nut chaff has shown that it has potentials for biogas production though the expected increased biogas yield and extended retention time was not achieved by blending it with both animal and plant wastes. Animal wastes have shown superiority in terms of biogas production, bio-methane and energy potentials (see Table 5). A total estimated bio-methane potential of 15.65 billion m^3 per annum has an energy value of 610, 350 TJ; with livestock wastes alone contributing 10.11 billion m^3 (394 290 TJ) which is approximately 64.6% of total of potential bio-energy generated from bio-waste. The remaining 35.4% came from crop residue, human excreta, and MSW.

However, Atuanya and Aigbirior, (2002) reported the feasibility of biogas production using a biogas reactor of 3.50 L capacity. Ilori *et al.* (2007) investigated production of biogas from co-digestion of banana and plantain peels using a 10 L laboratory scale anaerobic digester. The highest volume of biogas was obtained when the banana and plantain peels were in equal proportions as feedstock. Seeding of co-digested pig waste and cassava with wood ash was reported to result into significant increase in biogas production compared with unseeded mixture of pig waste and cassava peels (Adeyanju, 2008). The potential use of local algal biomass for biogas production in Nigeria was recognized by Weerasinghe and Naqvi (1983). Odeyemi (1991) compared four other substrates, namely *Eupatorium odoratum,* water lettuce, water hyacinth and cow dung as potential substrates for biogas production. *Eupatorium odoratum* gave the highest yield of biogas and cow dung was the poorest substrate. He concluded that *E. odoratum* was a cheap source of biogas in Nigeria because of its luxuriant and ubiquitous growth. These laboratory studies demonstrated the potential of biogas production from agricultural waste, industrial and urban waste and animal waste in Nigeria. It appears that some ground works for biogas research and development have been initiated in Nigeria.

RESEARCH GAPS FOR BIOGAS PRODUCTION IN NIGERIA

In order for biogas technology research to have a positive impact in Nigeria, the relevant and appropriate areas of research need to be identified and prioritized. Prioritization of biogas technology research activities result in the selection of the optimal research portfolio given the resource constraints. Thus, resource allocations based on identified research priorities will be more efficient and responsive to the research system objectives than when resource allocation is not based on research priorities. Nigeria is endowed with abundant biomass resources which include agricultural, municipal and industrial waste and wastewater for anaerobic digestion and therefore biogas production. These resources consist of a wide range of forms and classes and fractions. Researchers need to focus on the resources sustainably available locally and carry out investigations that would result in optimized biogas production from them following the stages of anaerobic digestion. Co-digestion of these substrates would provide opportunities to optimize biogas production in Nigeria.

Although, anaerobic digestion of sewage sludge is already being practiced but most of the digesters are being operated at far below capacity and therefore there is need to carry out research focusing on improving the performance of biogas digesters at wastewater treatment plants. The biogas currently being produced at sewage treatment plants is not being utilized since most of it is vented into the atmosphere and little is sometimes being used to heat the digesters. Therefore, the biogas should be collected, utilized to generate energy.

In order to promote the implementation and proper use of anaerobic digestion technology, it is important to initiate long-term anaerobic digestion and other renewable energy training and capacity-building programmes, and to perform scientific work in this field (through appropriate research). It is important to establish contacts between research and university groups and experienced contractors, and to initiate collaboration with polluting industries, that is, to interest them in the system, either for use as an environmental protection method, or for energy production. Stakeholders and partners including farmers, extension agents, academics, processors, NGOs, donors, business and policy makers must be involved in setting research and development priorities. Involvement is essential to ensure that research is relevant to the needs of the targets and that adequate research funding is guaranteed. In addition, experts should provide reliable and pertinent information about the biogas technology and its potential to local authorities, politicians, and the public in general. It demands a lot of efforts in achieving an efficient transfer of knowledge from research centers and universities to state sanitation companies, consulting engineers' firms and government environmental control agencies. There is also need to obtain grants from the government or international organizations, and industry for pilot-plant and/or demonstration-scale projects.

Biogas energy research should be planned and conducted as the main factor leading to its contribution to the solution of the current energy problems in the country. Keeping this in mind, the results of the research should be applicable on a nationwide scale and constitute a part of the country's development plan. According to Mshandete and Parawira (2009), in many of the developing countries, there is remain of some basic research areas mostly on the quantity and potential biogas yield of fermentable organic wastes available, the size and type of biogas digesters which can be economically viable for the potential consumers of the biogas technology.

LIMITATIONS OF BIOGAS PRODUCTION IN NIGERIA

Organic waste from crop and animal residues cannot be used directly as source of energy without first being converted to a more suitable and stable form. An optimum stable condition for various agricultural wastes are essential and must be established. The constraints in utilization of crop and animal wastes are summarized as follow:

1. Availability of Manure: In order to generate reasonable and sustainable quantity of biogas, relative large size digesters are needed. This implies large quantities of manure to comply with the daily biogas need. This is a big concern for farmers when cattle's breeding is hampered by more difficulties to collect animal feedstock, water and then sustain the cattle healthy and productive. The labor need for acquisition of animal feeding material, collecting of water for mixing with animal feedstock, regular maintenance all have increased the stress to the farmers meaning that the potential biogas users required to pay more investment and operational cost.
2. Fear of food shortage: There is a certain apprehension that biogas industry would deplete the amount available food in the rural environments; that is, threat to food security.
3. Some of the wastes from crops are light and voluminous in nature, the cost of handling and transportation of these materials to site where they are finally utilized other than the site of production is of great concern.
4. The current security threat in most parts of Nigeria may cause a slowdown in the pace of biogas technology dissemination. People from unsecured areas are often hesitant to invest in long-term projects. These insecurity problems are sometimes linked with food security crisis that overwhelms economic development at various levels and may cause direct or indirect effect on biogas technology.
5. Lack of infrastructure: Due to lack of basic amenities in most rural settings, the effective development of biogas industry would be impeded.
6. Lack of skilled labour: Biogas technology requires some skills, social acceptance and mind set for reliable operation, which may not be readily available for smooth running of the industry.
7. Lack of Public support: Public support is very important in the promotion of biogas. If the people don't have confidence in investing in biogas they will continue to use diesel fuel and other none renewable energy that are already available. Spreading information about biogas and its positive effects is important. One approach is for the government to implement pilot biogas projects in rural agricultural areas to showcase the benefits of biogas technology.
8. Lack of effective and clear policies: The lack of effective and clear policies are a major hurdle to overcome in the dissemination of biogas technology. Governments need to actively set policies that promote biogas usage and encourage collaboration with governmental organizations (GOs) and non-governmental organizations (NGOs). If the Nigerian Government has little capacity of financing biogas projects collaboration with GOs and NGOs can increase chances of foreign funding and technological import. If our government doesn't have any policies to aid biogas promotion, e.g. subsidies and loans, it will be much harder for local entrepreneurs and organizations to build biogas digesters for poor rural households.

CONCLUSION

This paper focuses on the organic wastes from plants and animals as well as municipal wastes available in Nigeria, and the potential to utilize them for biogas production. There exists a great opportunity for exploitation of organic waste given the amount of energy generated from it annually. Developing alternative energy source to replace traditional fossil fuel has recently become more and more attractive due to the high energy demand, constant power failure, limited resource of fossil fuel, and environmental concerns as well as a strategy to survive post-fossil fuel economy era. Biogas has become more attractive as an alternative to fossil fuel because of its environmental benefits and the fact that it is made from renewable resources. It is very obvious that Nigeria has immense potentials for a viable, elaborate and sustainable biogas project. The conversion of crops and animal residues to biogas and bio-fertilizer is quite rewarding, given the large availability of arable lands for crops and animal production.

However, production of biogas has not been given serious implementation attention in Nigeria as if fossil fuel will last *infinitum*. Government should look inward to see that the future generations will not be put at serious disadvantage through the continued exploitation of fossil resources by exploring alternatives energy sources such as bio fuel, solar, wind tidal etc. However, a well-articulated national and rural biogas projects will not only solve the chronic solid waste management problems that has defied successive governments, but will also positively impact on the energy, agriculture, economy, public health and environment sectors. The adoption of biogas can ease the financial strain relating to the heavy burden of fossil fuel subsidy and also enhance local livelihood within the production chains. With the very high potential for biogas production, the government as well as private investors should take steps towards investing in agriculture for the production of energy crops and the establishment of biogas processing plants in Nigeria.

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APPENDIX

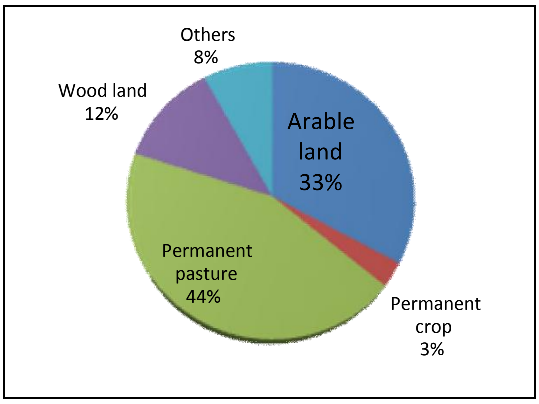

Figure 1: Land use estimate in Nigeria
(Agbro andOgie, 2012).

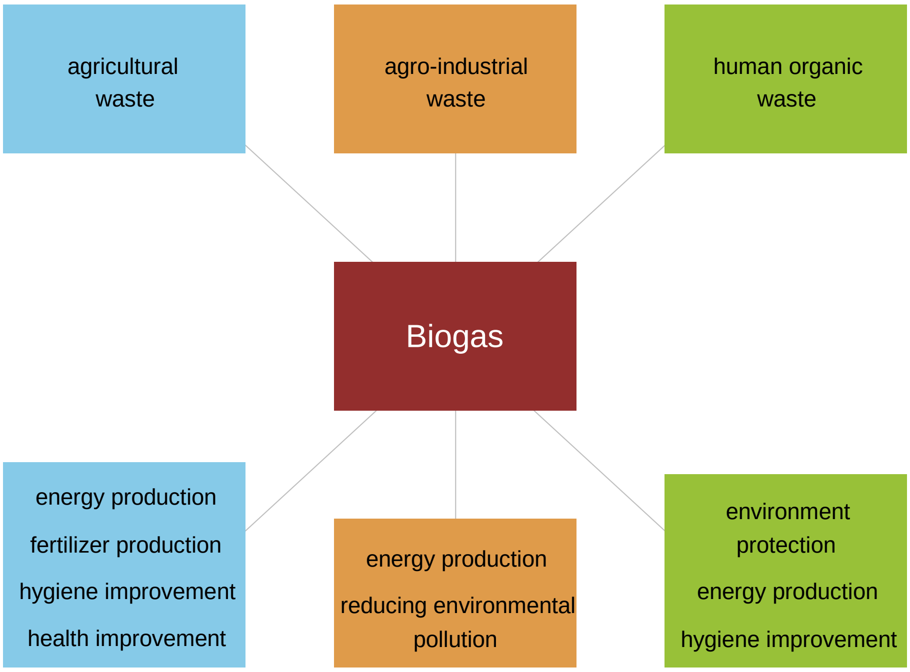

Figure 2: Multiple benefits from integrating waste flows for energy production
Source: IFAD (2012).

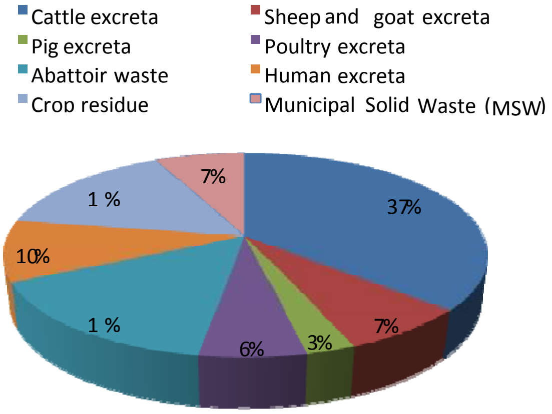

Figure 3: Sector tonnage distribution of generated organic waste in Nigeria.
Source: Ngumah *et al.* (2013).

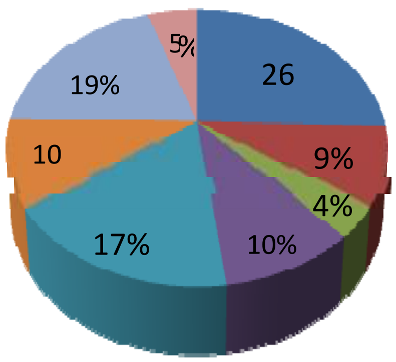

Figure 4: Sector volume distribution of potential biogas obtainable from organic waste generated in Nigeria.

Table 1.Production data for major agricultural crops in Nigeria, 2010.

Crop residue	Total production (thousand metric tons)
Cowpea	3368
Cassava	42533
Maize	7677
Cotton	602
Soybeans	356
Groundnut	3799
Sorghum	7141
Millet	5171
Rice	4473
Yam	220
Cashew	300
Plantain	9450
Coffee	400
Sugarcane	300
Oil palm	400

Potato	600

Extracted from: Agbro and Ogie (2012); Simonyan and Fasina (2013).

Table 2: Estimates of crop residues as at 2010.

Crop residue	Component	Total amount of residue (Millions tons)	Calorific value (LHV, MJ/kg)	Total available energy (PJ)
Rice	Straw Husk	7.86 1.19	16.02 19.33	125.92 23.00
Maize	Stalk Cob Husk	15.35 2.10 1.54	19.66 16.28 15.56	211.35 34.19 14.32
Cassava	Stalks Peelings	85.07 127.60	17.50 10.61	297.68 812.30
Groundnut	Shells Straw	1.81 8.74	15.66 17.58	28.35 76.83
Soybean	Straw pods	0.91 0.37	12.38 12.38	11.27 4.58
Sugarcane	Bagasse Tops/leaves	0.14 0.14	18.10 15.81	1.99 2.21
Cotton	Stalk	2.25	18.61	41.87
Millet	Straw	9.05	12.38	89.63
Sorghum	Straw	8.93	12.38	88.39
Cowpea	Shell	9.77	19.44	95.06
Total				1,958.94

Extracted from: Simonyan and Fasina (2013).

Table 3**.** Residues from Perennial Plantation Crops, 2010.

Crop type	Production (kg)	Residue	Total amount (Million tons)	Total amount available (million tons)	Calorific heat (MJ/kg)	Total energy potential (PJ)
Oil Palm	8,500,000	Fibre	1.275	1.020	11.34	11.57
		Empty bunches	1.955	1.955	8.16	15.95
	1,170,000	Palm kernel	1.170	0.878	18.83	16.53
Cocoa	360,000,000	Pods	0.202	0.181	15.12	2.74
Coconut	170,000	Husk	0.0803	0.072	18.63	1.34
		Shell	0.0376	0.028	18.09	0.51
Natural rubber	143,500,000	Leaves	0.483	0.338	17.63	5.96
Total				4.472		54.6

Table4: Potential biogas derivable from biomass generated in Nigeria

Organic waste (biomass)	**Number of Units (millions)**	**Total biomass generated (million tons year^{-1})**	**Estimated biogas potential (billion m^3 year^{-1})**
Cattle excreta	21	197.6	6.52
Sheep and goat excreta	100.9	39.6	2.3
Pig excreta	9.6	15.3	0.92
Poultry excreta	112.9	32.6	2.5
Abattoir waste	-	83.3	4.42
Human excreta	130	52	2.6
Crop residue	-	83	4.98
Municipal solid waste (MSW)	-	39.1	1.29
Total		542.5	25.53

Source: Ngumah *et al.* (2013).

Table 5: Bio-methane potential and energy values of organic waste generated in Nigeria.

Organic waste (biomass)	Estimated biogas potential (billion m^3 year^{-1})	Bio-methane potential (BMP) of biogas (billion m^3 year^{-1})	Energy potential of biogas (TJ) per annum
Cattle excreta	6.52	3.65	142 350
Sheep and goat excreta	2.3	1.61	62 790
Pig excreta	0.92	0.55	21 450
Poultry excreta	2.5	1.65	64 350
Abattoir waste	4.42	2.65	103 350
Human excreta	2.6	1.69	65 910
Crop residue	4.98	3.0	117 000
Municipal solid waste (MSW)	1.29	0.85	33 150
Total	25.53	15.65	610 350

INVASION, MANAGEMENT AND ALTERNATIVE USES OF TYPHA LATIFOLIA: A BRIEF REVIEW

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ABSTRACT
Typha spp. is an aquatic, emergent monocotyledon with linearly erect leaves and green stems extending well above the surface of the water as well as with extensive rhizomes and roots systems with well-developed vascular systems and supporting tissues. They can be beneficial or nuisance in aquatic systems depending on the defined uses of the aquatic systems. The current rate of Typha spp. invasive is historically unprecedented and threatens ecosystems worldwide. There is a lack of information on biological and ecological characteristics of Typha spp. in Nigeria wetlands. Therefore, to enable the planning of appropriate management practices, more extensive studies of Typha spp. are needed. Identifying the characteristics of Typha spp. is the first step in developing management strategies and a stepping stone to further detailed studies on Typha spp. management. This study aim to provide information that will reduce detrimental impacts of Typha spp. on water quality as well as to create wealth out of waste by establishing alternative uses of the harvested Typha biomass.

***KEYWORDS**: Typha spp.; invasion; management; alternative-uses; constructed-wetlands.*

INTRODUCTION
Water for irrigation, industrial and human use is removed from rivers, lakes, reservoirs and aquifers at large environmental cost (Greenway, 2005). This depletion of water resources have negative influence on stream flows and natural aquatic ecosystems. However, water is recognised socially, economically, and politically as a critical resource requiring sustainable management, there is need to shift away from purifying water simply to be discharged directly back into rivers and oceans, unless it assists in restoring environmental flows. The cost of wastewater reclamation and the availability of water for reuse must be affordable to the community (Greenway, 2005). Similarly, the activities of irrigation are a source of pollution into watershed/water bodies by the discharge of nutrients and salts through the application of fertilizers. Moreover, excessive nutrients may cause eutrophication and impact ecosystem health. Thus, irrigation wastewater treatment and reuse of treated irrigation water are potential solutions for addressing the water management problems of poor quantity and quality in an irrigation scheme. On the other hand, soil erosion and increased agriculture are removing nutrients from the soil, causing a depletion of fertility

There is a lack of information on biological and ecological characteristics of *Typha spp*. in Nigeria wetlands. Therefore, to enable the planning of appropriate management practices, more extensive studies of *Typha spp*. are needed. Identifying the characteristics of *Typha spp*. is the first step in developing management strategies and a stepping stone to further detailed studies on *Typha spp*. management.

The specific objectives of this review is focusing on understanding the role of *Typha* in water bodies with respect to water quality (this is critical to the development of sound management plans), secondly, to describe the problem of invasion and identify possible causes for the problem, thirdly, to discuss evolving knowledge on the management of *Typha spp*. strategies (physical and mechanical, chemical, and biological controls). To provide information that will reduce detrimental impacts of *Typha* spp. on water quality as well as to create wealth out of waste by establishing alternative uses of the harvested *Typha* biomass. This study will contribute to scientific knowledge.

TYPHA SPP.
Typha spp. (cattail genus) is a native species in the neotropics and it is considered useful and desirable in many instances (Barreto, Charudattan, Pomella, & Hanada, 2000). It is an erect, perennial freshwater aquatic herb which can grow 3 or more meters in height. The linear cattail leaves are thick, ribbon-like structures which have a spongy cross-section exhibiting air channels. The subterranean stem arises from thick creeping rhizomes (Hall, 1993).

Typha spp. is an aquatic, emergent monocotyledon with linearly erect leaves and green stems extending well above the surface of the water as well as with extensive rhizomes and roots systems (Salako, Sawyerr, & Olalubi, 2016) with well-developed vascular systems and supporting tissues (Kay, 2001). They can be beneficial or nuisance in aquatic systems depending on the defined uses of the aquatic systems (LAKEWATCH, 2007). For example, in North America, *Typha spp*. is used to stabilize shorelines and channels from wave action erosion and have been used to reduce salinity in rice fields (Apfelbaum, 1985). Also, *Typha spp*. has been used in wastewater treatment to remove nutrients, organic matter (Mustapha, van Bruggen, & Lens, 2015) and heavy metals

(Mustapha, Rousseau, van Bruggen, & Lens, 2011). *Typha* stands can increase silting, increase water loss in fields and reservoirs and hinder fishing (MPLP, 2006). Furthermore, the need to control *Typha latifolia*, and *Typha augustifolia* have simulated several researches on aquatic plants (LAKEWATCH, 2007). However, effective planning and efficient aquatic management can greatly eliminate or reduce the need for costly and time-consuming weed control practices (Peterson & Lee, 2005). *Typha angustifolia* is a native to Europe and likely came across the Atlantic in the ballast of water ships (Marsh, 2014). *Typha* is one of the most common types of moisture-tolerant plant used in constructed wetlands. They are effective in improving the quality of effluents, although, they are known to yield 200% more water loss through evaporation (Belmont, Cantellano, Thompson, Williamson, & S´anchez, 2004). In the USA, *Typha spp*. has been recognised as a particularly suitable biomass crop for wetlands, this is because of their superior productivity (40 Mg/ha standing crops), pest resistance, adaptability, and chemical composition (Pratt, Dubbe, Garver, & Johnson, 1988).

Fig 1. A colony of *Typha* spp. intersperse with open water at Bambori near Nguru. Source: (Salako, Sawyerr, & Olalubi, 2016).

INVASION BY TYPHA SPP.

Typha spp. are considered as invasive species due to its rapid spreading range and the ability to form monospecific stands that replace native plants (Selbo & Snow, 2004). The current rate of invasive species introduction is historically unprecedented and threatens ecosystems worldwide (Kellogg & Bridgham, 2004). These plants degrade biological integrity and decrease native biodiversity (Spyreas, et al., 2010). For example, *Typha spp*. tends to quickly establish, expand in numbers and ranges rapidly in the new habitat, often displacing or extirpating populations of native species in the process (Culliney, 2005). They were accidentally or deliberately introduced by humans as ornamentals or for use in aquariums from their native range South America to many parts of the world where they have become invasive (Ajuonu, et al., 2010). By the end of 1980s, many of the water bodies in West Africa were invaded by this alien plant species (Ajuonu, et al., 2010). The devastations caused by the invasive species cost national economies tens of billions of dollars annually (Culliney, 2005). For example, Ajuonu et al. (2010) reported annual losses incurred in West African due to aquatic plants invasion in the range of USD 28-56 million for fisheries, USD 4 - 6 million for health, USD 7-14 million for hydro-energy and USD 36 -76 million for agriculture.

The problems of *Typha spp*. invasion include interference with flood control, navigation, recreation (Duchatel), creates impediment of water used for agricultural and domestic purposes, disturbs fishing and farming activities, have negative consequences on income generating activities of the local communities (Birnin-Yauri, Daddy, Adesina, & Owotunse), breeding sites for vectors of disease organisms, high cost of control and change in stream ecology (Cilliers, 1989), and also it could create conditions where dissolved oxygen can reach critically low levels (Saeed & Guangzhi, 2012) and cause catastrophic fish kill. Thus, the control of alien species has become a priority for environmental management (Miyawaki & Washitani, 2004). According to Duchatel (n.d) weed control is possibly the most difficult type of maintenance required in urban wetlands coupled with high variability of the assemblages of aquatic plants and lack of effective control techniques. Thus, the best strategies for managing weed invasion are prevention, eradication and control (Culliney, 2005; Duchatel, n.d). This can be achieved by early detection and immediate response with an integrated approach to weed management encompassing all weed species, a sound understanding of the mechanisms which make them successful invaders, identifying and managing their sources and spread, and continued education and learning opportunities (Duchatel, n.d). Control measures are applied to minimise the economic and environmental impacts of a weed invasion.

Typha spp. its role in water bodies

The presence of *Typha spp*. in water bodies is vital for the conversion of solar energy into chemical energy for the development of aquatic fauna such as fish, prawns, etc. as well as for the continuous addition of oxygen to water during photosynthesis (Varshney, Suhilkumar, & Mishra, 2008). *Typha* provide breeding sites for mosquitoes (Salako, Sawyerr, & Olalubi, 2016); (MPLP, 2006), pollute water when they die (Fig. 1) and decay in it (Varshney, Suhilkumar, & Mishra, 2008), invade large areas impeding the free movement, use of water for irrigation (such as the case of Hadejia Irrigation Valley Project in Nigeria) and eliminates habitat and species diversity (MPLP, 2006).

Problems of Typha invasion and possible causes

For example, in Nigeria, the Hadejia irrigation canal is invaded by massive growth of *Typha Spp*. This can constitute a serious menace to agriculture. The growth of *Typha* in irrigation canal can reduce designed flow by 40 - 50%, this can result into forced seepage, water logging and soil salinity (Varshney, Suhilkumar, & Mishra, 2008). This invasion may be related to changes in water elevation (hydroperiod), water chemistry, nutrient loads, and other viable (LAKEWATCH, 2007); (Varshney, Suhilkumar, & Mishra, 2008). Some problems of *Typha spp*. invasion are as follows:

Organic sedimentation

This is the filling of reservoir or lake bottoms or wetlands with decomposing terrestrial and aquatic plants (both phytoplankton and macrophytes). This is more significant in warmer latitudes (such as Hadejia Nguru Wetlands), where aquatic plant productivity is enhanced by warm weather (LAKEWATCH, 2007); (Katsenovich, Hummel-Batista, Ravinet, & Miller, 2009). Active control management would be necessary to stop, reverse, or slow *Typha Spp*. succession such as keeping *Typha Spp*. populations low during the growing season (LAKEWATCH, 2007). Sediment types affect plant establishment and growth. Thus, sediment characterization should be included in the assessment of aquatic plant management options.

Plant piles

Fig. 1 showed piles of *Typha Spp*. at Bambori near Nguru. These piled *Typha* plants can create odour problems. It can also provide breeding locations for mosquitoes and other disease-carrying organisms. The dead and decay plants will add nutrients back to the wetlands (water column) which would lead to eutrophication and oxygen depletion (Saeed & Guangzhi, 2012).

Water clarity

Aquatic plants are inversely related to water clarity. Thus, as aquatic macrophyte abundance increases in a water body, water clarity (abundance of suspended solids) decreases (LAKEWATCH, 2007). This problem should be included in any aquatic plant management scheme. This is because the control of abundant aquatic plants may create another problem.

Typha spp. management techniques

The most appropriate method or combination of methods to manage *Typha* plants should carefully be chosen bearing in mind the potential impacts on non-target plants and animals as well as impacts on water uses such as irrigation, livestock watering, fishing and domestic consumption.. The management strategies for *Typha spp*. invasion include physical removal, habitat alteration, biological controls, mowing, herbicide application, grazing, shading, flooding and bio-agents (Culliney, 2005). The various management strategies are classified below. Many chemical agents are available to land managers for *Typha spp*. although glyphosate (N-(phosphonomethyl) glycine) have been reported to be most effective. However, biological agents are preferable due to minimal or acceptable side effects. Four appropriate methodologies will be discussed here: biological, cultural, physical/mechanical and chemical.

Biological control

This is the act of deliberately introducing an exotic species, such as insects and pathogens to control invasive plants populations to, and maintain them at densities that are economically insignificant (Culliney, 2005); (Goolaby, et al., 2006); (LAKEWATCH, 2007); (Varshney, Suhilkumar, & Mishra, 2008)). Other biocontrol agents include triploid grass carp, snails, manatees, ducks, geese, and tilapia. Of all the natural enemies, insects have received greatest attention as biological agents for the control of weeds and this has been used only when all cultural and chemical methods prove ineffective and expensive (Gnanarethinam & Meenakshi, 1995). Introduction of natural enemies into the invaded habitat can reduce a weed's population density to levels similar to those that naturally occur in the home range, leading to a restoration of ecological balance and recovery of the previous floral diversity (Culliney, 2005). To be effective, natural enemies must respond in a density-dependent manner to changes in the target weed's population density, thus serving to regulate the weed's abundance. For this reason, the use of higher vertebrates, such as domesticated mammals and birds, for weed control is more akin to mechanical control, as the densities of these animals are kept under the artificial control of their human handlers and are not allowed to respond, as in natural populations, to changes in density of the weed (Culliney, 2005). The disadvantages of biological control is its lack of predictability in terms of establishment and success (Goolaby, et al., 2006) and the spread of introduced pests to other localities (Cilliers, 1989).

Cultural control

***Effects on light penetration*:** All plants require a certain amount of light to grow. Light penetration can be reduced by the use of dyes, special fabric bottom covers, fertilization, and/or raising water level (Clayton, 2009). Dyes block the light plants need for photosynthesis. These dyes are not toxic to aquatic organisms, humans or animals that might drink the treated water. They are generally effective only in water greater than 3 feet in depth (LAKEWATCH, 2007). Specially made bottom covers are effective for preventing submersed aquatic plant growth. These materials also physically prevent rooted aquatic plants from becoming established. For example, Active growing *Typha spp*. was killed when completely covered for at least sixty days (Apfelbaum, 1985). However, these materials are expensive and must be maintained to prevent sediment accumulation on top of the cover. Their use is restricted to ornamental ponds, swimming areas or around boat docks (LAKEWATCH, 2007).

Water level manipulation (drawdown): This refers to rising of water levels to control aquatic vegetation either by drowning or lowering water levels to expose plants to freezing, drying or heat. For example, *Typha spp*. has been shown to decrease, sometimes remain the same or even increase after drawdown activities (LAKEWATCH, 2007); (Clayton, 2009). This method is limited by adequate water control structures, water use patterns, water rights or a predictable source of water for refilling.

Nutrient limitation

Theoretically, nutrient limitation could be used as a method of aquatic plant management by sufficiently limiting the availability of at least one critical nutrient (nitrogen, phosphorus and/or carbon) needed for growth (LAKEWATCH, 2007); (Varshney, Suhilkumar, & Mishra, 2008). Generally, *Typha spp*. can survive on very little nutrients from sediments and those in solution even in nutrient-poor wastewater such as refinery wastewater (Mustapha, van Bruggen, & Lens, 2015). Thus, nutrient limitations may not be a viable management strategy for aquatic plant control (LAKEWATCH, 2007). However, excessive nutrients should be prevented from getting into the water since it will stimulate rapid plant growth (Peterson & Lee, 2005). Also, if human inputs (such as fertilizer application) is identified as a source of nutrient availability to the water bodies then control by precipitation with agents such as alum is necessary or runoff should be prevented.

Mechanical controls

The use of mechanical method includes hand-pulling, hoeing, tillage, mowing, grubbing, chaining, bulldozing, harvesting, and draining (Culliney, 2005). The advantages of mechanical controls are immediate control of weeds in small areas and immediate use of water (Linz & Homan, 2011). The disadvantages are that it is expensive, energy and labour intensive, disrupting habitats, disturbing wildlife, and contributing significantly to soil compaction and erosion (Culliney, 2005; Linz & Homan, 2011). Aquatic weed harvesting also entails transport and disposal of the biomass removed, which would add to the cost of managing the weed (Culliney, 2005). For example, in Nigeria, the cost estimate of using mechanical and chemical control of water hyacinth was \$639 and \$161 ha^{-1}, respectively as reported in Culliney (2005). These figures indicate that both mechanical and chemical control of plant invasions over wide expanses of land or throughout extensive aqutic systems would be prohibitively expensive (Culliney, 2005).

Hand removal: This is the removal of vegetation by hand. Though, it is labour intensive. Plants such as *Typha* which can reproduce from small root fragments, require frequent removal because it is impossible to remove *Typha* without leaving root fragments in the sediment. It is also necessary to combine hand removal control with other methods, for example, hand or mechanical cutting of *Typha spp*. followed by submergence of all *Typha* stems resulted in high control with no visible *Typha* regrowth after one year and its rhizomes were dead (Apfelbaum, 1985). Selective removal of unwanted plant species is one advantage of hand removal technique.

Physical removal: Mechanical harvesters, aquatic weed cutters, or weed harvesters are machines used in mechanical control of weeds (Clayton, 2009). Mechanical control method has several advantages than other methods. These include: immediate control of weeds in small areas, immediate use of water unlike water use restrictions in the case of herbicide use and objectionable dead and dying vegetation that are associated with other methods is minimized. The disadvantage of this method are: it is expensive, are labour intensive, have high maintenance and repair costs, slower, and less efficient than other methods, may not be suitable for use in some water bodies because of water depth and presence of obstructions (Linz & Homan, 2011), the disturbance of sediment during harvesting temporarily increases water turbidity, and provision of suitable disposal site (LAKEWATCH, 2007).

Dredging: Dredging machines are used to remove vegetation and associated sediments. This is used in extreme cases when aquatic vegetation is overgrown. Dredging is expensive, with an additional cost of disposal. Dredging is usually short lived if not done deeper than the photic zone. It also needs to be followed by other methods to prevent recurrence of extreme situation. Also, careful consideration to secondary environmental effects should be considered.

Chemical control

This is the use of synthetic herbicides, which include photosynthesis inhibitors, lipid biosynthesis inhibitors, amino acid biosynthesis inhibitors, cell division inhibitors, auxin mimics, and respiration inhibitors (Culliney, 2005). They must have the capacity to be taken up by plants quickly and in sufficient amount from water. They should be toxic to the target plants and sufficiently have low toxicity to man and other organisms in the aquatic environment. In the use of herbicides, firstly the problem plant should be identified then the right labelled herbicide should then be selected (Clayton, 2009).

Chemical method is efficient in controlling weeds in limited areas (Culliney, 2005). However, they are expensive (Harris, 1989), energy and labour intensive, water use restriction immediately after application, and requires repeated applications (Linz & Homan, 2011). In addition, the problems of chemical weed control are the development of herbicide resistance in weeds and the potential for herbicides to pollute the environment, impacting non-target species and presenting a hazard to human health (Culliney, 2005). Human exposure to pesticides is extensive, and comes not only from direct occupational contact with compounds, but also from resdues found in air, water, and especially food (Culliney, 2005). The health effects resulting from exposure to herbicides include acute poisonings, longer term influences on reprodction and immune and nervous systems, and the potential induction of cancers (Culliney, 2005). Chemical control of *Typha spp*. in Nigeria is not particularly appropriate or feasible with increasing concern about environmental pollution (Harris, 1989) and the dependence on the water for domestic use by the locals in the vicinity of the project site. However, it can be applied as an immediate action.

Herbicides are short lived in the environment and they do not accumulate in organisms. The residues are subject to dispersion, dilution, sorption, uptake and degradation in the aquatic environment. Application of herbicides can result into decaying vegetation and lack of oxygen production which may cause dissolved oxygen depletion and occurrence of fish kill. However, this can be minimized with the use of herbicide that is effective on higher plants and not on phytoplankton. There are different types of herbicides available in the markets which include contact herbicides, systematic herbicides, broad-spectrum herbicides and selective herbicides. The use of chemical (dalpan spray) for the control of *Typha spp*. achieved varied success. However, the greatest control occurred where Typha stems were cut below water depths regardless of the herbicide quantity used and the poorest results were attained in areas with shallow fluctuating water levels (Apfelbaum, 1985).

Constructed wetlands for wastewater treatment

Constructed wetlands can be used for the treatment of various types of wastewater ranging from agricultural to industrial (Mustapha, van Bruggen, & Lens, 2015). They are integrated eco-systems consisting of shallow ponds or channels planted with aquatic plants (for example, *Typha spp*.), which rely on microbial, biological, physical and chemical processes to purify wastewater containing dissolved or particulate pollutants. Constructed wetlands are inexpensive (Mustapha, van Bruggen, & Lens, 2015), appropriate technological for wastewater treatment in developing country (Belmont, Cantellano, Thompson, Williamson, & S´anchez, 2004) such as Nigeria (Mustapha, Rousseau, van Bruggen, & Lens, 2011).Wetlands are lands that are wet during part or all year round (Kadlec & Scott, 2009). Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including disturbance (US EPA, 2011). Indeed, wetlands are found from tundra to the tropics and on every continent except Antarctica (US EPA, 2011). Wetlands are ecological systems that utilize natural resources involving vegetation, soils, and their associated microbial assemblages for effluent purification (Zhang, et al., 2010).

Natural wetlands have an innate ability to remediate contaminants from water. They have a higher rate of biological activity than most ecosystems. They can transform many of the common pollutants that occur in conventional wastewaters into harmless by products or essential nutrients that can be used for additional biological productivity (Kadlec & Scott, 2009). They have been used for wastewater treatment for centuries as convenient wastewater discharge sites for as long as sewage has been collected (Vymazal, 2008). Scientists and engineers have been investigating the ability of plants and inactivated bio materials as remediation alternatives for contaminated soils and waters for the last thirty years. Multiple benefits derived from wetlands are: habitat, water quality, recreation, education, CO_2 reduction, etc.

Wetland systems are exploited in wastewater management for treating a wide variety of contaminants in domestic, agricultural and industrial wastewater ((Imfeld, Braeckevelt, Kuschk, & Richow, 2009); (Marchand, Mench, Jacob, & Otte, 2010)). High success stories have accumulated with time for the developed world (Vymazal, 2008); these technologies have been largely ignored in developing countries where effective, low cost wastewater treatment strategies are critically needed (Dipu, Anju, Kumar, & Thang, 2010). Although the use of wetland system technology for water recovery from agricultural contaminated wastewater is an emerging technology, it holds promise for water quality improvement that is favourable to the environment, human health and other living organisms.

Alternative use of Typha biomass from constructed wetlands

The development of surface and subsurface flow constructed wetlands have several benefits; the gains in vegetation biomass in constructed wetlands can provide economic returns to communities when harvested for biogas production, animal feed, fibre for paper making and compost (Belmont, Cantellano, Thompson, Williamson, & S´anchez, 2004); (Greenway, 2005). Economic benefits from constructed wetlands are an important consideration in developing countries where additional incentives are required to encourage communities to maintain treatment wetlands (Belmont, Cantellano, Thompson, Williamson, & S´anchez, 2004).

Other uses of *Typha spp*.

- *Typha* can be woven into waterproof mats for side of lodges and sleeping mats
- *Typha* can be used as stuffing quilts and dolls and also for dressing wounds
- *Typha* can also be used as diet supplements
- Cooking oil and wax can be extracted from the seeds and the by-product used in cattle and chicken feeds
- Harvested biomass is a good source of plant biomass fuel (according to (Pratt, Dubbe, Garver, & Johnson, 1988) the energy content of aboveground *Typha* biomass is between 17.6 and 18.9 MJ/kg) and in Indiana (USA), (Apfelbaum, 1985) reported that *Typha* contributed 700 kg of biomass per hectare where it grew in monocultures.
- *Typha* provide a source of cellulose pulp for industry
- Studies in Mexico show that woven *Typha* leaves coated with plastic resins have potential as place mats, building siding and roof tiles
- Rhizomes of *Typha* contain high content of starch and sugar (Pratt, Dubbe, Garver, & Johnson, 1988) which is yet to be utilized.
- *Typha* absorb nutrients from wastewater, harvesting *Typha* spp. by cutting can reduce the nutrient concentrations in the irrigation canal which can then result into better water quality (Mustapha, van Bruggen, & Lens, 2015).

Fig. 2. Uses of *Typha* plant. Source: http://urbanprepperchick.blogspot.com.ng/2015/03/things-you-can-make-with-cattail.html

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COMPARISON OF DIFFERENT METHODS OF DETERMINING INFILTRATION RATES USING DIFFERENT MULCH MATERIALS IN A SEMI-ARID ENVIRONMENT

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ABSTRACT

Soil organic additives such as mulches improve soil quality and reduce soil negative environmental problems. Previous studies have documented the significance of mulches in modifying soil infiltration. Different methods of measuring soil infiltration characteristics are also reported. This study explored the effect of different methods of measuring infiltration rates and various Mulch materials on the infiltration characteristics of sandy loam soil. The study found that more reliable results were obtained using double ring infiltrometer. Sawdust mulches best improved the soil condition that offered best infiltration results. The interactions of double ring infiltrometer method and sawdust mulching presented best infiltration rate results. The results show the significance of this common traditional practice of mulching in arid and semi-arid regions, and stressed the need for prudent selection of tools when measuring soil infiltration characteristics. Results from such measurements could be used to improve choice of materials for optimal decision-making in working out plants-soil-water dynamics problems.

***Keywords**: Infiltration characteristics, Methods of measuring infiltration rate, Mulching, Sandy loam soil, Semi-arid region, Nigeria*

INTRODUCTION

Infiltration is the process of vertical entry of water from the ground surface into the soil (Igbadun and Idris, 2007). It is one of the core elements of the hydrologic cycle and has been described using many different equations. It is influenced among other factors by many soil and water management practices such as soil tilth (Abdu Samari, 2002), Mulching (Sujaul et al. 2012), soil texture (Dibal et al. 2010), planting cover crops (Szabó et al. 2015) and water stream size (Dibal et al. 2010).

The knowledge of soil infiltration characteristics is a key element in soil and water management decision making and practices, especially, in irrigation, drainage, erosion, and flood control designs. Hence, an accurate instrumentation and/or prediction of soil infiltration rate is an essential tool in planning and designing of water resources systems (Parhi, 2014). For instance, Tuffou and Bonsu (2014) show that rate of infiltration defines the roadmap for the prediction of flooding, erosion and pollutant transport. Infiltration rate is also necessary for the computation of reference evapotranspiration (ETo), a factor that determines the availability of water for crop growth and irrigation water requirement. Bloem and Laker (1994) had indicated the critical position of infiltration rate data in establishing the intake opportunity time and consequently controlling the advance rate and avoiding excessive deep percolation and runoff during irrigation exercises. Understanding the soil's infiltration characteristics hence occupies a central position in managing soil-plant-water dynamics (Khatri and Smith, 2005).

Many attempts were made to estimate soil infiltration rate using models (Igbadun and Idris, 2007; Tuffou and Bonsu, 2014), and physical measurements (Mudiare and Adewumi, 2000) even though the performance of many infiltration equations are questionable due to the inherent modeling difficulties (Tuffou and Bonsu, 2014). An accurate method for predicting the real infiltration process correctly is, therefore, required for a detailed investigation of soil infiltration characteristics to inform planning in soil and water management.

The accuracy and reliability of any measured data is however, often a subject of human factors, but most importantly, a subject of the tool used in the measurement. Many methods for estimating/ measuring soil infiltration exist, they include the single ring infiltrometer (Gregory et al., 2005), double ring infiltrometer (Selim, 2011), tube infiltrometer, sprinkling type infiltrometer (Amin, 2005), tension infiltrometer (Hillel, 1998) and the furrow inflow-outflow method (Dibal et al., 2014) among others. Many merits and demerits are associated with any method chosen. For instance, Selim (2011) reported the single ring infiltrometer to have over -estimated the infiltration rates by 20 - 30 %. This, he said was due to small diameter (15 - 30 cm) of the ring. Similarly, variations in the soil bulk density were reported to influence the precision in the furrow inflow-outflow method. On the

other hand, many mulch materials such as rubber, farm yard manure, poultry droppings, recycled wastes, sawdust, pine straw, dyed, plastic, shredded, grass, compost, and hay among others are conventionally used as biological measures mulching, for effective reduction in risks of water runoff and soil erosion, improving soil quality and ultimately, increase crop yields (Junge 2007). The purpose of the mulching and the soil-mulch interaction advantages informs which material to be used.
Despite the foregoing facts, there exist a gap in knowledge related to optimal method of measuring soil infiltration and mulch material that gives a reliable soil infiltration characteristics in Maiduguri and environs. A precise method for measuring /predicting the real infiltration process correctly is, therefore, required for a detailed investigation of soil infiltration characteristics to direct optimum soil management and irrigation system plan and modifications.

Thus, this study was conceived to gain understanding on the variations of soil infiltration rate under different methods of determining infiltration rate using different mulching practices in a semi-arid environment.

MATERIALS AND METHODS

Study Area

This study was conducted during the dry season of 2014 through 2015 in the Maiduguri, northeastern region of Nigeria. The area lies between 11.5oN and 13.5oE with mean elevation of 345 m above mean sea level. No rainfall was recorded during the study period. The climate of the environment is semi arid and is characterized by distinct wet and dry seasons. The land cover is an open grass Sahel savanna, with scattered trees and bushes. The soil type is sandy loam. Annual rainfall of the region is about 300-500 mm and average daily temperature ranging from 22-35^oC, with mean of the daily maximum temperature often exceeding 40^oC (Dauda and Samari, 2002).

Treatments and Experimental Design

The experimental factors were methods of determining infiltration rates and mulching materials each at three levels. The methods testes were the single ring infiltrometer, double ring infiltrometer and the furrow inflow-outflow methods. While zero mulch (control), saw dust and poultry litter mulch constituted the mulch treatments. Three replications were used to make a total of 27 treatments laid in a randomized complete block design (RCBD)

Experimental Procedures

Single Ring Infiltrometer Experiment

The land was cleared to be devoid of foreign materials such as stones, woods, and plastics. The mulched plots were prepared some two weeks before the experiment to allow for initiation of biological actions. During the experiments, a wooden bar (65 cm long and 15 cm thick) was first placed on the galvanized metal ring (60 cm in diameter and 90 cm deep) at the experimental site. The wooden bar served as an impact absorber material. A mallet was used to hit the impact absorber placed on the ring thereby driving the rring into the soil. Hitting continued until 20 cm of the metal ring was driven into the soil. The hollow cavity was the filled with water and a stop watch was started. The measurements were made by observing the changes in the water level in the ring as indicated on the measuring rod during a certain interval. The measurements continued until the infiltration rate became steady. The time intervals used were (2, 5, 10, 20, 30, 45, 60, 60, and 60 minutes) that took approximately five hours. The same procedure was followed at all the plots. The infiltration (mm), infiltration rate (mm/hr) and the cumulative infiltration (mm) were measured as detailed in Selim, (2011) and Brouwe et al. (2016),

Double Ring Infiltrometer Experiment

This is similar to the single ring experiment, except that the double ring involved two rings (outer and inner rings). The outer ring was 60 cm in diameter and 90 cm deep and the inner ring was 30 cm in diameter and 90 cm deep. The outer ring was first filled with water, then the inner ring. All measurements are the same as in single ring method.

The Furrow Inflow-Outflow Method

This method involved the use of three adjacent furrows, each 30 m long and water was flown into them at 2.5 l/s. Two 10-cm cut-throat flumes were installed some 5 m from entry at the upstream and 5 m before the tail end of the middle furrow and the inflow of water at the upstream and outflow at the downstream were measured there from. Effectively, 20 m length was used for this exercise. The two outer furrows were used to minimize lateral outflow of water from the middle furrow. A stop watch was used to measure time interval between successive infiltrations. The heads, H, at the upstream and downstream were used to calculate the inflow and outflow of the 30 m furrow. The equation CH^n was used for the calculation of the outflow, where C is coefficient of discharge, and 'n' is an exponent. The flume was earlier calibrated and the values of 'C' and ' n' were found to be 0.719 and 4.724 respectively. The difference between inflow and average outflow yielded the average infiltration rate.

The average infiltration/30 m is a product of time interval and average infiltration rate, and the successive summation of average infiltration resulted into the cumulative infiltration. The infiltration rate l/min (volume/time) was converted into mm/hr (depth/time) by dividing by the area covered by the furrow (Dibal et al. 2015)

Data Analysis

All data collected were analyzed with the General Linear Model (GLM) procedure using Design Expert Statistical Package. Treatment means were compared by using the Least Significant Difference (LSD) test at 0.05 probability levels

RESULTS AND DISCUSSION

Table 1 presents the influence of different methods of determining infiltration rates and Mulching on infiltration characteristics of Sandy loam soil. The Table shows that the effects of all the methods and the mulches applied were significantly different. The furrow inflow-outflow method resulted into highest infiltration rate, I.R. (28.735 mm/hr) and highest cumulative infiltration C.I. (703.523 mm). This was closely followed by the Single ring infiltrometer method. But all the I.R. values are within the standard infiltration rates values as provided by Brouwe et al. (2012) (Table 2), A close look however revealed that the furrow inflow-outflow method nearly over estimated the I.R. values. This is attributed to the loose condition of the soil that allows for two dimensional (lateral flows and vertical flows). The lateral deviation is due to sorption and capillary forces of the adjacent dry layers of relatively higher hydraulic conductivity.. The lateral flow causes the steady infiltration rates that are quickly approached to be very much greater than the infiltration capacities or hydraulic conductivity values of the soils Selim (2011) reported that loose soils favors lateral flows of water, thereby resulted elevated I.Rs and C.I values.. The Single ring methods also had similar results. This is due to absence of the outer ring that minimizes lateral flows from the inner ring. Similar results were observed with other I, and C.I. Apparently the Double ring performed best in measuring the infiltration characteristics. (Lai and Ren (2007) also reported similar experience

Table 1: Effects of different methods of determining infiltration rates and Mulching on some infiltration characteristics of Sandy loam soil

	Infiltration I, (mm)	**Infiltration rate I.R.**	**Cumulative infiltration**
Methods			
Single Ring	**23.011b**	**26.010b**	**390.140b**
Double Ring	**22.323b**	**24.384b**	**334.161b**
Furrow inflow-	**43.994a**	**28.735a**	**703.523a**
SE	***2.030***	***0.827***	***36.036***
Mulching			
Zero mulch	**30.428a**	**20.245a**	**408.928c**
Sawdust	**30.798a**	**24.891a**	**565.291a**
Poultry Litter	**28.145b**	**24.436**	**459.035b**
SE	***2.029***	***2.511***	***72.711***

Table 2: Basic Infiltration Rates for Various Soil Types

Soil type	**Basic infiltration rate (mm/hour)**
Sand	less than 30
sandy loam	20 – 30
Loam	10 – 20
clay loam	5 – 10
Clay	1 – 5

Source: Brouwe et al. (2012)

The sawdust mulch resulted into higher I.R (24.436 mm/hr) relative to other mulches. The zero mulch (control) had the lowest I.R value. Similar results were observed with I and C.I. values.

This points that the soil was initially compacted, and the Poultry litter mulch might have increased the clay content of the soil that caused clogging and thereby depressed the infiltration characteristics values. Conversely, the sawdust must have increased the porosity of the soil that allows for more water infiltration.

Interactive effects of different methods of determining infiltration rates and Mulching on some infiltration characteristics of Sandy loam soil

From Figures 1, it obvious that the interactions of the single ring and zero mulching resulted into the highest infiltration rates (34.75 mm/hr), followed by the interactions of and Furrow inflow-outflow method and the zero mulching (30.5 mm/hr), but the values are rather on the higher side relative to the standard infiltration values in Table 2.

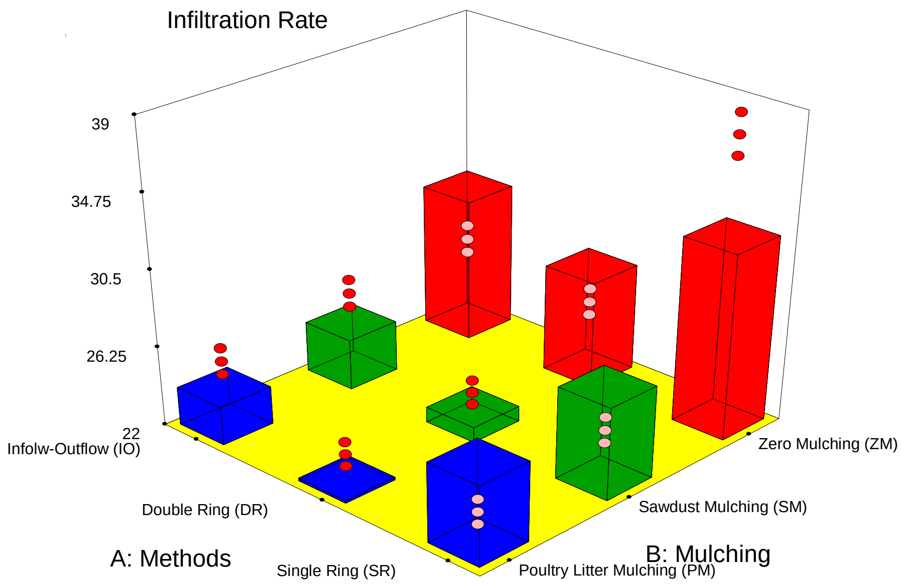

Fig. 1: Interaction effects of Mulching and Methods on infiltration rates

The interactions of the double ring method and the poultry litter mulching turned in to the lowest infiltration rate values. The interactions of inflow-outflow method with sawdust mulching appeared to be within the standard range of 20 – 30 mm/hr (Table 2). Similarly, cumulative infiltration was highest due to the interaction of the zero mulching and the inflow-outflow method, and it is least from the interaction of the double ring method with poultry litter mulching. (Fig. 2)

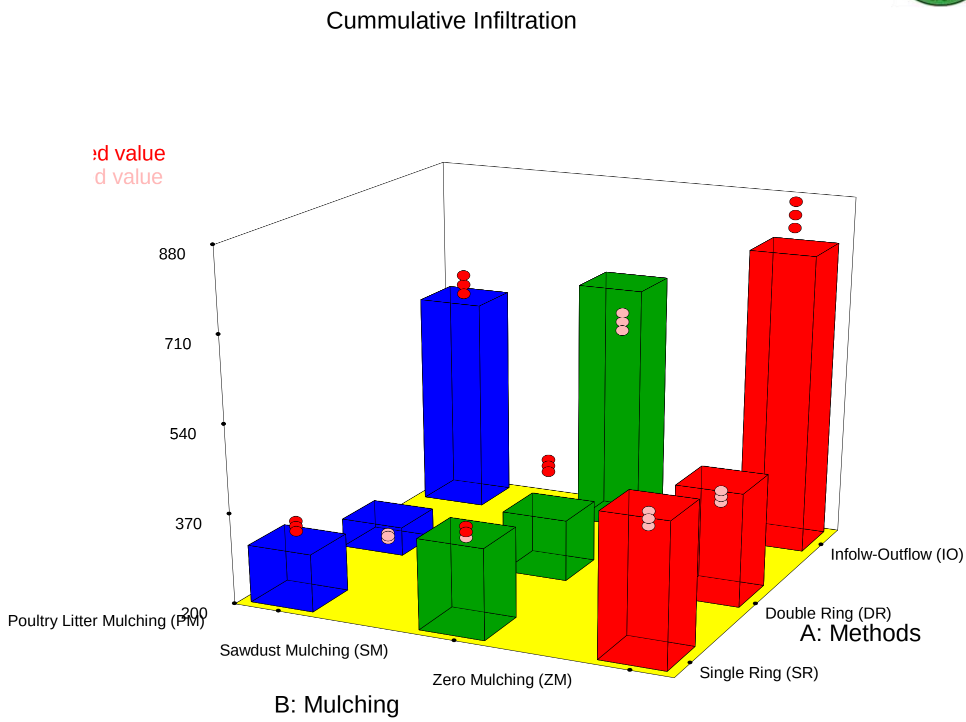

Fig. 2: Interaction effects of Mulching and Methods on Cumulative infiltration

CONCLUSIONS

From this study, we concluded that:

1. The infiltration rate depend mainly percentage fine particle, clayey content and bulk density.
2. The soil infiltration characteristics rate was influenced by the biological action resulting from plants residues or mulch materials.
3. The poultry litter has heavy clayey content that lower the permeability soils.
4. The natural soil had a low infiltration rate compared to the treated plots due to possible compaction effects from the farm machineries that were operated in the previous rainy season farming. The double ring method remained the best method, while the saw dust mulch performed best in modifying the soil structure

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DEVELOPMENT AND EVALUATION OF AEROTHERMAL-MACHINE FOR SEPARATING MELON SEEDS COTYLEDON FROM ITS SHELLS

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ABSTRACT
Literature has shown several successes in mechanical shelling of melon seeds although, without separation capabilities. The conventional winnowing method failed due to high surface moisture in shelled melon seeds and similar gravimetric properties that exist between thick edges of Bara specie and its cotyledon. To tackle this challenge, an Aerothermal-machine for separating melon seeds cotyledon from its shells was designed, fabricated and tested. It consist of a hopper, heat exchanger chamber, blower chamber, prime mover, drying chamber, sieve separation unit, a frame and delivery chute for pure melon cotyledons, thick edges and polythene-like shells respectively. It does the separation aerodynamically. The machine was tested using the two major and available melon seed varieties: Serewe (thin-edge) and Bara (thick-edge) varieties. Based on preliminary investigation results carried out on the machine, 2872rpm operation speed and melon seeds moisture content level of 21.5% wb was used in the test. Samples weighing 200, 250 and 300g were prepared from each variety of the mechanically shelled melon seeds in two replicates. The analysis of the obtained data showed that the separation efficiency of the machine was 97.83% at a single pass of Serewe through the machine, while it was 71.26% for Bara at a single pass and 86.50% at a double pass. The maximum capacity of the machine obtained was 7.4Kg/h. This new technology can therefore be adjudged to be efficient, energy saving, rural and environmentally friendly. It is hereby recommended for adoption domestically and commercially.

***Key words**: Aerothermal-machine, Blower, Exhaust, Melon seeds, Heat exchanger, separation*

INTRODUCTION

Melon (*Citrullus lanatus*), popularly known as Egusi in Nigeria is an oil-seed crop that is widely cultivated and consumed in the tropics. According to Aguayo *et al.* (2004), melon is the fourth most important crop in the world in terms of production (18 metric tons). Bara and Serewe are the major varieties in Nigeria (Adekunle *et al.*, 2009; Iorpev *et al.*, 2015). Bara seeds are characterised by thick black edges, large, brown seeds and a mean dimension of 16 x 9.5 mm. It is dominantly found in the Northern and western regions of Nigeria. Serewe seeds are smooth, light brown; unthicken (thin) whitish edge with 15 x 9 mm mean dimension. The Serewe variety is mainly found in the Eastern part of Nigeria (Adekunle *et al.,* 2009). Melon seeds are highly nutritious, furnishing the human diet with good quality proteins (Ogbonna and Obi, 2007). According to Ajibola *et al.* (1990), melon seeds consist of about 50% oil by weight, 37.4% protein, 2.6% fibre, 3.6% ash and 6.4% moisture. The presence of unsaturated fatty acid in melon oil according to him makes it nutritionally desirable due to its hypocholesterolemic (lowering of blood cholesterol) effect. The nutritional value of melon per 100g is reported by Adekunle *et al.* (2009) to be 7.6g carbohydrate, 0.4g dietary fibre, 0.2g fat, 0.6g protein and 8.0g vitamin C.

Melon is mainly grown for its shelled kernel which could be grounded into a thick paste or sprinkled into soup or stews. Melon seed cotyledons are raw material in the production of vegetable oil, margarine, salad, "robo cake", baby food and livestock feeds. Its oil is used in the production of local pomade, soap and its shell used as poultry litter (Shittu and Ndrika, 2012).

There are several successes in mechanical shelling of melon seeds achieved by researchers such as Odigboh (1979), Fadamoro (1999), NCAM (2000), Sobole *et al*. (2015) and others although without separation capabilities. Since mechanical shelling of melon seeds without a mechanical separation offers a partial solution to the drudgery associated with melon seeds processing and its availability for industrial uses, researchers are seeking to address the challenge. But the attempts published by Kassim *et al.*, (2011) and Sobowale *et al.*, (2015) have no separation efficiency statement, perhaps, no significant success was achieved. Those designs for separating melon seeds from shells failed since there were typical conventional winnowing devices.

Therefore, the need for an efficient, energy saving, rural and environmental friendly machine that could separate melon seeds cotyledon from its shells remains imperative. Hence, the objectives of this work are to design, fabricate and test a petrol engine powered Aerothermal-machine for separating melon seeds cotyledon from its shells.

MATERIALS AND METHODS

Materials

The materials used were selected based on strength, durability, suitability and availability without compromising the engineering codes and standards for fabrication of machines.Engineering principles were employed for the designs and fabrication of components in order to enhance satisfactory performance of the machine. The following are the equipment, tools, machines and seeds that were used in the work: Lathe machine, arc welding machine, Electric drilling machine, Electric cutter, Mild steel metal sheet, stainless steel metal sheet, Angular bar, Prime mover, Pulleys, V-belt, Water, plastic bowls, digital weighing balance, moisture meter, thermometer, stop watch, polythene bags and Melon seeds (Bara and Serewe variety).

Methods

Physical and engineering properties of the melon seed cotyledon and the shells collected from the existing NCAM melon seed shelling machine were studied in order to establish design parameters at the National Centre for Agricultural Mechanisation, Ilorin. In the study, 100 melon seeds were randomly selected. There length, width and thickness and mass were measured using a micrometre screw gauge and digital weighing balance respectively. The average diameter was calculated by using the arithmetic mean and geometric means of the three axial dimensions. The arithmetic mean diameter and geometric mean diameter of the melon seeds were calculated according to Galedar *et al*. (2008) and Mohsenin, (1980). Bulk density was calculated from the mass of bulk seeds divided by the volume containing mass (Garnayak *et al.*, 2008). The true density was determined using the unit values of unit volume and unit mass of individual seed as in Burubai *et al*. (2007). The dynamic angle of repose was determined using the method described by Maduako and Faborode (1990). The determined values of size, shape and angle of repose, mean diameter, geometric diameter, bulk density of the melon seed cotyledon and shells were respectively considered in the design since fan design for effective grain cleaning takes advantage of the variation in the aerodynamic properties of the grain (Kassim *et al.*, 2011). Heat conductivity and other heat transfer characteristics of metals were also considered during material selection. Engineering principles such as bending moment, and shear stress were employed in components development.

A preliminary investigation for the required operation conditions was conducted on the machine. Based on the result from the preliminary investigation, a single operation speed of 2874rpm and 21.5% wb moisture content level of melon seeds was used during performance evaluation of the machine. Thin-edge melon seeds variety (Serewe) and thick-edge variety (Bara) were used as the testing material.

Design of Machine Components

Shaft Design

The required diameter of the shaft was determined by using the ASME code equation (Eric, 1976; Shittu and Ndrika, 2012) for solid shaft design as in equation 1.

$$d^3 = \frac{16}{\pi S_s}\sqrt{(k_b M_b)^2 + (k_t M_t)^2} \quad (1)$$

Where, S_s = Allowable shear stress, N/m^2; K_b = Combined shock and fatigue factor applied to bending, Nm; M_b = Bending moment, Nm; K_t = Combined shock and fatigue factor applied to torsional moment, Nm; M_t = Torsional moment, Nm.

By calculation, a minimum shaft diameter of 18.00 mm was designed to safely bear the bending moment, shear stress and shock generated during operation.

Power Requirement

The power requirement of the machine was determined using equation 2 and 3 (Hannah *et. al.*1984).

$$P = \frac{2\Pi NT}{60} \quad (2)$$

$$T = Fr \quad (3)$$

Where, P = Power requirement of the machine, Kw; N = Speed of shaft, rpm; T = Torque on the shaft, Nm; F = Total load on the shaft, N; r = radius of the driven pulley, mm.

Fan diameter design

The diameter of the axial fans and centrifugal fan was determined by using equation 4 and 5 as in Gϋsoy and Gϋzel (2010), and Takahashi (2002).

Airflow rate $Q = V + A_x$ (4)

Airflow rate of fan $Q = D^3$N (5)

Where, D = Runner diameter, m; N = Rotational speed, rpm; V = Terminal velocity, m/s; A_x = Cross sectional area of duct, m.

Pulley and Belt Design

A suitable pulley size and belt length was determined using equation 6 (Aaron, 1975) and equation 7 (Khurmi and Gupta, 2004) respectively.

$$N_1 D_1 = N_2 D_2 \quad (6)$$

$$L = 2C + 1.57(D_2 + D_1) + \frac{(D_2 - D_1)}{4C} \quad (7)$$

Where, N_1 = Speed of driven pulley, rpm; N_2 = speed of driving pulley, rpm; D_1 = Diameter of driven pulley, mm; D_2 = Diameter of driving pulley, mm; L = Length of belt, mm; C = Distance between driving and driven pulley, mm.

Hopper Design

The volume of the hopper and the total area of metal sheet required was designed using the mathematical expression for the volume of a truncated frustum as in equation 8 and 9 respectively (Adejuigbe and Bolaji, 2005).

Volume of hopper $= \frac{1}{3}[C^2(h + y) - K^2 y]$ (8)

Total area of hopper $= 4\left(\frac{1}{2}b_1 h_1 - \frac{1}{2}b_2 h_2\right)$ (9)

Where, C = side length of hopper top, m; h = vertical height of truncated hopper, m; y = vertical height of the frustum removed, m; k = side length of the frustum top removed, m; b_1 = base length of bigger triangle, m; b_2 = base length of smaller triangle, m; h_1 = vertical height of bigger triangle, m; h_2 = Vertical height of smaller triangle, m.

Heat Exchanger Design

Thermal conductivity of metals was considered during material selection for the fabrication of the heat exchanger. According to James (2005), thermal conductivity of copper is 411 BTU/hr ft.˚F, aluminum is 164 BTU/hr ft.˚F, mild steel is 56 BTU/hr ft.˚F and stainless steel is 19BTU/hr ft.˚F. So, due to conductivity coefficient and cost analysis, mild steel sheets and square pipes of 0.001m thickness was selected and used for the fabrication of the heat exchanger. The dimension of the heat exchanger is 0.25 x 0.25 x0.10m. A mild steel sheet of 0.001m thickness was suitably used as heat conduction plates in the design since the rate of heat penetration through thin mild steel sheet is higher.

Machine Description

The machine consists of a hopper, heat exchanger, blower chamber, petrol engine, drying chamber, frame, delivery chute for melon cotyledons and shells, and sieving mechanism. Figure 1 presents the isometric view while figure 2 presents the pictorial view of the fabricated machine showing its component parts. The machine is 1.14 m high and covers an area of 0.8 m^2. The hopper is a square frustum of 0.35 x 0.35 m made from 0.001 m thick stainless steel metal sheet. The sides of the hopper are inclined at 25 degrees from the vertical axis to enable easy flow of the wet materials under gravity. The hopper anchors the chimney that enables the escape of moist air during drying. The combusted gas from the prime mover was channelled to the heat exchanger through a 0.02 m diameter pipe. The heat exchanger absorbs the heat, excluding the carbon content and transfers the heat to the cool air which is then sucked into the drying chamber for drying purposes.

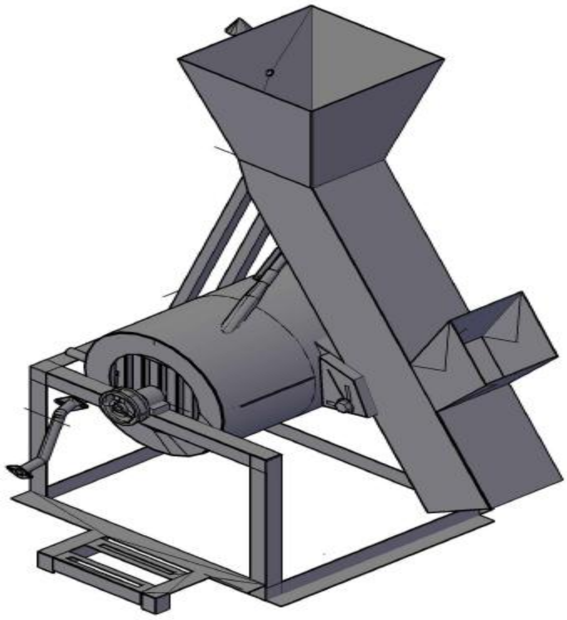
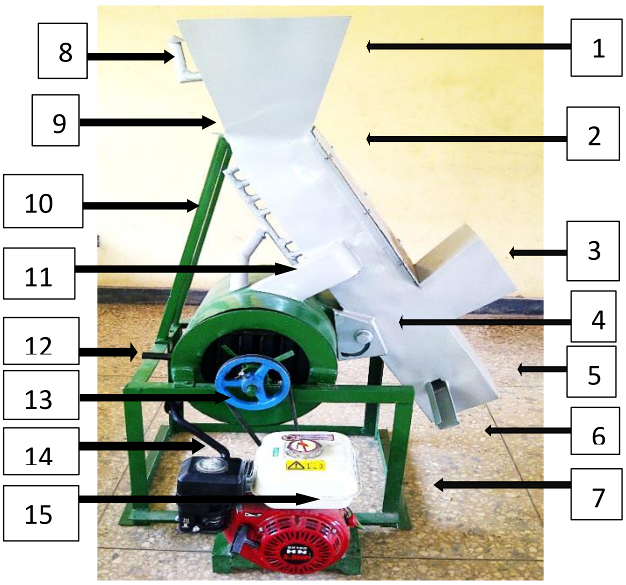


Fig. 1: Isometric view of shelled melon seed separation machine



Key

1. Hopper
2. Drying Chamber
3. Polythene–like Shells delivery chute
4. Air flow rate control
5. Clean melon kernel delivery chute
6. Thick edges delivery chute
7. Frame

Fig. 2: Pictorial view of shelled melon seeds separation machine.

A counter flow of the hot air in the drying chamber dries the high moisture shelled melon seeds for easy aerodynamic separation. The air stream from the blower chamber blows off the polythene-like part of the shells while the thick edges of the shells are sieved out by the sieve separation unit. The machine is anchored by a frame made from mild steel angle iron, 0.04 x 0.04 m and 0.003 m thick. The dimension of the frame is 0.62 x 0.56 x0.46 m.

Before operation, the prime mover was fuelled and switched on for 5 minutes to raise ambient air temperature to 54˚C and beyond in a progressive manner while the shelled melon seeds were poured into the hopper. After 5minutes warming time, the feeding valve was opened for it to flow under gravity through the drying chamber, the blower chamber and the sieve separation unit for effective separation.

Performance Evaluation

About 2kg of each variety was conditioned by adding 2 litres of water and then drained after 20 minutes. The two varieties were then mechanically shelled using the NCAM melon sheller. Samples weighing 200, 250 and 300g were prepared from each shelled melon seed variety and replicated twice. Samples of shelled thin-edge melon seed variety were passed through the Aerothermal-machine once at a half way opening of the feeding rate and air flow rate regulating valves. The samples of shelled thick-edge melon seeds were also sent through it at a single pass and double pass since Bara cotyledons and it shells have similar gravimetric properties which comparatively make its aerodynamic separation more difficult. Pure cotyledons and shells of each sample from each variety was collected and analysed. Separation efficiency of the machine was determined by using equation 10 as expressed in Simonyan and Yiljep (2008). It is the ratio of the number or mass of pure cotyledons collected to its total number or mass of shelled melon seeds passed through the machine.

$$\text{Separation Efficiency} = \frac{N_1 + N_2 + N_3}{N_1 + N_2 + N_3 + N_4} X\ 100 \quad (10)$$

Where, N_1 = Mean number of seeds unshelled, N_2 = Mean number of whole seeds shelled, N_3 = Mean number of seeds shelled but broken, N_4 = Mean number of shell particles in product.

The separation capacity of the machine is the quantity of cotyledon separated per unit time as expressed in equation 11 (Kassim et al., 2011).

$$\text{Separation Capacity of machine} = \frac{Mass\ of\ melon\ cotyledon}{time\ taken} \quad (11)$$

The results obtained are presented in tables 1, 2 and 3 respectively.

RESULTS

Tables 1 and 2 present the data of machine performance at 2874 rpm machine speed and 21.5% mc for Serewe (thin-egde) at single pass, Bara (Thick-edge) at single pass and double pass of samples respectively. Table 3 contains the respective time taken to separate various samples at half way opening of the feeding rate control, while table 4 shows the machine performance parameters under the same conditions. Figure 2 shows a pictorial view of shelled melon before and after separation. The unshelled seeds in figure 2b can still be seen among the separated cotyledons. Figures 3 and 4 show the polythene-like shells that were blown off by the machine and the thick edges of the seeds sieved off by the machine.

Table 1: Machine Performance on Serewe and Bara at Single run

Sample	**Serewe**				**Bara**			
	N_1	**N_2**	**N_3**	**N_4**	**N_1**	**N_2**	**N_3**	**N_4**
1	29	328	51	9	11	130	20	63
2	20	201	10	5	14	110	16	55
3	27	273	49	8	18	183	29	100
4	25	256	46	7	17	180	25	97
5	22	204	36	6	10	135	22	56
Mean	24.6	252.4	38.4	7	14	147.6	22.4	74.2

Key: N_1=Number of seeds unshelled, N_2= Number of whole seeds shelled, N_3= Number of seeds shelled but broken, N_4=Number of shell particles in product

Table 2: Machine Performance on Bara at double run.

Samples	**N_1**	**N_2**	**N_3**	**N_4**
1.	14	100	18	20
2.	25	140	20	31
3.	29	155	25	35
4.	12	105	17	19

5.	16	135	22	25
Mean	19.2	127	20.4	26

Table 3: Time taken to separate samples at half way opening of feeding rate control

Sample	**Mass(g)**	**Time (min)**		
		Serewe single run	**Bara Single run**	**Bara double run**
1	200	1.60	1.80	2.50
2	200	1.80	1.90	2.30
3	250	1.96	2.00	2.70
4	250	2.00	2.10	2.90
5	300	2.30	2.40	3.00
6	300	2.50	2.50	3.10
Mean	250	2.03	2.12	2.75

Table 4: Machine Performance Parameters at 2874 rpm and 21.5% mc

Parameter	**Serewe**	**Bara**	
		Single run	**Double run**
Separation Efficiency,%	97.83	71.26	86.5
Machine Capacity,Kg/h	7.40	7.10	5.50

(a) Before (unshelled, cotyledon, and shells) (b) After (unshelled, and cotyledon)

Fig. 3: Picture of shelled melon before and after separation

Fig. 4: Polythene-like shells blown off

Fig. 5: Thick edges of seeds sieved off

Discussion

From table 4, machine separation efficiency for thin-edge melon seeds variety (Serewe) at 21.5% moisture level and 2874 rpm operation speed was 97.83%. This result was achieved due to the dehydrating effect of the drying chamber that works at a maximum temperature of 60˚C. The presence of a drying chamber in the design is responsible for its high performance. At the same operational conditions, the separation efficiency for Bara variety (thick edge melon seeds) which challenges aerodynamic separation method was 71.26% at a single run and 86.50% at a double run. The separation efficiency of Serewe variety is higher than that of Bara as a result of the great difference that exist between terminal velocities of the cotyledons and shells of Serewe while it is an opposite in the case of the cotyledons and shells of the Bara variety. It is clearly shown in figure 5 that the incorporated sieve separation unit is the most suitable option for removing the thick-edges of shells that could not be blown off by the optimal air flow rate during aerodynamic separation. The capacity of the machine is 7.4Kg/h for Serewe variety at a single pass through the machine. On the other hand, the capacity is 7.1Kg/h and 5.5Kg/h for Bara variety at a single pass and double pass through the machine respectively. The performance of this machine is higher than the performance in Kassim *et al.*, (2011) and Sobowale *et al.,* (2015). Its success was possible since the machine was designed based on the understanding that the cotyledons and thick-edges of Bara usually have similar terminal velocity but vary in shapes and sizes. The performance of this new technology can be adjudged satisfactory for commercial production of pure melon seeds cotyledons for domestic and industrial purposes.

CONCLUSION

An aerothermal-machine for separating melon seeds cotyledon from its shells was designed from first principle, fabricated and tested. The heat from the exhaust gases of the prime mover (small gasoline engine) was successfully tapped by the machine through waste heat recovery approach (WHRA) to dehydrate the seed and ease aerodynamic separation. The machine can effectively separate melon seeds cotyledon from its shells (polythene-like shells and thick-edge shells) at separation efficiency of 97.83% by passing the Serewe variety at 21.5% moisture content through the machine operating at 2874 rpm once. Also, at the same speed and moisture level, a single pass of the Bara variety yielded 71.26% separation efficiency and 86.50% separation efficiency after a double pass. The maximum capacity of the machine was 7.4Kg/h. This new technology is therefore recommended for adoption domestically and commercially.

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FEATURES EXTRACTION IN AGRICULTURAL PRODUCTS USING COMPUTER IMAGE PROCESSING

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ABSTRACT

The study was based on the application of image processing and machine vision technology in the extraction of some features of interest in agricultural products. It involved the development of an algorithm that used some computer programs written in the FORmular TRANslation (FORTRAN 95) programming language to carry out tests on some input data images. The input data images were obtained by digitizing the original images of some Amaranthus vegetables, cowpea seedlings and some food samples on which some fungi were found to be growing as captured by a digital camera. The results of this study carried out on the images showed that the algorithm was able to extract both the boundary of the leaves and the crop position by discriminating between the crop and the uncovered soil surface as well as the growth of the fungi on the food samples. The extracted images as produced by the programs compared favourably well with the original images as captured by the digital camera. This visual comparison showed that the approach is very promising in developing automated sorting and quality inspection techniques which can be applied to some agricultural and food products.

Keywords:*mage Processing, Machine Vision Technology, Formular Translation, Automated Sorting, Quality Inspection Techniques.*

INTRODUCTION

In the developing countries, leafy vegetables are part of the daily diets used as the soup to accompany the common and popular solid staple food. The production of these vegetables is one of the new initiatives embarked upon in empowering the youth who are encouraged to be self employed. The increased production has been found to make the markets for food products very competitive. This has made the customers' choices to be based on the quality of the products. The harvesting of these products by pruning, inspection and quality evaluation still depends largely on manual labour which has been found to be tedious, laborious, costly and highly subjective in approach (Pujari *et al.*, 2014). There is therefore, a need to explore other methods of carrying out these processes which are suitable and cost effective in these regions to ensure the success of the youth economic empowerment programme.

The potential of applying computer vision to the food industry has been recognized (Tillett, 1990). Recently, it has been gaining much research and development attention in the food industry (Sun, 2004) and it is increasingly being applied to quality inspection of a wide range of food products. A review of some of the researches and studies carried out to investigate the prospects of computer vision automation sorting systems in agricultural process operations in Nigeria was reported by Raji and Alamutu (2005). One of the useful areas identified is the automatic quality inspection of produce which helps in grading and sorting of produce according to their internal characteristics, size, texture, colour, shape and defects on agricultural products such as bruises, dark spots, dirt, cracks and so on.

The primary aim of the computer vision system is to ultimately replace the human visual decision-making process with automatic procedures. Therefore, it tries to imitate human behaviour of performance in colour, content, shape, and texture inspection (Domenico and Gary, 1994). It involves the application of image processing programs, combined with an illumination system, in connection with electrical and mechanical devices to substitute the human manipulative effort in the performance of a specific task. This also involves the provision of a mechanism in which human thinking process is simulated artificially and can help in making complicated judgments accurately, quickly and very consistently over a long period of time (Abdullah *et al.*, 2004).

Many studies have been carried out by some researchers and scientists with varying degrees of success. Some of these include classification of apples based on bruises using image processing and neural networks (Shahin *et al.*, 2002), features measurement system for grafted tomato seedlings (Yi-Chich *et al*., 2006), and prediction of mango ripeness (Federico, 2002) with a relatively high degree of accuracy. Other studied aimed at obtaining some quality parameters of tomato such as colour, colour homogeneity, defects, shape and stem detection for proper classification (Laykin *et al.*, 2002); weed discrimination from crop (Tsheko, 1998; Kavdir, 2004; Burgos-Artizzu *et al.*, 2010) estimation of crop position using template matching in rice production (Kentaro *et al.*, 2003); measuring the three dimensional locations of fruits on trees for apple harvesting in an orchard (Teruo *et al.*, 2002); judging the presence of stems of Huanghua pears using templates with different sizes (Ying *et al.*, 2003); measuring hog weights without physical contact (Wang *et al.*, 2006); detection of skin tumours on chicken carcasses (Kim *et al.*, 2004); prediction of the tenderness of cooked beef using its textural features (Jeyamkondan *et al.*, 2001); identifying pests from images captured from a paddy field using the digital values of colour, shapes and texture features (Abdul-Rashid *et al.*, 2006); detecting and quantifying tetrazolium staining in sectioned corn kernels (Xie and Paulsen, 2001); grading egg plants by inspecting the fruit colour, size, shape, bruise, disease and dark spots as well as checking the fruits position and orientation (Kondo *et al.*, 2004).

Raji (1999) also developed an algorithm for determining the area of two-dimensional objects by image analysis. This can be adapted in the detection of the leaf-type as a form of sorting to select the desired ones during harvesting and for selective weed destruction. With these advantages and benefits, this study aimed at investigating the potential of image processing and machine vision in feature extraction of objects with special reference to agricultural and food products.

MATERIALS AND METHODS

Amaranthus (green) vegetables and cowpea were raised on blocks of soil on the experimental farm of the Department of Agricultural and Environmental Engineering, University of Ibadan, Nigeria. Coloured images of the plants were taken and captured using a 5 Megapixel TEKXON digital camera (TX 410) with optical zoom lens (5x).

These images were obtained on a daily basis as the crops grew within a space of two weeks. A wooden framework to hold the camera was constructed over the plot such that the digital camera was always at a constant height (of about 1.2 m above the surface of the soil on which the vegetables were planted) and at the same position, such that the camera was kept on the same spot throughout the experiment. Snapshots of the vegetables were taken on a daily basis from this specified spot as they continued growing. The framework on which the camera was mounted during the period of image acquisition and the camera slot are as shown in Plates 1 and 2. Images of growing cowpea seedlings and fungi growth on some food samples were also obtained for analysis.

Plate 1: The framework for holding the camera

Plate 2: The camera slot.

The relatively high resolution of the camera helped to prevent loss in the image quality that could have been experienced if scanned photographic images were used. This also helped to minimize the effect of noise, which refers to the unwanted features existing in form of data that appear in an image to mask the features of interest.
The acquired images were transferred to a personal computer (PC) system and converted to digitised-picture format portable pixel map (*.ppm) format using Paintshop Pro 7.02. The ppm files were opened and read as digits with the gray scale values of each pixels in a text readable application and used as input into the programs or opened and read as images in graphic applications. Digitization involved the conversion of images to the digital form, that is, the numerals that could be used for carrying out further processing on the images.
The Eight-Connectivity or Star Method of Edge Detection was used for the boundary detection for the images. It involved the consideration of all the eight neighbouring pixels of the particular pixel tested for an edge pixel. Assuming that P(i, j) is the pixel being tested, we have the pixels of the neighbouring pixels as arranged in Figure 1.

i-j, j-1	i-j, j	i-1, j+1
i, j-1	**i, j**	i, j+1
i+1, j-1	i+1, j	i+1, j+1

Figure 1: Arrangement of the eight neighbouring pixels for star method

It follows that the pixel at (i, j) i.e. P(i, j) is an edge pixel on the object to be detected if at least one of the neighbouring pixels is not a background or is not a portion within the object whose edges are to be detected. This condition was capable of picking all the objects within an image no matter how small the object was. This condition was represented as:

$$P(i, j) = \text{edge pixel if} \quad \begin{cases} \{ (P(i\text{-}1, j\text{-}1) \text{ or } P(i\text{-}1, j) \text{ or } P(i\text{-}1, j+1) \text{ or } P(i, j\text{-}1) \text{ or } \\ P(i, j+1) \text{ or } P(i+1, j\text{-}1) \text{ or } P(i+1, j) \text{ or } P(i+1, j+1) \} \\ \neq \text{background pixel} \end{cases}$$

This method produced good edges since it considered all the eight neighbouring pixels that are closest to the pixel being tested with a subsequent reduction in the effect of noise.
Some programs were written in the FORmula TRANslation (FORTRAN 95) programming language using the principle of eight-connectivity or star method of edge detection as described. The equations or relationships developed between the particular pixel being tested and all the eight surrounding or neighbouring pixels were utilized by the computer programs developed. The two programs were used to extract the images of the leaves (of the Amaranthus vegetables and the cowpea seedlings) as solid objects, thereby differentiating them from the surrounding or the background (which in this case was the uncovered area of the soil) as well as the extraction of the boundary or the edges of the leaves. Meanwhile, the overlapping of the leaves was not put into consideration. These programs were also used to detect and extract fungi as they grew on some food samples.
Microsoft Excel was firstly employed in importing data from the output files of the programs and then plotting the pixel coordinates. This method is usually referred to as post-processing since it involved saving the output from the programs in output files and then plotting the pixel coordinates after the programs have been executed and run completely. This worked well for images of small sizes but it was found to be unsuitable for plotting the coordinates of images that were larger in size. This was due to the limitation of Microsoft Excel package in terms of the capacity of data that can be plotted at a time. This limitation led to the use of Fortran Online graphics package in plotting the pixel points. This helped to plot the pixel coordinates directly as they resulted from the

program tests, one by one, without necessarily saving unto a file. This reduced the quantity of data that were to be handled per time and thereby, helped in saving computer memory space.

RESULTS AND DISCUSSION

The results of the tests carried out to determine the adequacy of the developed algorithm to extract the boundaries and solid forms of the objects were obtained from the study. The original images as captured by the digital camera were presented with the respective figures showing the extracted solid form of the images and that of the extracted boundary or edges for the basis of comparison. The changes in the area covered by the leaves with respect to the total area of the soil surface were also determined.

Cowpea seedlings

The original captured images of the cowpea seedlings are presented in Plate 3 while the images extracted by the program tests as solid objects and the extracted boundary of the leaves are as shown in Figures 2 and 3. The images of the cowpea seedlings produced by image processing compared favourably well with the original images as captured by the camera.

The green portions represent the position of the crops while the background was represented with the grey colour in the figures showing the solid form of the leaves. Since the seedlings do not have too many flaps that are lying over another, it was very easy to differentiate between the area of soil covered by the crops and the portions left uncovered. The figures showing the extracted boundary of the leaves also compared well with the original images. The only limitation was that the program did not take the overlapping of the leaves into consideration.

With the possibility of obtaining the area covered by the leaves from the pixel analysis, the variations in the leaf area index (LAI) were plotted against the number of days as shown in Figure 4. The leaf area index was calculated as the ratio of the area covered by the leaf to the total area of the plot. This is an indication of the vegetative cover which is useful in determining soil-water evaporative factor, risk of weed survival and planning of weedicide and fertilizer application. This showed that the LAI of the cowpea seedlings increased with time as the crops continued to grow since the area covered by the crops continued to increase with an equivalent decrease in the area of soil left uncovered. The rate of increase of the leaf area index as the crops continued to grow was high initially but as the number of days increased, the growth rate decreased. This clearly indicated that the growth rate of cowpea decreased as the plant approached maturity. This reduction in the growth rate with the number of days can therefore, be used to predict the growth stage of the crops under similar soil and environmental conditions.

Plate 3: Original images of the cowpea seedlings on days 10 and 14 of image acquisition

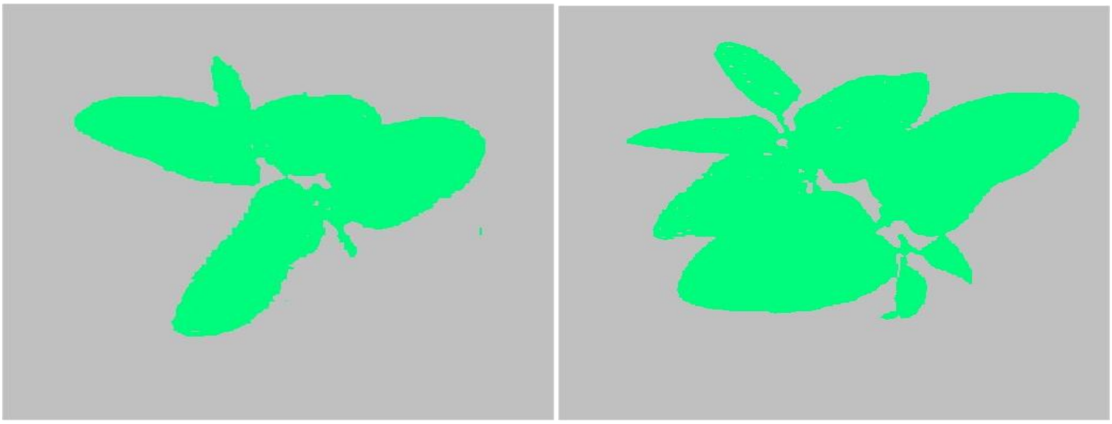


Figure 2: Solid forms extracted by image processing

Figure 3: The extracted boundary of the cowpea leaves

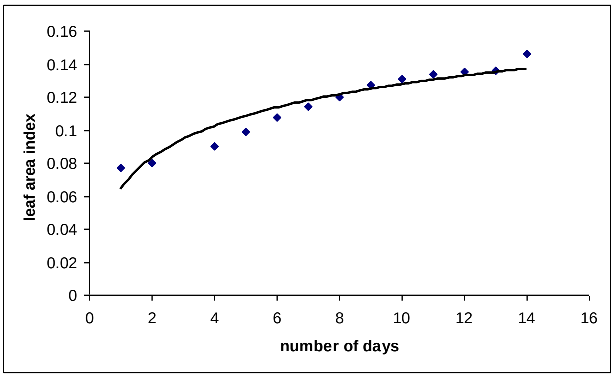


Figure 4: Leaf area index of cowpea

Amaranthus vegetables

Original images of the Amaranthus vegetables as captured by the digital image are presented in Plate 4 while the images as extracted by the programs are presented in Figures 5 and 6. The images of the vegetables extracted by the programs as solid objects (Figure 5) and the extracted boundary of the leaves (Figure 6) compared well with the original images but the major limitation is that there was excessive overlapping of the leaves which could not be detected by the program. Further studies to consider the overlapping boundaries are thereby recommended.

Plate 4: Original images of the vegetables for day 14 and 16 of image acquisition

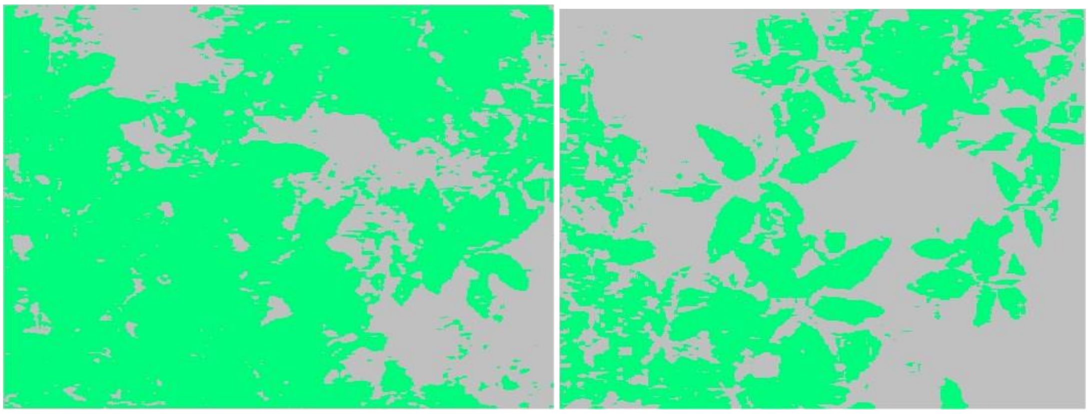


Figure 5: Extracted solid form

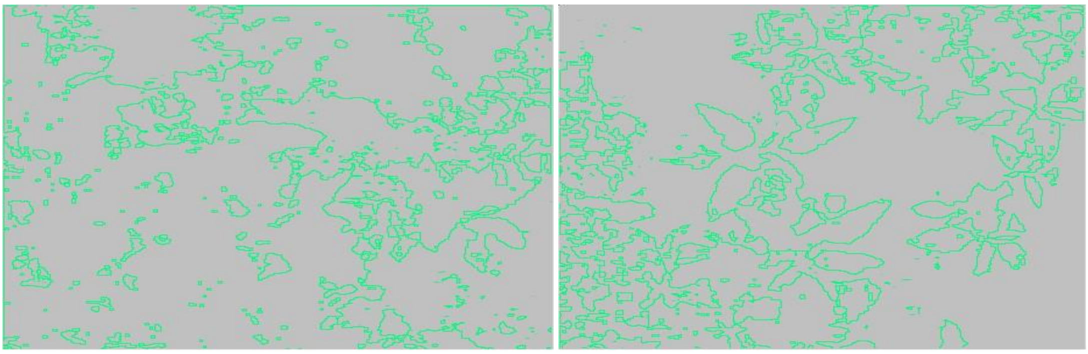
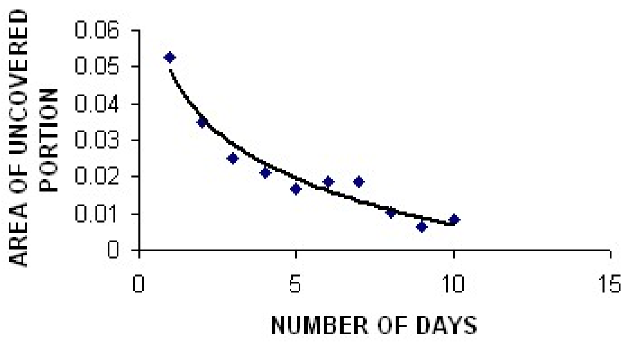


Figure 6: Extracted boundary of Amaranthus leaves

Variations in the area of uncovered soil surface and LAI as the crops continued growing are presented in Figures 7 and 8 respectively. The ratio of the uncovered portion to the total area of land continued to reduce while the LAI continued to increase. The rate of decrease of the uncovered portion of the land as the crops continued to grow was high initially but as the number of days increased, the rate was found to be reducing. This was also due to the reduction in the rate of crop growth which was very high at the early stage of the crop growth resulting in greater coverage of the soil surface.

The extraction of the crop positions and the discrimination between the leaves of the seedlings and the background or the uncovered portions of the soil can be used to predict the growth stage of the crops.



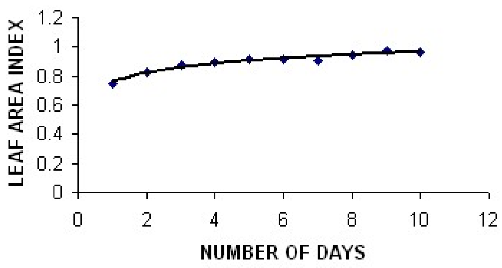


Figure 7: Area of uncovered soil

Figure 8: Leaf area index

Fungi Growth

The programs were also used to detect and extract some fungi as they were found growing on some food samples. The original images of the fungi on the food samples are as shown in Plate 5 while the extracted images of the fungi growth are presented in Figures 9. The program was able to detect and extract the location of the fungi practically well and the results from such extraction could be of use in determining the growth rate of the fungi species and the level of deterioration of the food samples under specified conditions can be known. This was only used to confirm the flexibility of the program for other products other than leaves.

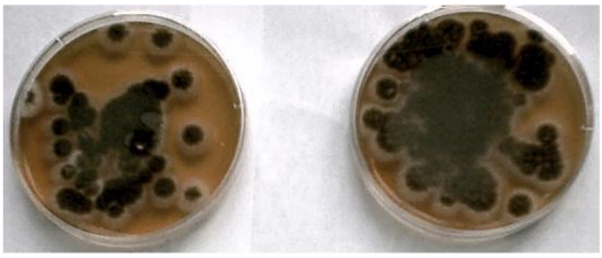


Plate 5: Original images of fungi growing on some food samples

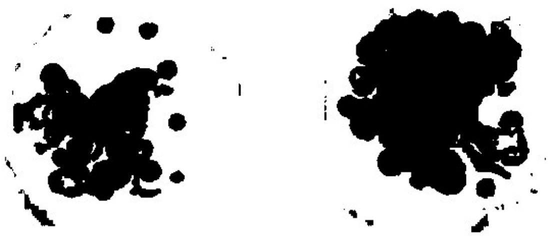


Figure 9: Image of the fungi as extracted by image processing

It is very obvious that the programs worked well in extracting the boundary of the leaves as well as their location as demonstrated by the results produced through image processing. There was virtually no noise level contained or noticed in the analyzed images due to the high resolution of the camera used. The approach employed in this study is very promising in developing a technique that can detect and extract features of interest from agricultural and food products. It could also be used to automate sorting by detecting spread of deterioration in the products being tested.

CONCLUSION

This study presents an algorithm for extracting the features that are of particular interest on agricultural and food products using the principle of computer image processing.

From the results obtained, it can be deduced that:

- The eight-connectivity or star method, which involves the consideration of all the eight surrounding or neighbouring pixels of the particular pixel being tested, is a promising approach;
- The image capturing device, the digital camera with high resolution, helped to maintain the quality of the images generated as compared to the original images of the crops and the fungi on the food samples, and this enhanced better extraction of the features;
- The algorithm is applicable in determining the area index in agricultural production and processes such as LAI, the tree density in a forest using aerial photographs, spread of deterioration in processed products and automatic detection of plant leaf diseases.
- The approach is very promising in developing automated sorting and quality inspection techniques which can be applied to some agricultural and food products.

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REMOVAL OF RESIDUAL POLLUTANTS IN PRE-TREATED BREWERY EFFLUENTS BY ADSORPTION USING LOCAL ADSORBENTS: A COMPARATIVE STUDY

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ABSTRACT

In the present study, activated carbons were produced from low-cost agricultural residues and characterized. These were; coconut shells carbon (CSC), palm kernel shells carbon (PKC) and a mixture of coconut and palm kernel shells carbon (CCPC). Batch equilibrium experiments were carried out in the laboratory using the adsorbents for the treatment of effluents from a brewery in Makurdi Metropolis, Nigeria.Carbon characteristics ranged between 6.58-7.03%, 0.57-0.65g/cm^3, 76.0-93.5%, 928.0-1126.0m^2/g, 23.0-33.7% and 192-303mg/g for ash content, bulk density, iodine sorption, specific surface area, carbon yield and methylene blue number respectively. In the batch equilibrium experiments, pollutants removal efficiency increased with increase in carbon dosage, contact time and pH. The highest removal efficiencies were observed at a dosage of 8g/100ml, contact time of 120minutes and pH of 8 for COD, TSS and TDS as well as for CSC, PKC and CCPC. Comparatively, CSC and CCPC performed better than PKC in terms of pollutants removal efficiency and carbon adsorption capacities in the order; CSC > CCPC > PKC.

Key Words: *Activated Carbon, Removal Efficiency, Brewery Effluent, coconut shells, palm kernel shells*

INTRODUCTION

Most industrialist employ only primary and secondary treatments of their wastewater (physical and biological treatments), which do not efficiently remove all contaminants of concern in the wastewater. This is basically due to economic reasons, as every manufacturer is poised to maximizing profits. In other to meet stringent wastewater discharge standards, there is need for industrialists to employ tertiary and/or advanced treatments of their wastewater, especially for those whose wastewater constituents are difficult to remove by only physical and biological means.

Brewing industries are one of the major industrial users of water. These industries have one of the wastes most difficult to treat satisfactorily. The high organic content of brewery effluent classifies it as a very high-strength waste in terms of chemical oxygen demand, from 1000 mg/L to 4000 mg/L and biochemical oxygen demand of up to 1500 mg/L (Sangodoyin, 2012). The treatment of brewery wastewater effluent is a costly task for the brewer in order to meet the government regulations and to practice environmentally friendly manufacturing. The untreated effluent discharge from these industries is coloured and highly intoxicating due to the presence of alcohol and can be toxic to aquatic life in receiving waters, hence the need for the treatment of brewery wastewater effluent before being discharged into water courses. However, the current problems in water and wastewater treatment stem from the increasing pollution of waters by organic compounds that are difficult to decompose biologically because these substances resist the self-purification capabilities of the rivers as well as decomposition in conventional wastewater treatment plants. Consequently, conventional mechanical-biological purification no longer suffices and must be supplemented by an additional stage of processing. Among the physical-chemical processes that have proved useful for this, adsorption onto activated carbon is especially important because it is the dissolved, difficult-to-decompose organic substances in particular that can be selectively removed by activated carbon (Olafadehan and Aribike, 2000).

The use of activated carbons for the removal of toxic substances in wastewater has been reported to be efficient by various scholars (Adie, *et al.*, 2014: Olafadehan and Susu, 2005: Olafadehan and Aribike, 2000).

In Nigeria and similar developing nations, activated carbon requirements are met by importation in enormous quantity at a very high cost, whereas vast quantity of agricultural residues, which can be used for its production to meet local demands and even for exportation, are generated annually.

The thrust of this study is to create wealth from waste, by converting these materials considered by-products into activated carbon adsorbents (a value added product and resource for other industries), which can be used for water and wastewater treatment, one of its most important fields in terms of consumption to remove hazardous organic compounds or those that impart odour or taste (Olafadehan and Susu, 2005; Olafadehan and Aribike, 2000), cleanup of off-gases containing volatile organic compounds, decolourization, solvent recovery and purification, treatment of industrial waste, surface and groundwater redemption, food processing, pharmaceutical and environmental remediation, amongst other uses.

Several studies have been conducted by various researchers on the use of agricultural waste biomass as low cost adsorbents and potential substitutes for conventional activated carbons, for the removal of pollutants in water and wastewater in Nigeria.

Adie *et al.,* 2014, studied the suitability of using activated carbon produced from locust bean pods in comparison with that from bone char, for the treatment of domestic wastewater. They asserted that, locust bean pod which is an agricultural waste is a suitable sorbent for the removal of Nitrates, Phosphates and chemical oxygen demand from domestic wastewater. However, they did not establish equilibrium and kinetic studies in the adsorption process.

In their studies, Dada, *et al.,* 2012 compared the adsorption capacities of coconut and palm kernel shell activated carbons and found out that coconut shells activated carbon was a better adsorbent than palm kernel shells, with both acid and base activations. These findings suggest that the efficiency of activated carbons in removing pollutants in wastewater is a function of; type of feedstock , type of activating agent and nature of pollutant to be removed.

In a similar study, Ademiluyi, *et al.,* 2009 found out that waste Nigerian Bamboo were good adsorbent for the removal of organic pollutants in wastewater if prepared and activated into granular activated carbons (GAC). They asserted that the experimental data fitted well into the Freundlich isotherms when compared with the Langmuir isotherm. A break through time of 1.5 hours was reported for the study. The effects of contact time on the removal of COD from the wastewater stream were also established.

Amuda and Ibrahim (2006), compared the adsorption efficiency of coconut shell-based granular activated carbon (Acid and barium chloride activation), with the adsorption efficiency of commercial carbon, (Calgon carbon F-300), with respect to organic matter from a beverage industrial wastewater. Freundlich adsorption isotherm was used to analyze the adsorption efficiencies of the two activated carbons. The studies indicated that the acid activated coconut shell carbon had higher adsorption for organic matter expressed as chemical oxygen demand (COD), than Calgon carbon (F – 300) at all carbon dosages used. In most of these studies, the efficiencies of removal and/or adsorption capacities of the locally produced carbons competed favourably with the conventional/commercial carbons which are made from non-renewable sources (Ademiluyi, *et al.,* 2013; Olafadehan *et al.,* 2012; Amuda and Ibrahim, 2006; Mohammed, *et al.,* 2005).

The performances of the activated carbons are reported to depend on a number of factors such as; contact time, carbonization and activation temperatures, activation agent (type of acid or base), carbon dosage (mass of carbon used per volume of wastewater), column height, pH of adsorbate solution and the characteristics of the produced GAC, which also depends on nature of the parent material from which the GAC was produced (Ademiluyi, *et al.,* 2009; Amuda and Ibrahim, 2006; Awoyale, *et al.,* 2013; Ushakumary, 2013).

In all of these findings in literature, there have been no efforts toward the production of GAC from a mixture of two or more agricultural waste materials. However, it is suspected that a proper combination of some selected agricultural materials for the production of GAC can greatly improve the efficiency of the GAC in removing pollutants in solution. These is because, most of the materials used to produce GAC do not poses all the required characteristics for efficient removal of pollutants in solution when used in isolation. Thus combining two or more agricultural waste materials together in known proportions, before carbonizing and activating them into GAC may greatly improve the overall characteristics of the GAC, thus improving their efficiencies and adsorptive capacities. The main objective of the present study is to produce and characterize acid based granular activated carbons

(ABGACs) from palm kernel shells, coconut shells and a mixture of both. Other objectives are to comparatively study the effects of carbon dosage, contact time and initial effluent pH on the removal efficiencies of residual pollutants in brewery effluents by each of the produced ABGACs using laboratory-scale, batch equilibrium experiments.

MATERIALS AND METHODS

Experimental Set Up

The experimental work was divided into two major parts: (i) production of granular activated carbon using coconut shell, palm kernel shell and a mixture of both and characterization of the manufactured activated carbons, and (ii) treatment of brewery wastewater effluent in batch and column equilibrium experiments, using the produced granular activated carbon (GAC).

Production of Activated Carbons

Materials:

The coconut and palm kernel shells used for the production of activated carbons for the treatment of biologically pre-treated brewery effluents were gathered from a market and local palm oil processing company all in Makurdi, Benue State, respectively (plate 1). Other materials used for the production process are, furnace (carbolite, model DH150) fitted with a thermocouple, electric oven, electric weighing balance, crucibles, activation agent (H_3PO_4), beaker, pH meter, mortar, and pestle, sieve. The production process proceeded in two phases: Carbonization and Activation Phases. (Olafadehan *et al.,* 2012; Ademiluyi, *et al.,* 2009).

Carbonization

Coconut and palm kernel shells were dried in the sun for 10 hours to remove moisture content. After drying the shells were crushed to pieces of 10-15mm. Shells were then separated from other materials such as fibres and sand, cleaned and prepared to be placed in the furnace. 5000g of the coconut shell was weighed, put on a crucible and then put into the furnace for carbonization. The furnace was switched on, and the temperature adjusted until it reached 600^oC and was maintained for a period of 2 hours with limited supply of oxygen. After 2 hours the carbonized samples were collected from the furnace after quenching with cold water and transferred to the oven for further drying at 110^oC for a period of 30 minutes. After this, the samples were ready for acid activation (plate 2). The process was repeated for palm kernel shells as well as for a mixture of palm kernel and coconut shells, which comprised of 2500g of coconut shell and 2500g of palm kernel shells.

Activation

The carbonized coconut shells were weighed and mixed with 0.1M phosphoric acid in a beaker for the purpose of activation and stirred into a paste. The resulting moist paste upon mixing the char with phosphoric acid (H_3PO_4) (30% by weight) was again charged into the furnace and heated at a temperature of 800^oC, for a period of 1hour. Cold water was used to quench the activated carbon produced, and this further dried for 60 minutes at 110^oC, till a constant weight of activated carbon was obtained. After the chemical activation, the activated carbon was rinsed thoroughly. Washing was used to remove the remaining phosphoric acid and ash in the carbon to a pH of 6-7. This was accomplished by washing with distilled water. The activated carbon was then drained and spread on a tray at room temperature. The activated carbon was dried in an oven at a temperature of 110^oC for 3 h. Weight of activated carbon produced was taken and yield calculated. The activated carbon was then crushed using a mortar and pestle and sieved with an American standard mesh 200 to obtain granular activated carbon particles of 1.185 to 2.5 mm. The activation process was repeated for the palm kernel shells and the mixture of both. The activated carbons were thus ready for the characterization process (plate 3).

Characterization of Activated Carbons

The produced activated carbons were each subjected to characterization. The parameters determined were, bulk density, specific surface area, ash content, carbon yield, methylene blue value and iodine sorption, all experiments were done in triplicates and the mean values were obtained and reported for each of the produced activated carbons.

All carbon characteristic were determined experimentally according to the methods described by Okibe *et al.,* (2013).

Treatment of Brewery Effluents with Granular Activated Carbons

A fresh sample of biologically pretreated brewery effluent was collected from the effluent outfall point in the month of August by grab method. Samples were stored in a cooler containing ice block at 4^{o}C and immediately taken to the laboratory. In the laboratory, samples were tested to determine the initial concentrations of the following criteria, residual pollutants: COD, Phosphates, Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and Ammonia. The samples were tested in replicates based on the standard methods for the examination of water and wastewater (APHA, 2005) and values were recorded as means. Samples were then fixed and stored in a refrigerator at 4^{o}C for use during the batch equilibrium experiments.

The tested samples were then subjected to batch experimental studies (treatments), using each of the produced activated carbons. Adsorption capacities and pollutant removal efficiencies were determined for each GAC produced. The effects of carbon dosage, pH, and contact time on the removal efficiencies of the residual pollutants for each GAC were also evaluated and compared according to the method described by Amuda and Ibrahim 2006, Ademiluyi, *et al.,* 2009 and Awoyale, *et al.,* 2013 respectively.

Statistical Analysis

A summary index was used to determine the mean values of results obtained from various parameters. One-way ANOVA was used to test for significant differences in characteristics of the prepared activated carbons. The results were investigated by using the least significant difference at a 95% confidence level using SPSS 20 (Adeolu, *et al.,* 2016)

Plate 1: Precursors used to produce granular activated carbons (GAC).

Plate 2: Carbonized products

Plate 3: Experimentally Produced Granular Activated Carbons (GAC)

RESULTS AND DISSCUSSION

Production and Characterization of Experimental Activated Carbons

The mean characteristics of the activated carbons are presented in Table 1. The ash content (%), bulk density (g/cm^3), carbon yield (%), iodine sorption (%), methylene blue number (mg/g) and specific surface area (m^2/g), ranged between 6.58-7.03, 0.57-0.65, 23.0-33.7, 76.0-93.5, 192.0-308.0 and 928.0-1126.0 respectively.

The CSC had the highest ash content, iodine sorption and specific surface area and was closely followed by CCPC, while the PKC had the lowest values of these parameters. This may be due to the low carbon content of CSC as compared to PKC and CCPC, which indicates low output of carbon per given mass of precursor material. The CCPC had the highest methylene blue number and was closely followed by CSC, while PKC had the lowest methylene blue number. These may be due to the molecular attractions that exist differently in each of the activated carbons, which mean that CCPC has the highest affinity for methylene blue as against CSC and PKC. CCPC also had the highest carbon yield, followed by PKC, while CSC had the lowest value in carbon yield. The PKC however, had the highest bulk density and CPC had the lowest, these shows that PKC and CCPC will be less subjective to attrition during usage as adsorbents as compared to the CSC. There was significant difference in means of all the carbon characteristics between the three carbons at $p = 0.05$ level of significance.

Characteristics of Residual Pollutants before Treatment with Activated Carbons

The pollutants characteristics determined were, COD, TSS, TDS, PO_3^-, and NH_4^+. The results of the residual pollutants characteristics before treatment with granular activated carbons (GACs) are presented in Table 2. From the table, the mean values for COD, TSS, TDS, PO_4^{-3} and ammonia were, 318.00, 69.00, 185.50, 7.00 and 3.80 mg/l respectively. The effluent mean pH value was 6.80, while ambient and wastewater temperatures were respectively, 31.0 and 35.0 ^{0}C. Considering the FEPA discharge limits, these values are too high especially COD, TSS and TDS for acceptable disposal into the surface water bodies.

Batch Equilibrium Experiments

The results of the batch equilibrium experiments conducted for each experimental carbon in comparison with CSC are presented in the following sub-sections. These include the effects of carbon dosage, wastewater pH and contact time on the removal efficiencies of the identified residual pollutants.

Effects of Carbon Dosage on Removal Efficiency of Residual Pollutants.

This was done for COD, TSS and TDS. Carbon dosages used were 0-8g/100ml (0-80g/l) of the wastewater. (Figures 1a, 1b and 1c,). CSC exhibited the highest removal efficiencies of 78.46, 100, 93.53%, for COD, TSS and TDS, respectively at the highest dosage of 8g/100ml (80g/l), except for TSS which recorded a100% removal efficiency even at a dosage of 6g/100ml (60g/l).

CCPC exhibited a close removal efficiency of pollutants to that of the CSC, with COD, TSS and

TDS, having values of 72.5, 100 and 88.14%, respectively at the maximum dosage of 8g/100ml. PKC, however, had the lowest removal percentages of 67.79, 73.62 and 67.65%, for COD, TSS and TDS, respectively at the same dosage of 8g/100ml.

Table 1: Characteristic of the Experimental Activated Carbons

		Experimental Granular Activated Carbons (GACs)		
S/No	**Characteristics**	**CSC**	**PKC**	**CCPC**
1	Ash Content (%)	$7.03^{b} \pm 0.23$	$6.58^{a} \pm 0.07$	$6.82^{a} \pm 0.18$
2	Bulk Density (kg/m^3)	$0.57^{a} \pm 0.02$	$0.65^{a} \pm 0.06$	$0.60^{a} \pm 0.02$
3	Carbon Yield (%)	$23.00^{a} \pm 4.36$	$31.70^{b} \pm 1.47$	$33.70^{b} \pm 1.53$
4	Iodine Sorption (%)	$93.50^{b} \pm 5.63$	$76.00^{a} \pm 2.00$	$88.00^{b} \pm 2.00$
5	Methylene Blue Value (mg/g)	$223.00^{b} \pm 2.89$	$192.00^{a} \pm 8.74$	$308.00^{c} \pm 14.42$
6	Specific Surface Area (m^2/g)	$1126.00^{c} \pm 4.04$	$928.00^{a} \pm 2.51$	$1027.00^{b} \pm 37.15$

CSC is Coconut Shell Granular Activated Carbon, PKC is Palm Kernel Shell Granular Activated Carbon, CCPC is Combined Coconut and Palm Kernel Shell Activated Carbon. Values are means and standard deviations of triplicate experiments .Means in the same row with same superscript are not significantly different at P=0.05.

Table 2: Brewery wastewater Characteristics before Treatment with GACs

S/No	**Characteristics**	**Replicate1**	**Replicate2**	**Mean**
1	COD (mg/l)	315.00	320.00	318.00
2	TSS (mg/l)	68.50	69.50	69.00
3	TDS (mg/l)	185.00	186.00	185.50

4	Phosphates (mg/l)	6.90	7.10	7.00
5	Ammonium ion (mg/l)	3.80	3.80	3.80
6	pH	6.80	6.80	6.80

Ambient Temperature = 31.0^0C and Wastewater Temperature =35.0^0C

This can be attributed to the pore structure and specific surface area of the various carbons, as those with higher specific surface areas tend to adsorb more pollutant than those with small specific surface areas (Ushakumary, 2013). The poor removal of pollutants by adsorption is usually as a result of their low initial concentrations in the wastewater before treatment with the carbons. The pollutants with higher concentrations tend to diffuse faster into the available adsorption site in the carbons as compared to those with low initial concentrations (Metclef and Eddy, 2003).

The general trend shows that the pollutant removal efficiency increased with increase in carbon dosage for each of the experimental carbons used. Among all the carbons studied, only CSC reduced COD concentration below the FEPA discharge limits, however TSS and TDS were both reduced to acceptable FEPA limits by all the experimental carbons at a dosage of 8g/100ml. There was significant difference between treatments (experimental carbons) and levels (dosage) at p=0.05, for the removal of COD, TSS, and TDS.

Effects of Contact Time on Removal Efficiency of pollutants

The effects of contact time between the wastewater and the experimental carbons on the removal efficiencies of COD, TSS and TDS were studied for all the three activated carbons (Figures 2a, 2b and 2c,). Contact times of 0-120 minutes, at successive intervals of 30 minutes were used in this study. From the tables, CSC exhibited the highest removal efficiencies of 78.56, 100 and 93.5%, after a contact time of 120 minutes for COD, TSS and TDS, respectively. The removal efficiencies of CCPC were close to those of CSC at the same contact time with values of 71.82, 100.0 and 88.25%, respectively. PKC, however showed the least removal efficiencies for all pollutants studied, with values for COD, TSS and TDS after a contact time of 120 minutes being, 66.48, 73.19 and 69.37%, respectively.

The general trend for each experimental carbon and pollutant studied shows that the removal efficiencies increased with contact time, throughout the period of the experiment. This is in agreement with the findings of Mohammed *et al.*, (2005); Awoyale *et al.*, (2013) and Olafadehan *et al.*, (2012).

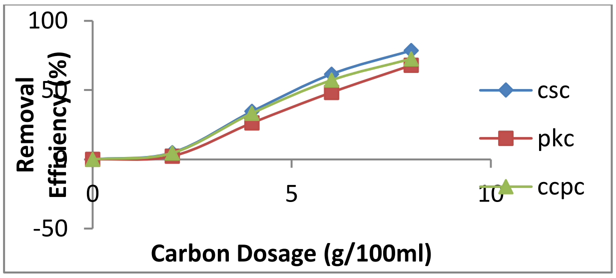

Fig. 1a: Effect of carbon dosage on COD removal efficiency

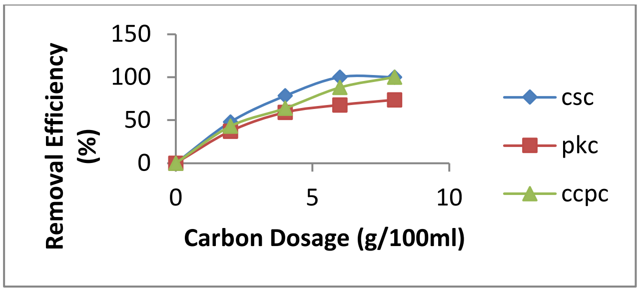

Fig. 1b: Effect of carbon dosage on TSS removal efficiency

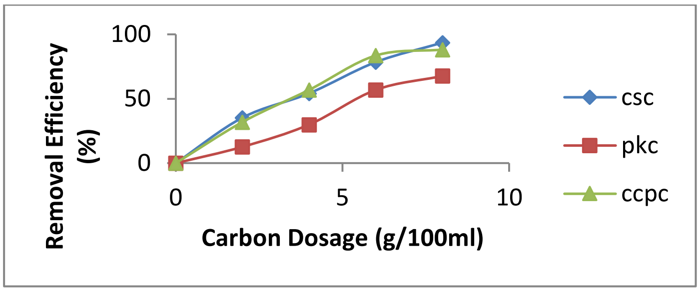

Fig. 1c: Effect of carbon dosage on TDS removal efficiency

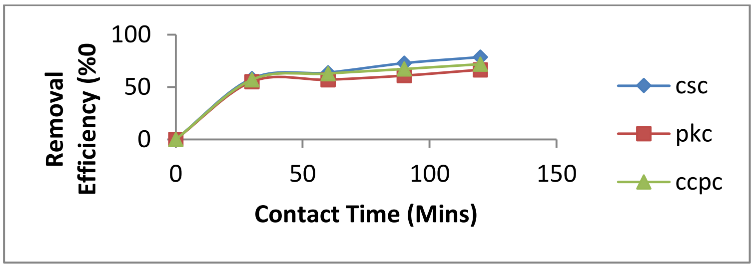

Fig 2a: Effects of Contact Time on COD Removal Efficiency

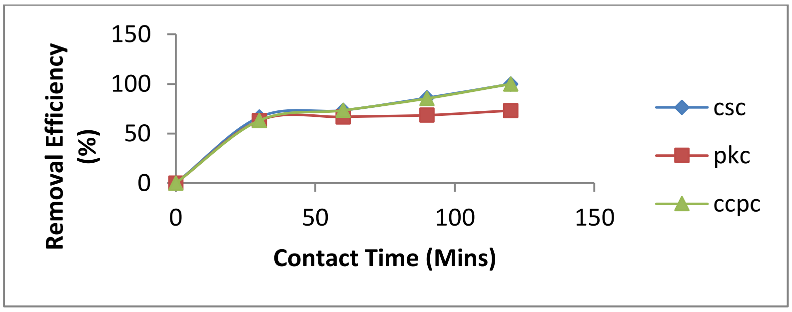

Fig. 2b: Effects of Contact Time on TSS Removal Efficiency

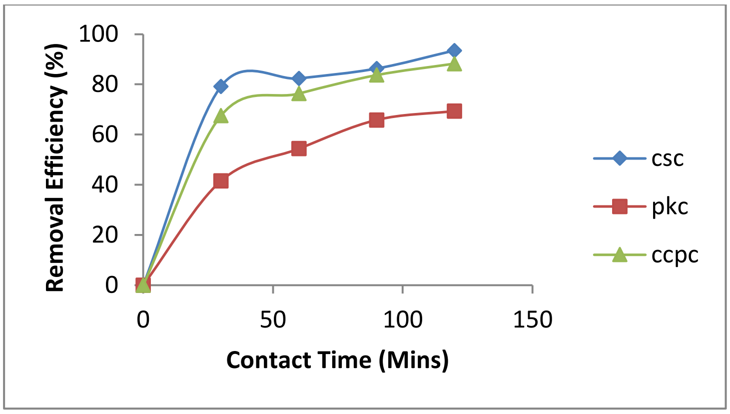

Fig. 2c: Effects of Contact Time on TDS Removal Efficiency

Among the three carbons studied, only CSC reduced COD concentrations below the acceptable FEPA limits of 80mg/l after a contact time of 120 minutes. TSS and TDS were however, reduced below the FEPA set limits by each of the experimental carbons after a contact period of 120 minutes.

Statistical analysis showed that the mean removal efficiencies of all the pollutants were significantly different between treatments and levels at p = 0.05.

Effects of pH on the Removal Efficiency of Pollutants

The effect of pH on adsorption of pollutants in pretreated brewery effluents by locally produced adsorbents was studied within a pH range of 2 – 10 covering both the acidic and the alkaline ranges. Figures 3a, 3b, and 3c show the results obtained. From the Tables, it was observed that the general trend indicated that removal efficiencies were higher in the alkaline (higher) pH range than in the acidic (lower) range, for all pollutants studied and for all experimental carbons used. CSC exhibited better removal efficiencies at a pH of 8 for all parameters and was closely followed by CCPC at the same pH, while PKC exhibited the lowest removal efficiencies at all the pH ranges considered.

Statistics show that there was significant difference in means between treatments (activated carbons) and levels (pH) for all the pollutants studied.

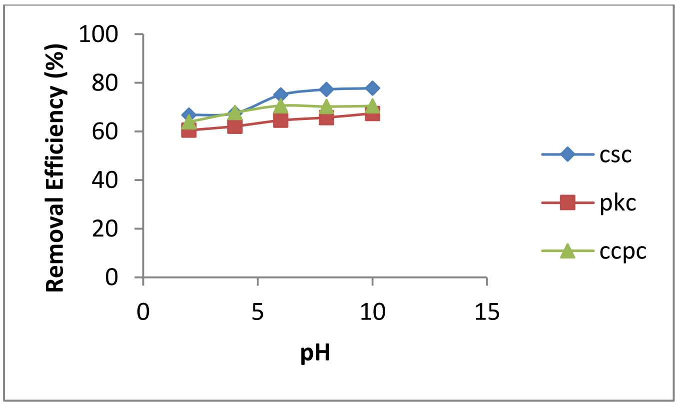

Fig. 3a: Effects of pH on COD Removal Efficiency

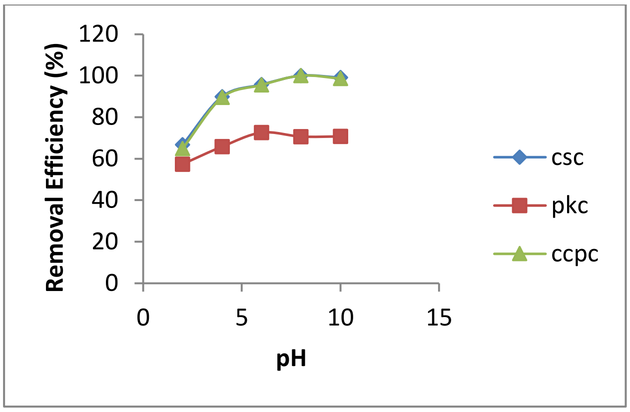

Fig. 3b: Effects of pH on TSS Removal Efficiency

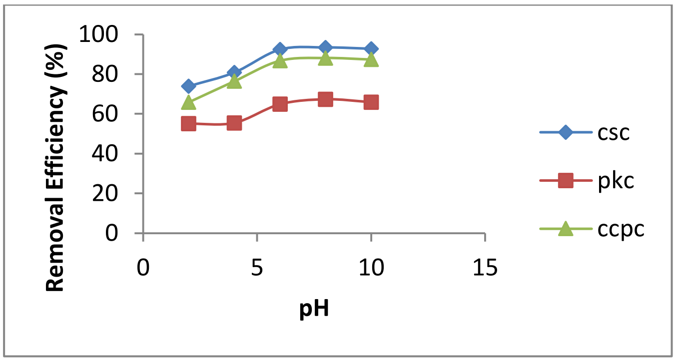

Fig. 3c: Effects of pH on TDS Removal Efficiency

CONCLUSIONS

Three different granular Activated carbons (GACs) were produced and characterized. These were; CSC (Coconut based), PKC (Palm kernel based) and CCPC (coconut and palm kernel based). From the characteristics determined, it was observed that CSC had the highest ash content, specific surface area and iodine sorption and was closely followed by CCPC, while PKC had the lowest values of the mentioned characteristics. CCPC had the highest methylene blue number, followed by CSC and then PKC. As for bulk density, PKC had the highest value and was followed closely by CCPC, then CSC. Carbon yield was higher in CCPC, followed by PKC, then CSC. There was significant difference in mean characteristics between the three carbons considered at $p = 0.05$.

The experimentally produced carbons were used to remove the residual pollutants, through the use of batch equilibrium/ adsorption experiments. The effects of carbon dosage, contact time and pH on the removal efficiencies of the pollutants were investigated.

Results show that adsorption increased with increasing carbon dosage for all the activated carbons and pollutants studied. The highest removal efficiencies were recorded at a dosage of 8g/100ml for all the carbons and pollutants. In all cases, the COD, TSS and TDS were reduced to acceptable discharge limits at the highest dosage of 8g/100ml.

Removal efficiencies also increased with increase in contact time and were highest at a contact time of 120 minutes for all the carbons used and pollutants treated.

The experimental results also revealed that, best removal efficiencies were more favoured in the alkaline pH ranges than in the acidic pH ranges. The highest removal efficiencies were recorded at a pH of 8 for all the carbons and pollutants. There was significant difference in means between the carbons and within all treatments levels, for all pollutants treated at p = 0.05.

Thus, it could be concluded that, CSC and CCPC are better adsorbents for the removal of COD, TSS and TDS in terms of adsorption capacity and intensity, while PKC is not suitable for complete or acceptable removal of the studied pollutants in pre-treated brewery effluents.

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SIMULATION OF DRYING KINETICS OF INDUSTRIAL CASSAVA FLOUR BY THE FINITE DIFFERENCE METHOD

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ABSTRACT

The production process of High Quality Industrial Cassava flour from grated unfermented cassava mash involves drying under different parameters without uttering the quality. Evaluation of drying kinetic as a function of drying conditions helps in drying simulation for predicting the suitable drying conditions that will retain quality. Mathematical models were developed to describe moisture transport phenomena in the particles of unfermented grated cassava mash during drying process. Finite-difference method was adopted to solve the resulting model equations and a computer programmed crop-drying simulator 1.0, was developed for the simulation of the average moisture distribution per time during drying process. The model was validated experimentally using a fully automated laboratory Model dryer. The simulated and the experimental result shows reasonably close agreement. This finite difference model satisfactorily predicts the moisture diffusion during drying.

Keywords: Drying; Finite difference; High quality industrial cassava flour; Simulation

INTRODUCTION

Cassava is a root crop with excellent source of carbohydrates. It's bulky in nature (containing about 70% moisture), highly perishable, low protein and free amino acid content and high content of the poisonous cyanogenic glucosides (CNG). It is widely recognized as a productive crop and a good energy source (Osakwe et al., 2008) with high drought tolerance and low demand for nutrients. After rice and maize, cassava is the third most important food source in the tropics (Cock, 1985). Processing of cassava roots into different end products through drying provides a means of producing shelf stable products for value addition to cassava and also, preserve cassava root for exportation in a longer storage form which minimizes qualitative and quantitative losses thereby ensures steady production and availability. High Quality Industrial cassava flour is a cassava product produced from grated unfermented cassava mash. The production process of High Quality Industrial Cassava flour from grated unfermented cassava mash involves drying under different parameters without uttering the quality. Evaluation of drying kinetic as a function of drying conditions helps in drying simulation for predicting the suitable drying conditions that will retain quality. Simulation results and information of drying kinetics of food products such as drying rates, time-temperature-moisture content distributions, as well as theoretical and empirical approaches to moisture movement, are very essential for the prevention of quality degradation and for the achievement of fast and effective drying. [Mujumdar, 2006].

Drying is widely used in the preservation of cassava and it,s products but a scientific approach has not so widely been applied, most often, traditional technics are often used to set up industrial production, particularly in small and medium scale industries. The formulation of sufficient mathematical drying models to optimize drying process can enhanced product quality, reduced process cost, improve speed and decrease the time taken to share information and make critical decision. The mathematical model using partial differential equation (PDE) is a helpful tool that can be use to estimate the drying rate at any moisture condition of a material and to estimate drying time for particular task during drying. Computer simulation is a powerful tool for measuring changes in temperature and moisture during drying process (Islam, 2010).The increasing development of computer program had a great impact on the quality evaluation of agricultural products. Invention of the computer also influenced the field of numerical analysis, by aiding the solving of longer and more complicated calculations. Therefore, the objectives of this study are: (i) To simulate moisture content versus time in the drying process of high quality industrial cassava flour based on convection-diffusion model using partial difference equation (PDE) and (ii) To provide solution to the derived partial differential equation using finite difference method (iii) to compare the data predicted by the model with the data from the experiment.

Several studies have been conducted on finite difference modeling of drying of cereal grains.(Yahaya, 1979, Patil, 1988). A number of studies have been reported on finite difference modeling of heating and drying of food materials. However, little or no studies have been reported on finite difference modeling of drying of unfermented cassava mash to produce high quality cassava flour. Two methods are commonly applied to model heat and mass transfer: the finite difference method and the finite element method. The basic ideal of finite difference method is solving partial differential equations by replacing the spatial and time derivatives with suitable approximations (Jeffrey, 2011). In all numerical solutions the continuous partial differential equation (PDE) is replaced with a discrete approximation. In this context the word "discrete" means that the numerical solution is known only at a finite number of points in the physical domain. In general, increasing the number of points not only increases the resolution (i.e., detail), but also the accuracy of the numerical solution. The discrete approximation results into a set of algebraic equations that are solved in order to determine the values of the discrete unknowns.

MATERIALS AND METHODS

The experimental investigation were carried out at the Engineering and Materials Testing laboratory of the Engineering and Scientific Services (ESS) department of the National Centre for Agricultural Mechanization (NCAM), Ilorin Kwara State. The materials used for this research work are classified into two groups namely: the grated unfermented cassava mash and the fully automated Model Laboratory dryer. The cassava tubers were obtained from the NCAM farm and was processed into grated unfermented cassava mash.

Description of the Model Laboratory Dryer

The laboratory Model Dryer is a fully automated dryer with Aluminium Load Cell, (OIML) for monitoring of the weight of moisture removed and was interface to a personal computer at
an interval of 30 seconds. A sample tray which was hanged to the load cell, voltage/frequency AC motor speed controller for air flow rate variation, temperature controller K - type, model WRX – 31 for the variation of dryer temperature and K-type thermocouples for monitoring the temperature of the sample at 8 different points on the sample tray. The temperature sensed by these thermocouples were logged into the personal computer via the TC-08 Thermocouple Data Logger. The power rating of the dryer fan motor is 0.75kW. The heat source is from 2kW electric heater powered by 230 Volt AC supply via the temperature controller.

Figure 2.1: Dryer with Associate Instrumentation

FINITE DIFFERENCE MODELING OF GRATED UNFERMENTED CASSAVA MASH TO PRODUCE HIGH QUALITY INDUSTRIAL CASSAVA FLOUR.

Luikov's mathematical model for drying porous product was used in modelling the moisture movement within the particles of the grated unfermented cassava mash. Luikov's mathematical model is expressed as (Bhagwati, 2011) :

$$\frac{dm}{dt} = \nabla^2 k_{11} M \qquad (1)$$

Where, K_{11}=Phenomenological coefficient ,M=moisture content(% db).

Equation (1) is simplified and yields

$$\frac{\partial M}{\partial t} = D\left[\frac{n}{r}\frac{dm}{dr} + \frac{d^2 m}{dr^2}\right] \quad (2)$$

Where, D_{eff}= effective moisture diffusivity (m^2/s). T= time (Hr)

n= constant and it's dependent of shape of material.

The following assumptions which are based mostly on literature review aided in solving equation (2).

1. The particles of the grated unfermented cassava mash has uniform moisture content and temperature i.e uniform moisture distribution and internal heat generation.
2. The particles of the grated unfermented cassava mash are homogenous.
3. The moisture movement within the particls is radial. (temperature within, varied in the radial direction).
4. The mechanism of the drying process is predominantly controlled by liquid diffusion.
5. The temperature within the particls of the grated unfermented cassava mash and shrinkage of the particle are negligible. (Ogunleye, 2006, Osoka et,al,2006).
6. The particles of grated unfermented cassava mash are assume to be spherical. According to Moorthy (2002), cassava starch granules are mostly round with a flat surface on one side containing a conical pit, which extends to a well defined eccentric hilum under microscopic examination. Generally, granule size of cassava starch is express as spherical.(Adejumo, 2011).

Formulation of Equation

The diffusion of moisture within the particl of the mash and average moisture content at a unit time interval were analysed in a spherical coordinate using Crank's Diffusion equation in two dimensions. The diffusion equation becomes

$$\frac{\partial M}{\partial t} = D(M,\theta)\left[\frac{2}{r}\frac{dm}{dr} + \frac{d^2 m}{dr^2}\right] \quad (3)$$

Where, r = radial position (m), =grain temperature,^{0}C

$$\overline{M} = \frac{3}{R^3}\int_{R=0}^{R} Mr^2 dr. \quad (4)$$

$$\overline{M} = Averagemoisturecontent(\%drybasis)$$

.

NUMERICAL SOLUTION

Numerical method was applied to solve equation (3) and (4). Particles of the grated unfermented cassava mash were represesnted by sphere of equivalent radius and moisture was assumed to move from the interior to the outward surface by diffusion .The computational domain represented the divisional region and was assumed that the system of the differential equation was valid over the finite difference domain as shown in figure 1.

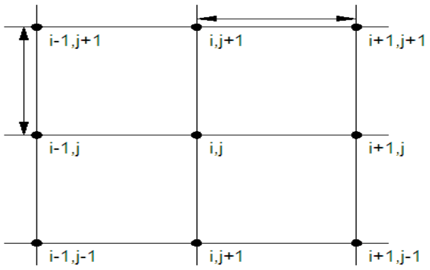


Figure 2.2: Grid points for the Finite Difference approximation

Where: i = radial grid index (1,2,3…….n) , j = time grid index(1,2,3………..n)

The grid generation was accomplish by using directory (i) in the direction R, therefore, every nodes had it's axis and expressed as :

$R_i = i\Delta R - \frac{\Delta R}{2}$; where $R = \frac{R}{n}$. Substituting for R; $R_i = \Delta R.\frac{2i-1}{2}$

In order to stabilize equation (3) over a domain, Central Finite Difference Approxi mation method was applied and is as stated thus:

$$\frac{dM}{dt} = \frac{M_{i,j+1} - M_{i,j}}{\Delta t} \tag{5}$$

$$\frac{dM}{dr} = \frac{M_{i+1,j} - M_{i,j}}{\Delta R} \tag{6}$$

$$\frac{d^2M}{dr^2} = \frac{M_{i+1,j} - 2M_{i,j} + M_{i-1,j}}{\Delta R^2} \tag{7}$$

(Jeffrey, 2011)

Substituting equations (5),(6)and(7) into equation(3) gave,

$$\frac{M_{i,j+1} - M_{i,j}}{\Delta t} = D\left[\frac{2}{R_i}\frac{M_{i+1,j} - M_{i,j}}{\Delta t} + \frac{M_{i+1,j} - 2M_{i,j} + M_{i-1,j}}{\Delta R^2}\right] \tag{8}$$

:

Substituting R_i and R into equation (8) and further solving using separation of variables yielded the moisture content profile at different regions of the mash.

2.3.1 At the interior region the moisture content distribution:

$$\frac{M_{i,j+1}-M_{i,j}}{\Delta t}=\frac{n^2}{R^2}*\frac{4}{2i-1}\left[M_{i+1,j}-M_{i,j}\right]+D\frac{n^2}{R^2}\left[M_{i+1,j}-2M_{i,j}-M_{i-1,j}\right] \quad (9)$$

Collecting like terms and making $M_{i,j+1}$ the subject of the formula:

$$M_{i,j+1}=M_{i,j}+D\frac{n^2}{R^2}\Delta t\left[\frac{4}{2i-1}M_{i+1,j}-\frac{4}{2i-1}M_{i,j}-2M_{i,j}+M_{i+1,j}-M_{i-1,j}\right] \quad (10)$$

After solving the equation (10), $M_{i,j+1}$ which is the moisture profile at the interior nodes at a unit time intervals becomes:

$$M_{i,j+1}=M_{i,j}+D\frac{n^2}{R^2}\Delta t\left[\frac{2i+3}{2i-1}M_{i+1,j}-\frac{4i+2}{2i-1}M_{i,j}+M_{i-1,j}\right] \quad (11)$$

2.3.2 At the centre region moisture content distribution:

At the centre, r = 0, i.e there is no moisture gradient at the center of the product the boundary condition is express as:

$$\frac{dM}{dr}\Big|_{r=0}=0$$

Therefore, the term $M_{i-1,j}$ in equation (11) equals to $M_{i,j+1}$ in equation (12) this is expressed as:

$$M_{i,j+1}=M_{i,j}+D\frac{n^2}{R^2}\Delta t\left[\frac{2i+1}{2i-1}M_{i+1,j}+M_{i+1,j}-\frac{4i+2}{2i-1}M_{i,j}\right] \quad (12)$$

Further simplification of equation (12) gave equation (13) therefore, the moisture distribution at the centre of the mash per unit time intervals gave:

$$M_{i,t+1}=M_{i,j}+D\frac{n^2}{R^2}\Delta t\frac{4i+2}{2i-1}(M_{i+1,t}-M_{i,j}) \quad (13)$$

2.3.4 The moisture distribution at the surface region:

The following Central finite difference approximation were employed to solve for the moisture distribution terms at the surface nodes as r = R:

$$\frac{dM}{dr}=\frac{2(M_{s,j}-M_{n,j})}{\Delta R} \quad \textit{and} \quad (14)$$

$$\frac{d^2M}{dr^2}=\frac{2M_{s,j}-3M_{n,j}+M_{n-1,j}}{\Delta R^2} \quad (15)$$

The algebraic form of equation (3) for the moisture distribution at the surface by substituting equations (14), (15), R and R_i with $M_{n,j+1}$ becomes the subject of the formulae yielded:

$$M_{n,j+1} = M_{n,j} + D\Delta t\left[\frac{n}{R} * \frac{4}{2i-1} * \frac{n}{R}(2M_{S,j} - 2M_{n,j}) + \frac{n^2}{R}(2M_{s,j} - 3M_{n,j} + M_{n-1,j})\right] \quad (16)$$

Where; s= at surface and n = number of hypothetical shell in the particles.

Further simplification by expansion of equation (16) gave (17):

$$M_{n,j+1} = M_{n,j} + D\frac{n^2}{R^2}\Delta t\left[(\frac{4i+6}{2i-1})M_{s,j} - (\frac{6i+5}{2i-1})M_{n,j} + M_{n-1,j}\right] \quad (17)$$

To determine the moisture content at the surface ($M_{s,j}$), Newmann boundary condition was considered for simplicity and accuracy. The convective boundary condition is express thus:

$$-D\frac{dm}{dr} = \big|_s h_D(m_s - m_e) \quad (18)$$

Where H_D = mass transfer coefficient, $M_{s=}$ Moisture content at the surface, $M_{e=}$ Equilibrium moisture content.

Substituting equation (14) into equation (18) yielded:

$$-D\left[\frac{2(M_{s,j} - M_{n,j}}{\Delta R}\right] = h_D(M_s - M_e) \quad (19)$$

Substitute for ΔR in equation (19) and expanded gave

$$M_{s,j} = \frac{Rh_D M_e + 2M_{n,j}}{h_D + 2Dn} \quad (20)$$

Substitute for $M_{s,j}$ in equation(17) gave the moisture distribution at the surface region:

$$M_{n,j+1} = M_{n,j} + D\frac{n^2}{R^2}\Delta t\left[(\frac{4i+6}{2i-1})\left[\frac{Rh_D M_e + 2M_{n,j}}{Rh_D + 2Dn}\right] - (\frac{6i+5}{2i-1})M_{n,j} + M_{n-1,j}\right] \quad (21)$$

2.3.5.Determination of Mass transfer coefficient h_D

H_D is the mass transfer coefficient which describe the convective mass tranfer that occur at the surface of the material and was calculated via Sherwood number.

$$Sh = \frac{h_D d}{D_w}, \quad h_D = \frac{ShD_W}{d} \quad (22) \quad \text{(Patil, 1998)}$$

Where, d = diameter of mash, D_w= diffusion coefficient of water vapour in air =2.20x10^{-5}m^2/s.

$$Sh = 2.0 + 0.552R_e^{0.53} + Sc^{0.33}, \quad \mathrm{Re} = \frac{ud\rho}{\mu}, \quad S_c = \frac{\mu}{\rho d} \quad \text{(Patil,1998)}$$

where, u = mass velocity of air (kg.m$^{-2.s}$), d = particle diameter (m), ρ = density kg/m^3

μ = viscosity of air. (kg s^{-1} m^{-1}

2.3.6. Determination of Equilibrium moisture content

Modified Herderson equation was applies:

$$rh = 1 - \exp\left[-A(T + 273.15^0 c)M_e\right] \quad (23)$$

2.3.7.Determination of the average moisture content

The solution of the equation (4) gave the average moisture content. This was solved by applying the Trapezoidal Rule of integration.

$$\int_b^a f(x)dx = \frac{h}{2}\left[f(a) + f(b) + 2\sum_{i=2}^{n} f(x_i)\right] \quad (24)$$

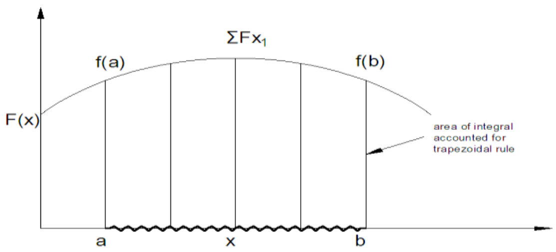


Figure2.3: Graphical Representation of the Trapezoidal Rule (Jeffry, 2011)

Where , A_i=area of each trapezoids

$$= \frac{h}{2}\left[f(x_i) + f(x_i + h)\right] \quad (25)$$

Where position of the left side of the i^{th} trapezoid is x_i

Summation of the average moisture content at the centre region is;

$$f(x) = \frac{\Delta R}{4}\left[R_{i,j}{}^2\ M_{i,j}\right] \quad (26)$$

where ,R=0 and i =1, $R_i = \frac{R}{n} * \frac{2i-1}{2}$, $R = \frac{R}{n}$

Substituting for R

2.3.8. The average moisture content at the centre of the node

$$f(x) = \frac{R^3}{16n^3}(2i-1)^2 \quad (27)$$

2.3.9. The average moisture content at the interior region where i<i<n:

$$f(x) = \frac{\Delta R}{2}\left[R^2{}_{i,j} M_{i,j} + \sum_{i=2}^{n-1} \Delta R(R_{i,j}{}^2\ M_{i,j}) + \frac{\Delta R}{2}(R^2{}_{n,j} M_{n,j}\right] \quad (28)$$

Substitute for R_i and R and expand, yielded

$$f(x) = \frac{8}{Rn^3}(2i-1)^2 M_{i,j} + \frac{R^4}{4n^4}\sum_{i=2}^{n-1}(2i-1)^2 M_{i,j} + \frac{R^4}{16n^4}(2i-1)M_{n,j} \qquad (29)$$

2.4.0 The average moisture content at the surface

$$f(x) = \frac{\Delta R}{4}\left[R^2{}_{n,j}M_{n,j} + R^2{}_{\max}M_{s,j}\right] \qquad (30)$$

Substitute for R in equation (30)

$$f(x) = \frac{R}{16n^3}(2i-1)^2 M_{n,j} + \frac{R^3}{4n^3}M_{s,j} \qquad (31)$$

$M_{s,j}$ represent the moisture at the surface which can be evaluated without considering the convective mass transfer which occur at the surface of the material and is determined via Sherwood number Sh (Bryan and Brian 1996). Therefore, Summation of equations (27), (29) and (31) yielded the average moisture content within the grated unfermented cassava mash.

$$\overline{M} = \frac{3}{R^3}\left[\frac{3R^3}{16n^3}(M_{i,j} + (2n-1)^2 M_{n,j}) + R^3\left[\frac{M_{n,j}}{4n+Sh} + \sum_{i=2}^{n-i}(2i-1)^2 M_{i,j}\right]\right] \qquad (32)$$

A computer programme written in Visual Basic programming was used to solve the set of equations (11, 13,21 and 32) and to simulate moisture transport and distribution within the particles of the grated unfermented cassava mash and to compute average moisture content of the particle at unit time intervals. The input parameters of the simulated program are the number of concentric shell of equal thickness of which product particle was divided, the initial moisture content ,the air, water and cassava mash properties. An empirical equation to calculate moisture diffusivity as a function of material temperature and moisture content, equations for computing Sherwood number, mass transfer coefficient and equilibrium moisture content.

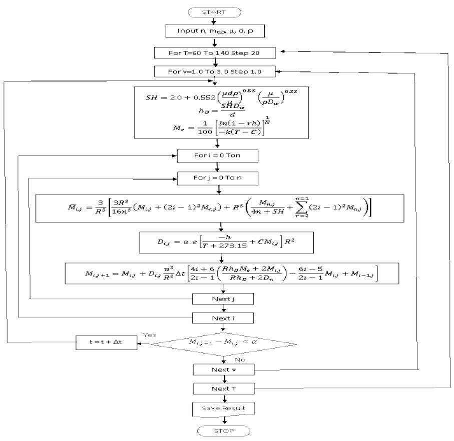


Figure 2.4 : Flowchart of Algorithm for the Drying Process of Industrial Cassava Mash

RESULT AND DISCURSSION

Computer Programme structure and Features

The computer programmed crop-drying simulator 1.0, was developed from the programme and is made up of software interface where by the user input all the necessary parameters required for the simulation of the average moisture distribution in the product during drying which were difficult to compute manually due to series of iteration steps involved. The interface also has the ability to import the experimental values in order to compute the differences between the observed and the simulated. The values are later exported into excel for further statistical analysis using statistical package for science and social sciences (SPSS). Crop drying simulator interface is divided into three section: the parameter section, the command section and the result section.

The command section consist of the execute command button, export command button and the close command button. The execute command button is clicked when all necessary parameters are properly entered in the parameter section. Clicking on the execute command button, the result of the simulation is displayed in the result section. The result section is in tabular form. It consist of columns for the display of time, observed values, simulated values and difference.

The close command button shut down the programme.

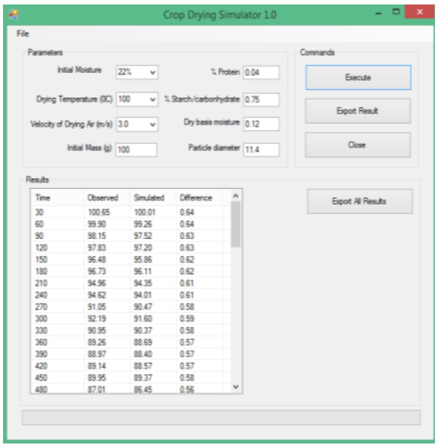


Figure 3.1: Computer Programme Crop-drying Simulator 1.0 Interface with display.

Validation of the Finite difference developed model.

Graphical presentation and statistical analysis were used for the validation procedure. The Model prediction were evaluated on the bases of Root Mean Square Difference (RMSD).

$$RMSD = \frac{\frac{\sqrt{\sum_{i=1}^{N} ypre_i - ymeas._i}}{N}}{\frac{\sum_{i=1}^{N} y,meas._i}{N}} \times 100 \qquad \text{(Niroot, 2010).}$$

Table 3.1: The summary of the Statistical Analysis of the Experimental and Simulated Results (Descriptive statistics).

	N	Range	Minimum	Maximum	Sum	Mean	Standard Deviation	Variance
RMSE	125	0.400	0.267	0.666	57.961	0.464	0.075	0.006
RMSD	125	0.506	0.337	0.844	73.397	0.587	0.096	0.009
DIFF	125	0.406	0.260	0.667	57.631	0.461	0.073	0.005

Table 3.1, shows the summary of the Statistical Analysis of the Experimental and Simulated results. From the table, the mean value of the Root Mean Square Difference RMSD is 0.59 %.This is within the acceptable limit which is 10%. (O'Callaghan, 1971 and Niroot Lamlert, 2010). Thus the prediction is very good .i.e the model can predict the moisture content distribution with reasonable accuracy.

Table 3.2: Average Time of Drying for Different Temperature

			95% Confidence Interval	
Temp(^{O}C)	Mean	Std. Error	Lower Bound	Upper Bound
40	2.565	.166	2.235	2.895
55	1.817	.166	1.487	2.147
70	1.471	.166	1.141	1.801
85	1.307	.166	.977	1.637
100	1.252	.166	.922	1.583

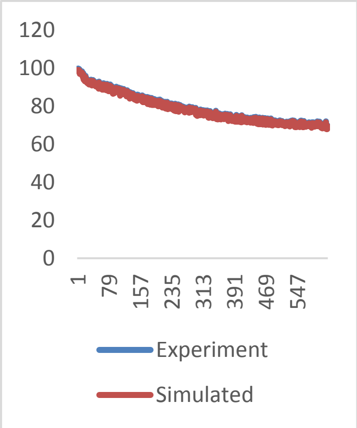
Table 3.2: shows the average time of drying for different temperature levels. From the table, it was observed that the time of drying reduces with increase in the temperature levels. At the lowest temperature level 40^{0}C, the highest average time of drying was observed to be 2hours: 57minutes. Similar trend was noticed with temperature level 55^{0}C which had average time of drying as 1hour: 82 minute .Also similar trend observed with by temperature levels 70^{0}C,and the average time of drying was 1hour:47 minutes. At the next temperature level which is 85^{0}C, the time of drying was 1 hour: 30 minutes. The highest temperature level, which is 100^{0}C, the average time of drying was 1hour: 25 minutes. This trend was reasonable because, in this study, it was assumed that the mechanism of the drying process is predominantly controlled by liquid diffusion. The driving force is the temperature difference between the center of the particle and the drying air. The greater the temperature, the greater the driving force, and the higher the rate of heat transfer to the product, hence, the shorter the drying time. In summary, the lowest time of drying, from the table was 0.92 seconds at the highest temperature which is temperature level 100^{0}C and the highest time of drying was 2hours: 90minutes at the lowest temperature level 40^{0}C.

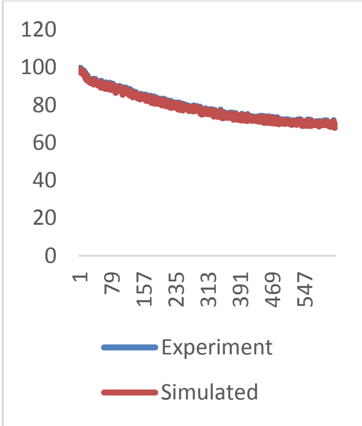
Comparison of the Simulated and the Experimental Drying Kinetics

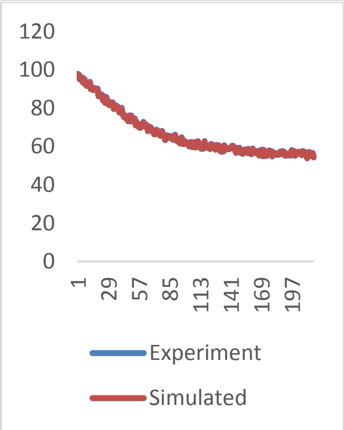
Figure 3.3a-3.3e, shows the comparison between the simulated and the experimental values of the moisture distribution within the unfermented grated cassava mash as a function of time of drying at typical air temperatures of 40^{0}C, 55^{0}C, 70^{0}C, 85^{0}C and 100^{0}C.

From figure 3.3a-3.3e, it can be observed that the moisture content of the unfermented grated cassava mash decreases as the drying time increases until equilibrium moisture content was attained. The graphical representation of the comparison shows that both the simulated and the experimental exhibit the same trend. Hence, the simulated and the experimental result shows reasonably close agreement.

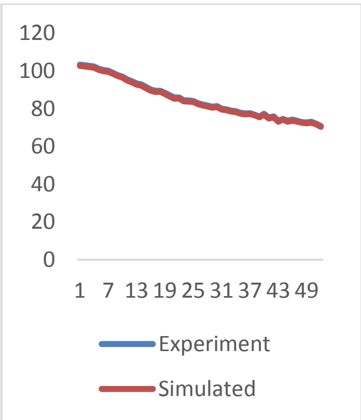
This is in agreement with other works carried by other researcher on the drying of agricultural materials.(Balaban and Pigott, 1988, Afolabi , 2014)

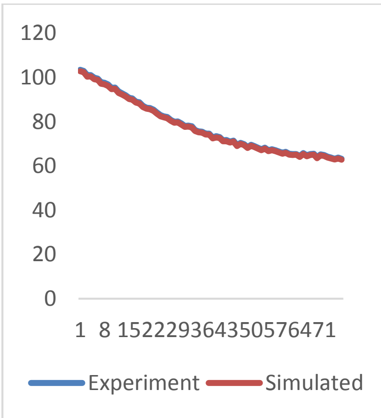






At temperature 40^0 At temperature 55^0 At temperature 70^0





At temperature 85^0 At temperature 100^0

Figure 3.3a-e , Experimental and Simulated Variation of Moisture Content with time

CONCLUSIONS

The following conclusions can be deduced from this study:

1. The application of the finite difference method to solve the mass transfer equations in unfermented grated cassava mass during drying was successful.
2 The developed computer programmed Crop-drying simulator 1.0 was capable of simulating the drying time and the drying process that was mathematically modelled.
3. The laboratory investigation was successfully carried out using fabricated Model dryer.

4. The mean value of the Root Mean Square Difference (RMSD) between the simulated and the experimental is 0.59 %.This is within the acceptable limit which is 10%. Meaning, that the simulated agrees favorably well

5. The mathematical model provided in this study is a useful way to predict the moisture transfer mechanism in unfermented grated cassava mash during drying process with reasonable accuracy.

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DRYING KINETICS OF AN INDUSTRIAL CASSAVA FLOUR USING AN EXPERIMENTAL MODEL DRYER WITH FULL AUTOMATIC CONTROL SYSTEM

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ABSTRACT.

A laboratory Model Dryer fully automated was fabricated for monitoring and control of drying process of agricultural products. Instrumentations were installed for monitoring rate of moisture remover using Aluminium Load Cell, and was interfaced to a personal computer at an interval of 30 seconds. A voltage/frequency AC motor speed controller for air flow rate, temperature controller K - type, model WRX – 31 and K-type thermocouples for monitoring the temperature at 8 different points on the sample tray which were later logged into the personal computer via the TC-08 Thermocouple Data Logger. The result of the evaluation of the drying kinetics of Industrial Cassava mash shows that the system allowed the dryer to operate at a constant temperature and desired drying airflow and also provided full control of the temperature and drying airflow in a wide range. It also gave room for computerized real-time automatic control system in order to retain quality. The automatic control system was reliable and of easy implementation and maintenance.

KEYWORDS; Automatic control, dryer, Quality.

INTRODUCTION

Drying is one of the main techniques for preserving agricultural and food products; it takes place in the processing of many products, as the main operation or as a consequence of other processing steps. Drying is applied to a wide variety of food products, from raw materials to by- products. The increasing need for producing efficiently high quality and convenient products at a competitive cost has led to the employment of several drying methods in practice.

The quality of foods refers first to safety, and then to sensory and nutritional properties. But in many cases, the severity of processing is differently related to safety and to sensory or nutritional quality. Severe processing generally results in higher nutritional loss and in poorer quality.

Automatic control in food process system is necessary to maintain final product quality, improve process efficiency and reduce waste. Due to limited understanding of the physicochemical interactions occurring during processing as well as large and unpredictable variations in raw material composition and characteristics in addition to large dead time make it difficult to design proper controls for food process system. Such variation introduces significant, unmeasurable disturbance to the process that can make manual control unreliable also food process system exhibit large dead time and are typically non-minimum phase system.

Smith predictive and mini variance controller scheme had achieved improvement in control performance with the use of improved controllers to overcome complexity caused by raw materials variability displayed in food process system. Generalized Predictive controllers (GPC) has been found to overcome the limitations associated with minimum variance and smith Predictive Scheme. The GPC with an auto-regressive with exogenous input ARX model has successfully been employed to control a twin screw food extruder and a continuous fryer. Dynamic matrix control (DMC) has been applied to a continuous frying process achieving good result. A combination of GPC with an on-line identification routine has been shown to be capable of providing stable control to processes with variable parameters and variable dead -time with model order that changes during the process, this type of controllers are refers to as adaptive.

In Nigeria especially, agricultural drying still adopts manual control method and the control process has long-time delay and poor stability, so the quality of the product cannot be ensured. The research on the automatic process control and instrumentation is an important means of studying agricultural drying process control in order to retain quality of products. This is to achieve automatic control during the drying process, ensure the accuracy and uniformity of the product moisture content, improve the relative germination rate after drying, and improve the poor stability of produce moisture and low quality during the manual control process in produce storage. Since drying is the post-harvest process that consumes more energy, representing an increasing in costs, the search for efficient processes with lower energy consumption has guided several studies and projects (Tippayanwong et al.,

2008; Nagle, 2010). More efficient drying systems can improve the operation conditions through intelligent controls of the temperature and airflow used in drying (Srzednicki et al., 2006; Tippayanwong et al., 2008; Shabde & Hoo, 2008).
The control of the drying process adopts the methodology of measurement and adjustment of values of temperature, relative humidity and airflow used in the drying, according to the product being processed, increasing the thermodynamic efficiency of the process, and preserving the maximum quality of the product.
The development of computer systems has facilitated the study of physical principles involved in agricultural processes. The interactions of agricultural processes with computerized control systems provide accurate data acquisition, and facilitate analysis and decision making with greater agility through automated systems. The combination of all these factors, among others, contributes effectively to the increased efficiency of agricultural processes.
The objective of this work is to measure the drying rate of an industrial cassava flour using an experimental model dryer with full instrumentation and control.

METHODOLOGY

THEORETICAL ANALYSIS.
Moisture is the quantity of water in the product. There are two basis in specifying moisture content, wet-weight basis (m_w) and dry-weight (m_d).
Where:

$$m_w = \frac{w-d}{w} \quad (1)$$

and

$$m_d = \frac{w-d}{d} \quad (2)$$

Where w=the total mass of sample (kg) d = the mass of the dry matter (kg)

The dry-weight basis is widely used in organic drying analysis because the dry weight of the matter is almost constant during drying process.

EXPERIMENTAL APPARATUS.

Description of the dryer.
The dryer is a rectangular, cupboard shaped like which consists of the following units: a drying chamber, the heating unit, the chimney and the automatic control unit. The drying chamber consists of the plenum chamber and the heating chamber. The plenum chamber is the unit in which the blower delivers the drying air before coming in contact with the materials to be dried. It was designed like a long, curved chute leading to the drying section from underneath in order to distribute the air uniformly trough the products. In the heating chamber, which has one electrical heating coils of 1.20 kW, air is heated and a backward curved centrifugal fan sucks the heated air into the plenum chamber while residual exits through the vent. The inside of the chamber allows a tray to be arranged at a time. The chamber has one door to allow the tray to be placed inside. Chimney serves as a vent through which the moisture from the product escapes to the atmosphere.

Figure 2.1: Dryer with Associate Instrumentation

Description of the prototype control system

The laboratory Model Dryer is a fully automated dryer with Aluminium Load Cell, (OIML) for monitoring of the weight of moisture removed and was interface to a personal computer at an interval of 30 seconds. A sample tray which was hanged to the load cell, voltage/frequency AC motor speed controller for air flow rate variation, temperature controller K - type, model WRX – 31 for the variation of dryer temperature and K-type thermocouples for monitoring the temperature of the sample at 8 different points on the sample tray. The temperature sensed by these thermocouples were logged into the personal computer via the TC-08 Thermocouple Data Logger. The power rating of the dryer fan motor is 0.75kW. The heat source is from 2kW electric heater powered by 230 Volt AC supply via the temperature controller. . In addition, the system performed real time data acquisition, generating graphs and reports in the format of spreadsheets and text files.

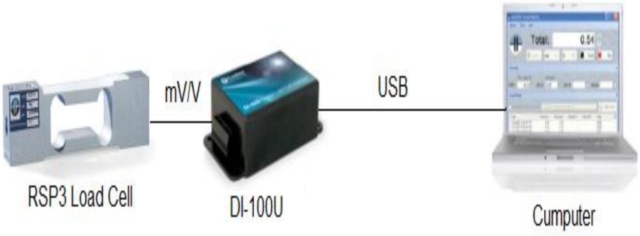
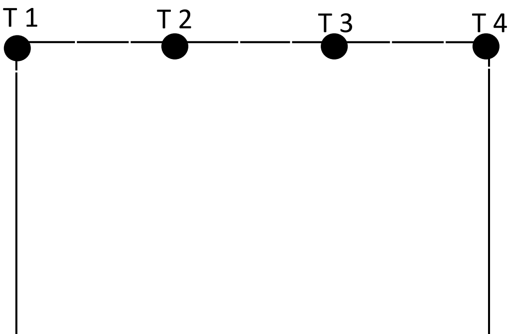


Figure 2.2 Connection of Load Cell, Interface Device and lap top computer.

Figure 2.3 V/F Control AC Motor Speed Controller

Figure 2.4 The TC-08 Thermocouple Data Logger



Legend:
T 1 - Thermocouple 1
T 2 - Thermocouple 2
T 3 - Thermocouple 3
T 4 - Thermocouple 4
T 5 - Thermocouple 5
T 6 - Thermocouple 6

Figure2.5 Arrangement of the thermocouples on the sample tray

Figure 2.6. The sensitive scale.

PROCEDURE

Drying experiments was carried out using grated unfermented cassava mash as the drying medium.. The cassava mash was processed from cassava tuber from the farm management unit of National Centre for Agricultural Mechanization (NCAM) Ilorin. It was peeled, washed, grated into mash and dewatered for a very short period of 1 hour in order to avoid fermentation and retain quality required for industrial purpose. The temperature of 40^0 C, 55^0C, 70^0C,85^0C, 100^0C and varied velocity levels of 1m/s,1.5m/s, 2m/s,2.5m/s and 3m/s were also investigated. The dewatered mash was placed on a stainless steel tray which was suspended from the load cell. The experiment continued until the sample weight became constant and the results was used for further processing.

RESULT AND DISCUSSION.

Figures 3.1a, presented the drying rate of the dewatered cassava mash at velocity 1m/s at temperatures levels 40^0C, 55^0C, 70^0C, 85^0C and 100^0C. An inverse relationship was noted between the air temperatures and the drying time. As the air temperature increases, the drying time reduces. This phenomenal was observed for other velocity levels which was as shown in figure 3.1b, 3. 1c, 3.1d and 3.1e. This indicates that the reduction of the moisture content of the grated unfermented cassava mash was not affected by the air velocity produce by the automated model dryer. This shows that that the velocity control system performed very well and adjusted the velocity to the desired value because at all the air velocity levels of 1m/s, 1.5m/s, 2m/s, 2.5m/s and 3m/s the same trend was exhibited by the temperatures supporting the fact that at any of this air velocity levels, drying process of unfermented grated cassava mash will occur.. The use of different velocities reveals no significant effect on the drying rate and this is in support of the work carried out by Amnart and Pongjet, 2006. This observation is a general report for other food products e.g. mulberry, eggplant, tomatoes, sweet pepper, cassava chips and peach slices. (Doymaz, 2004; Ertekin and Yaldiz, 2004; Doymaz, 2007; Kingsly *et al*., 2007).

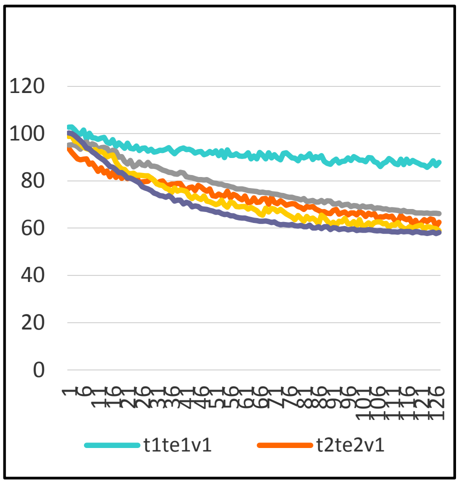


Figure 3.1 a; At velocity 1m/s

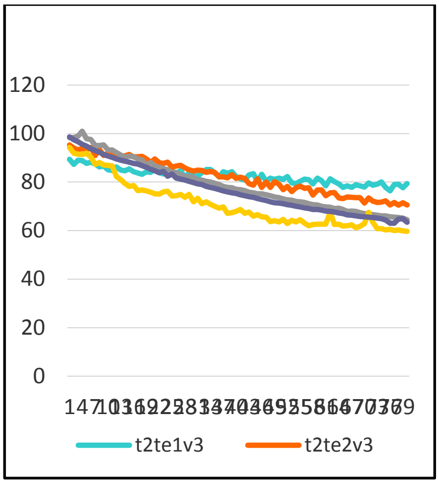


Figure 3.1b; At velocity 1.5m/s

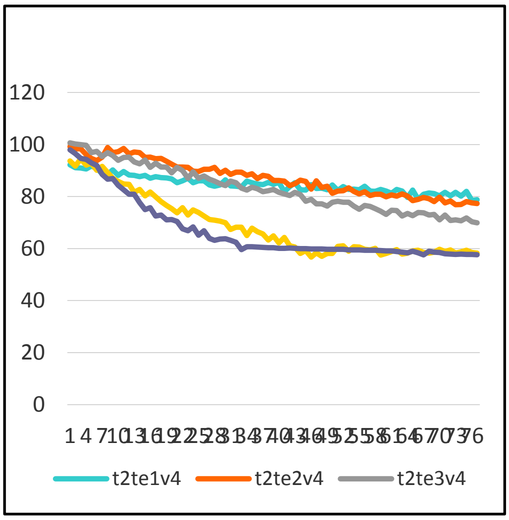


Figure 3.1 c; At velocity 2m/s

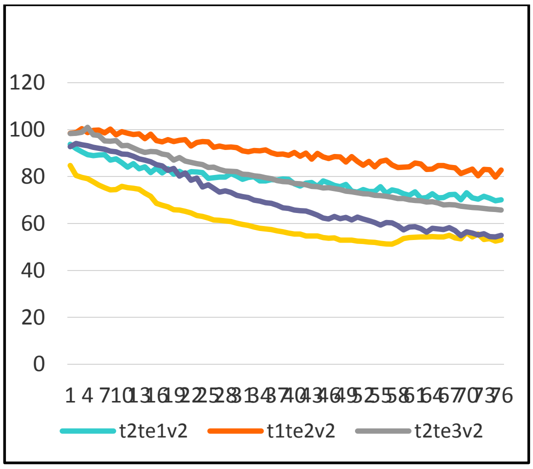


Figure 3.1d; At velocity 2.5 m/s

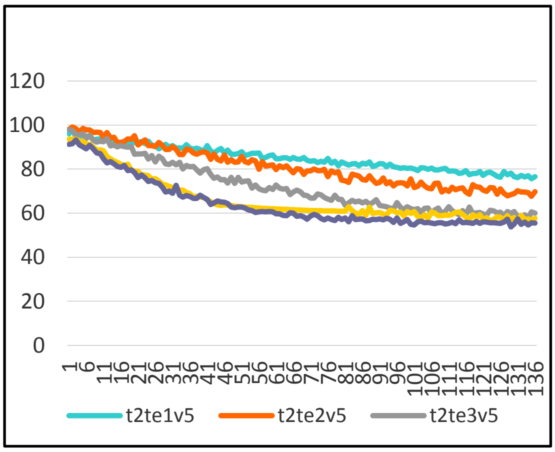


Figure 3.1e; At velocity 3m/s.

CONCLUSIONS.

The Instrumentation system allowed the dryer to operate at a constant temperature of the drying air and desired drying airflow. In addition to the automatic control, the system performed real time data acquisition, generating charts, graphs and reports in the format of excel and text files. The result of the experimental study of moisture content reduction during drying industrial cassava mash using the experimental model dryer with full automatic control system shows that that the velocity control system performed very well when adjusted to the desired levels. The automatic control system was reliable and of easy implementation and maintenance. The use of automatic control provided full control of temperature and drying airflow in a wide range of values (40^0c,55^0c,70^0c, 85^0c, 100°C and 1m/s,1.5m/s,2.0m/s,2.5m/s 3.0 m/s, respectively) there fore, monitoring the rate of moisture removal per time on a computer interface gave room for computerized real-time automatic control system for drying of agricultural products in order to maintain quality.

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PERFORMANCE EVALUATION OF AN HYDRO-SEPARATING COWPEA DEHULLER

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ABSTRACT
The use of dehulling machines has not been effectively promoted, disseminated and adopted by the Nigerian housewives, food vendors and working women in the urban areas unlike other mechanical aids in the kitchen and machines for commercial purposes. This is mainly due to lack of evaluation to ascertain its effectiveness in addressing the critical challenges of the target users, which can guide its development and use. The overall objective of this work is to evaluate the performance of an improved cowpea seeds dehulling machine. The performance of hydro-separating cowpea dehuller was evaluated using a 2hp electric motor at five (5) different operating speeds. Four (4) commonly available cowpea varieties were used for the experiment to evaluate the dehuller. The cowpea seeds were soaked for five (5) different times. The performance parameters determined are dehulling efficiency, cleaning efficiency, feed rate and output capacity. The results of the experiment were presented graphically. It was observed that the highest value of dehulling efficiency of the dehuller was obtained at operating speed of 150rpm and the soaking time of 6mins and 8mins depending on the variety. The highest cleaning efficiency and feed rate of the dehuller were obtained at 350rpm operating speed, while their lowest values were obtained at 150rpm. The soaking time of the cowpea seeds do not really have any effect on the cleaning efficiency of the dehuller but has on the output capacity and feed rate of the machine.

***Keywords**: Performance, Evaluation, Cowpea Seed, Dehuller, Hydro-separating*

INTRODUCTION
Dehulling of cowpea seeds is the most vital unit operation in the processing of cowpea seeds into finished products such as moin-moin, bean cake etc. Cowpea (***Vignaunguiculata*** or ***Vignasinensis***unguiculata) is the cheapest proteinous food crop and one of the most ancient crops known to man. Cowpea seeds which comprises hull, black eyed and cotyledon is produced from processing of dried cowpea pods through various unit operations such as threshing, separation, winnowing, cleaning and packaging which can be termed as primary cowpea processing. According to Ibrahim Yalcin (2007), the seeds are dried at a storage moisture content of most crop seeds which ranges between (10-12) % mc (wb). It is either cooked for direct consumption or dehulled for further operation.
According to Babatunde,(1995), dehulling of cowpea seeds is achieved traditionally by soaking cowpea seeds in water and rubbing the soaked cowpea seeds between the palms of the hands and discarding of hull from the cotyledons.
In the case of black gram, green gram and cowpeas, where the hull is firmly attached to the cotyledons, water soaking is used to facilitate hull removal. The hulls absorb moisture and swell, thereby facilitating dehulling by gentle rubbing of the seed byhand. The hulls are easily separated from cotyledons byfloatation. At this stage, the cotyledons are wet and must be used immediately or dried and stored for further processing.
Some dehulling machines have been developed by institutions like National Centre for Agricultural Mechanization, (NCAM), Ilorin and University of Ilorin, Ilorin, (Unilorin). These machines developed by these institutions do not have separating chamber for the hull and cotyledon and those that have are not functioning well. This reason prompted the development of an improved hydro-separating cowpea dehuller by Olotu (2012).
The use of dehulling machines has not been effect fully promoted, disseminated and adopted by the Nigerian housewives, food vendors and working women in the urban areas unlike other mechanical aids in the kitchen such as blending machine for pepper, dehulled cowpea and melon. That is low uptake and adoption is being experienced on the machines for commercial purposes unlike cassava root grating machine, milling machine for dried cassava, yam, plantain and pepper. This is mainly due to lack of evaluation to ascertain its effectiveness in addressing the critical challenges of the target users, which can guide its development.
This in-depth investigation for the modification and performance evaluation of the hydro-separating dehuller will give room for an improvement on the dehuller, so as to increase its performance which will encourage its increased and rapid promotional use by the population, thus, leading to an increase in the number of the dehulling machines produced by the fabricators and their net income.
The research work aimed at establishing appropriate processing conditions for detaching cowpea hull from its cotyledon when using hydro-separating cowpea dehuller so as to improve the quality of processed cowpea

products. The overall objective of this study is to evaluate the performance of an improved motorized hydro-separating cowpea seeds dehulling machine.

MATERIALS AND METHODS

An Improved Motorized Hydro- Separating Cowpea Dehuller

The components of the motorized hydro-separating cowpea dehuller were fabricated, assembled and its performance was then evaluated. The pictorial view of the improved motorized cowpea dehuller is shown in figure 1.The dehuller comprises an hopper, a dehulling unit, and a separating/cleaning unit. It is being operated by feeding soaked beans into hopper while the machine is in operation, the rotation of the auger which moves the soaked seeds along its length and drops the dehulled seeds with its coat inside the cleaning chamber for separation of the hull from the cotyledon.

Figure 1: The pictorial View of Hydro-separating Cowpea dehuller

Performance Evaluation

Test Procedure

The evaluation of the machine took the procedure illustrated thus, the motorized cowpea dehuller was tested using a 2hp electric motor. Five pulleys of different size diameters658mm, 493.50mm, 394.80mm, 329mm and 282mm given corresponding speeds of 150rpm, 200rpm, 250rpm, 300rpm and 350rpm using contact/phototachometer ascertain speeds value were fitted to the shaft. Four commonly available cowpea varieties such as oloyin, yari hausa, IAR 48 and IAR60/62 were used for the experiment.The selected cowpea varieties were weighed out in three replication of 1kg each using dial spring scale. The weighed quantities of cowpea were soaked for specified time of 2mins, 4mins, 6mins, 8mins and 10mins. The moisture contentsat each soaking time were then measured using AND Infrared Moisture Determination Balance.

The soaked and weighed cowpea seeds were fed into the dehuller at the various speeds of dehulling operation. The time taken to feed each weighed quantity of the cowpea at various speeds, weight of the dehulled seeds, and weight of the undehulled, weight of chaffs inside both chaff collectorand separating chamber were recorded using both the dial spring scale and ORMA BC electronic weighing scale. The performance parameters that were evaluated to determine the performance of the machine are dehulling efficiency, cleaning efficieny, output capacity and feed rate of the hydro-separating cowpea dehuller.

Performance Indices

The performance indices used for this experiment are the equations expressed below following the format of Standard test code for groundnut sheller, NIS (1997) and Babatunde, (1995).

i. **Feed Rate; F_R (kg/hr): -** This is the quantity of soaked cowpea seeds that is fed into the dehulling chamber from the hopper per unit time. It's determined the rate at which the soaked cowpea seeds are fed into the auger from the hopper. It can be expressed as;

$$F_R = \frac{W_1}{T_1} \text{ (kg/hr)} \quad (1)$$

Where,

W_1 (kg) = Total weight of soaked seeds fed into the machine.
T_1 (hr) = Time of feeding

ii. **Dehulling Efficiency; D_E (%): -**This indicates the quantity of soaked cowpea seeds that is being dehulled by the machine and it is expressed in percentage, this shows how efficiently the machine isdehulling the sample. It is expressed as below:

$$D_E = \frac{W_3}{W_2} x100 \ (\%) \quad (2)$$

Where,

W_2 (kg) = $W_3 + W_4$

W_3 (kg)=Weight of dehulled cowpea seeds.

W_4(kg) = Weight of undehulled cowpea seeds

iii. **Cleaning Efficiency; C_E (%):-** This indicates the quantity of hull (chaff) that is being removed from the dehulled seeds inside the separating chamber, it is expressed in percentage, it determines how efficiently the machine is able to remove hull from the cotyledon. It is expressed as:

$$C_E = \frac{W_6}{W_5} x100 \ (\%) \quad (3)$$

Where,

$W_5 = W_6 + W_7$

W_6 (Kg) = Weight of chaff inside chaff collector.

W_7 (Kg) = Weight of chaff remaining inside the cleaning chamber after operation

iv. **Output Capacity O_c (kg/hr):-** This is the quantity of soaked cowpea seeds that cleaned dehulled per batch per unit time. It can be expressed as:

$$O_C = \frac{W_1}{T_2} \ (\text{kg/batch/hr}) \quad (4)$$

Where,

T_2 (hr)= Time of operation

RESULTS AND DISCUSSION

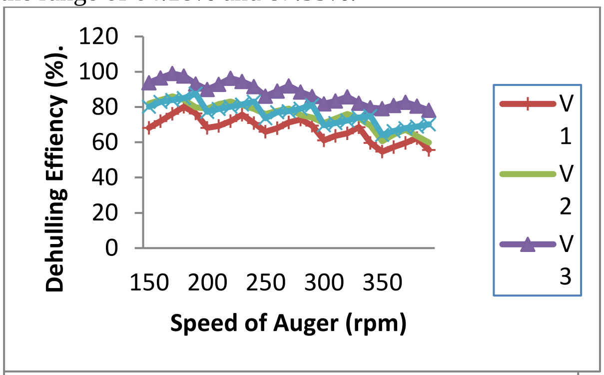
Dehulling Efficiency

The results obtained from the experiment were presented graphically as shown in figures 2–9. The operating speed of 150rpm had the highest dehulling efficiency mean value of the machine for all the four varieties of cowpea seeds, followed by 200rpm and the mean value of dehulling efficiency decreases as the speed of operation increases, that is, the least dehulling efficiency mean value was obtained at speed of 350rpm. Figure 2 shows how the dehulling efficiency of the machine decreases gradually as the speed increases for all the four varieties of cowpea seeds used. This is not in line with Babatunde (1995) which stated that dehulling efficiency of the manually operated cowpea dehuller increases as the speeds of dehuller increases. Although, Babatunde (1995) worked at low speeds of 60rpm, 80rpm and 100rpm while Reichert, *et al*.(1979) reported that dehulling of cowpea seeds at lower speed is more efficient than dehulling at higher speed. The low dehulling efficiency mean value obtained at speed of 350rpm might be that the residence time of the soaked cowpea seeds inside the dehulling chamber were shorten by the high conveying speed. Thus, there is no enough time for the seeds to rub against each other and wall of the dehulling chamber. At speed of 150rpm and the speeds chosen by Babatunde (1995), there was enough time for the seeds to rub against each other and the wall of dehulling chamber before they were being conveyed out.

Figure 3 shows a gradual increase in the dehulling efficiency of the dehuller as the soaking time of the cowpea seeds increases. At a certain soaking time of each cowpea variety, the dehulling efficiency of the dehuller began to decrease as the soaking time continue to increase except for oloyin variety that supported Babatunde (1995) which stated that the dehulling efficiency of the dehuller increases as the soaking time increases. This might be as a result of its low initial moisture content before soaking.

From this experiment, it was observed that all four varieties of cowpea seeds used behaved differently because cowpea seed is a biological material grouped into different varieties. Each variety is known with a specific characteristic or attributes. Henshaw (2008) also, stated that Seeds varied in all horticultural properties. These characteristics could be physical (shape, size, colour, moisture content), mechanical (hardness) or electrical. The least mean values of the dehulling efficiency of the dehuller was between the range of 55.6% and 80.14%, when cowpea variety of Yari hausa was used, this might be that the variety had a stronger adhesive force between hull and the cotyledon taking a longer time for the absorbed water to weakening the force between them for easy detachment. The dehuller had highest mean value of dehulling efficiency between the range of 78.11% and 99.02% when IAR48 variety was used, this might be that this variety has a weaker adhesive force between the hull and the cotyledon making it easier to detach from each other. According to Sefa-Dedeh *et al*. (1978); Sefa-

Dedeh and Stanley (1979), cowpea seeds with smooth seed coat texture tend to absorb less water than seeds with wrinkled seed coat. Seed coat texture could be an important selection index when processing cowpea seeds into flour, especially for ease of soaking and dehulling operations. The dehulling efficiency of the machine using IAR60/62 was between the range of 59.89% and 86.02%. When oloyin was used the dehulling efficiency was in the range of 64.18% and 87.55%.



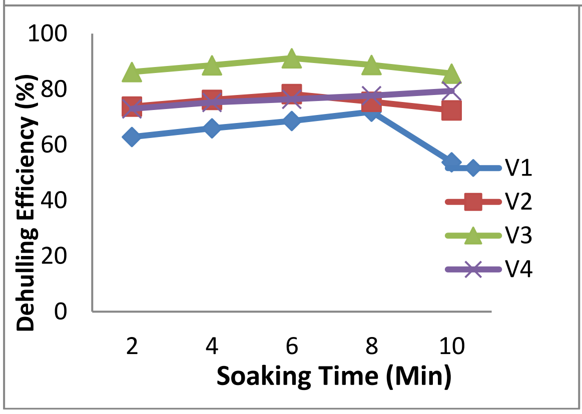


Figure.2: Dehulling Efficiency against Speed of Auger   Figure 3:Dehulling Efficiency against Soaking Time

Cleaning Efficiency

The speed of operation of the machine for all the four varieties of cowpea seeds used at level 150rpm had the least cleaning efficiency mean value; this was followed by 200rpm. The mean value of cleaning efficiency increases as the speeds of operation increases that is, the highest cleaning efficiency mean value was obtained at speed of 350rpm. Figure 4 shows gradual increase in the cleaning efficiency of the machine as the speed increases for the four varieties of cowpea seeds used. This was in line with Babatunde (1995) which showed highest values of cleaning efficiency of the manually operated cowpea dehuller at the highest speeds of operation despite the fact that Babatunde (1995) worked at a low speed levels of 60rpm, 80rpm and 100rpm.The highest cleaning efficiency mean value was obtained at speed of 350rpm. This might be that the agitators beat the water inside the separating chamber faster causing a turbulent action on the water and keeping the light hull afloat while the cotyledons that were heavier sunk. At speed of 150rpm, the agitator gently beats the water inside separating chamber and the turbulent action resulted is not strong enough to keep the hull afloat, hence, it sunk down with the cotyledon.

Fig 5 shows that the cleaning efficiency of the machine does not have a consistence values as the soaking times of the cowpea seeds varied. This might be that soaking time of cowpea seeds has nothing to do with cleaning efficiency of the hydro-separating dehuller. The cleaning efficiency of the machine using yari hausa was in the range of 50.45% and 91.40%, when IAR60/62 was used, it values were in the range of 50.99% and 91.34%. The IAR48 cowpea variety gave the machine the cleaning efficiency that was between 52.45% and 90.21%. The cleaning efficiency of the range 51.99% and 91.02% was obtained on the dehuller when oloyin cowpea variety was used.

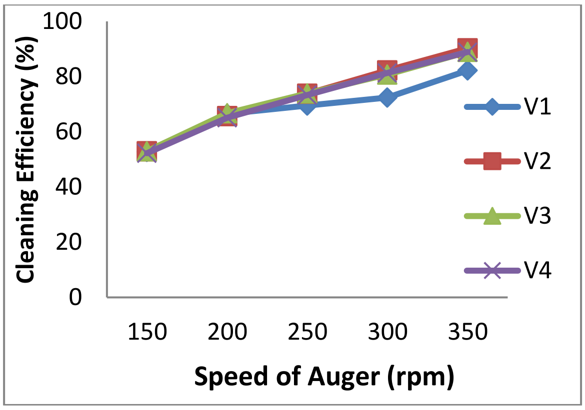


Figure. 4: Cleaning Efficiency against Speed of Auger

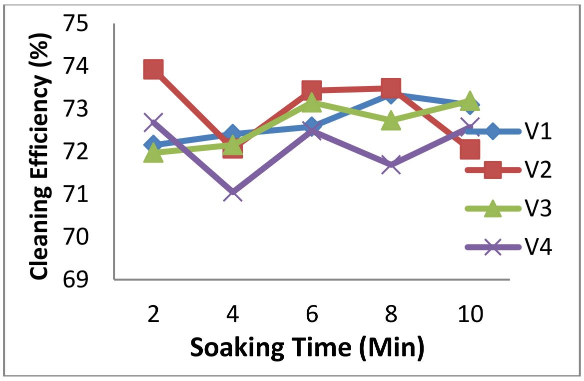


Figure 5: Cleaning Efficiency against Soaking Time

Feed rate

The dehuller at speed of 350rpm had the highest mean value of feed rate followed by 300rpm. The mean value of feed rate increases as the speed of operation increases, that is, the least feed rate mean value was obtained at speed of 150rpm. Figure 6 shows how the feed rate of the machine increases gradually as the speed of operation of the dehuller increases for all the four varieties of cowpea seeds used. The highest feed rate mean value at speed of 350rpm, this might be that the auger was conveying the soaked cowpea seeds faster, leading to faster intake of soaked cowpea seeds from the hopper into the dehulling chamber at very short time. While at speed of 150rpm, the soaked cowpea seeds were slowly take into dehulling chamber from the hopper, hence taken a longer time to feed into the dehulling chamber.

From the Fig 7 there is an increase in feed rate of the dehuller as the soaking times of the cowpea varieties used increase. This might be that as soaking time of cowpea variety increases, the quantity of the soaked cowpea seeds increased as well due to absorption of moisture during soaking, moreover, the same quantity of cowpea seeds were soaked for different time. That is quantity of soaked cowpea seeds fed in per time increases, hence, increase the feed rate of the dehulling machine.

The feed rate of the machine was between the range of 98.81kg/hr and 264.63kg/hr using yari hausa. When IAR60/62 was used, it values was between 101.22kg/hr and 268.32kg/hr, the IAR48 cowpea variety gave the machine the feed rate that was in the range of 98.45kg/hr and 265.95kg/hr and oloyin cowpea variety gave the machine the feed rate of the range 102kg/hr and 255.73kg/hr.

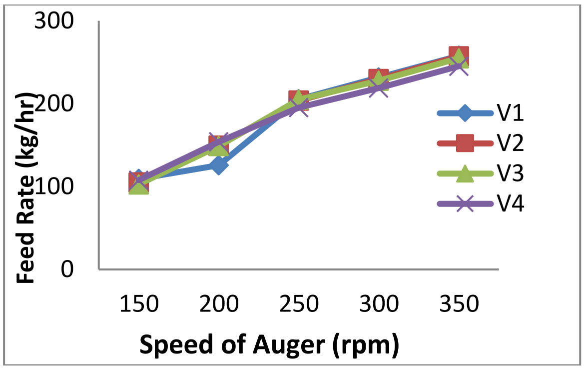


Figure 6: Feed rate against Speed of Auger

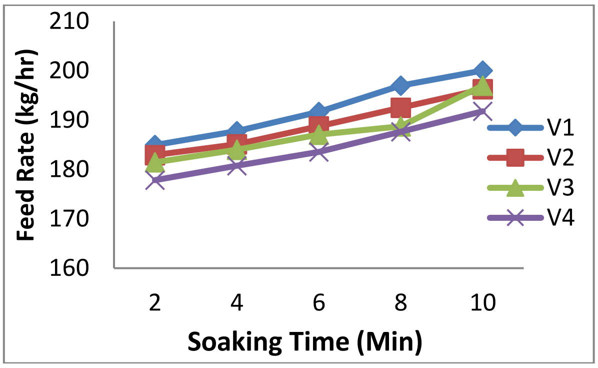


Figure 7: Feed Rate against Soaking Time.

Output Capacity

The output capacity of the machine was calculated in batch, the speed at which the machine runs does not really have effect on the dehuller, this can be seen in figure 8. For all the varieties, soaking time at 10mins had the highest mean value of output capacities of the machine and it increases with increase in soaking time. Soaking time at 2mins had the least mean value of output capacities as shown in figure 9. This might be that cowpea seeds soaked for 10mins had taken in more moisture which increases its weight before dehulling operation. The trend of the quantity dehulled per batch decreases as the soaking time decreases.

The output capacity of the machine using yari hausa was in the of range 16.45kg/batch/hr and 20.10kg/batch/hr, when IAR60/62 was used, it values fell between 16.52kg/batch/hr and 19.97kg/batch/hr, the IAR48 cowpea variety gave the machine the output capacity that was in the range of 16.42kg/batch/hr and 19.86kg/batch/hr while the oloyin cowpea variety gave the machine the output capacity of range 15.08kg/batch/hr and 18.86kg/batch/hr.

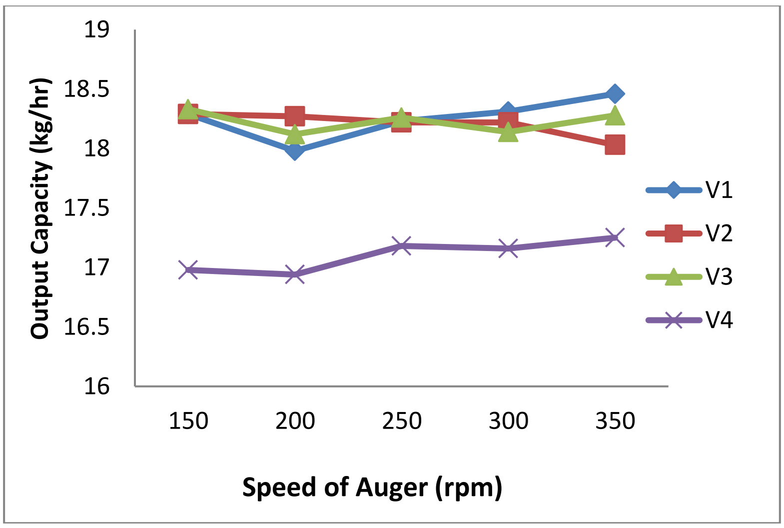


Fig.8. Output Capacity against Speed of Auger

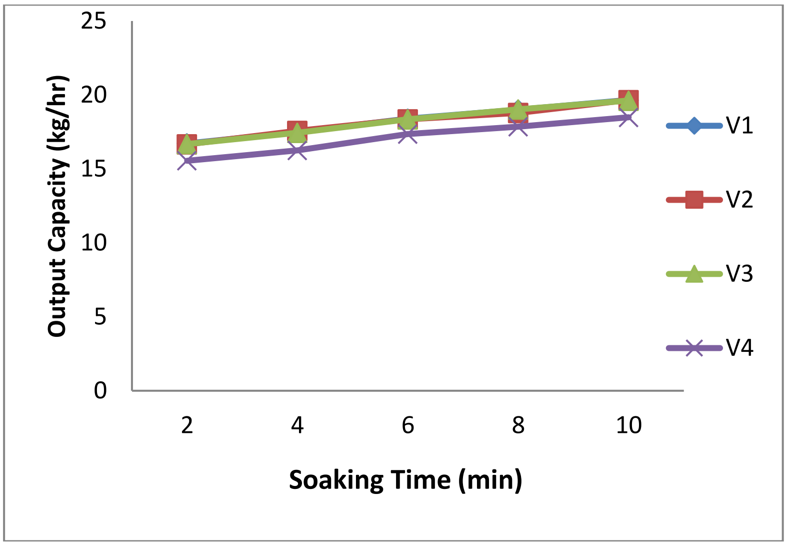


Figure 9: Output Capacity against Soaking Time

V1=Yari Hausa, V2=IAR 60/62, V3=IAR 48, V4= oloyin

CONCLUSION

A comprehensive performance evaluation was carried out on the hydro-separating cowpea dehuller to ascertain its performance when it is subjected under different operative processing conditions. It was discovered from the evaluation of the machine using four commonly available varieties cowpea seeds that operative processing conditions affect the performance of the dehuller. It was observed that at 150rpm speed, the machine gave the highest the dehulling efficiency of the dehuller, initially its dehulling efficiency increases as the soaking time of the cowpea seeds increases but at a point, it started decreasing. This behavior depends on the properties of the cowpea seeds dehulled. The highest cleaning efficiency and feed rate of the dehuller were obtained at 350rpm operating speed, while the lowest value of the cleaning efficiency and feed rate were obtained at 150rpm. The soaking time of the cowpea seeds do not really have any effect on the cleaning efficiency of the dehuller but has on the output capacity and feed rate of the machine because the output capacities and feed rates of the dehuller depend on the quantity of soaked cowpea seeds fed into it and these quantities depend on the time they were being soaked and moisture absorbed. So the highest value of output capacity and feed rate were obtained at 10mins soaking time while their lowest values were obtained at 2mins soaking time.

It is recommended that the further work should be carried on the dehuller, such as to improvise for the mechanism that can remove cleaned dehulled cowpea cotyledon during the operation and further research work to evaluate the performance of the dehuller on other legume seeds such as soybean as well as depodded and cooked locust bean seeds so as to make it a multi-crop dehuller for di-cotyledons beans and to increase its potentials, diversifications and sustainability.

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ASSESSMENT OF NOISE LEVELS IN AND AROUND SMALL AGRICULTURAL MILLS IN NIGERIA

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ABSTRACT

In Agricultural milling operations, a lot of noise is generated as a result of interactions of machine components within and with the material being milled, hence the need for periodic evaluation of the noise level in and around the mill to ensure the operators and their neighbours are not exposed to unacceptable noise levels. Considering the aforementioned, noise survey was carried out within and around two agricultural milling shops located in Gwadabe and Kure markets, Minna, Niger State, Nigeria. Sound level meter with model number CEL593 was used to measure sound levels at varying distances ranging from the operators ear level to as far as twenty five meters (25m) away from the operating machines in accessible directions. Polar Diagrams were used to illustrate the results obtained. The study revealed that the mill operators are exposed to noise levels as high as 99.98dB for more than ten hours daily without any noise protective equipment. This is far above the internationally accepted maximum allowable limit of 85dB. The study shows that a lot of awareness needs to be created for the operators to be aware of the dangers of the noise levels they are exposed to.

Key Words: Noise, Operators, Agricultural, Milling Machines.

INTRODUCTION

Assessment of the noise level operators of agricultural milling machines are exposed to is important as the data generated can be used as a very important tool by government and its agencies, private investors and regulatory bodies for development and decision making. Furthermore, results obtained from such assessments can also be used to develop an effective noise control programme which is capable of eliminating or reducing to the barest minimum the adverse effects of noise pollution generated by milling operations in particular and agricultural operations in general.

The word noise came from a Latin word 'Nausea' and it is defined as an unwanted sound, particularly loud ones that disturb people or make it difficult to hear wanted sound (Wikipedia, 2015). In common use, when speaking of noise in relation to sound, the word noise means unwanted or extremely loud sound that makes no meaning or is displeasing to the hearer. Shiru (2002) defined noise as any unwanted sound generated by the vibration of surface or by turbulence in an air stream which set up rapid vibration in the surrounding air. Excessive or disturbing noise that may harm the activity of human and animal or disturb their state of rest or interferes with normal activities such as conversation, sleeping, concentration, etc. is termed noise pollution (Wikipedia, 2016). Current noise condition exposes tens of millions of people to sound levels capable of provoking hearing loss, apart from other induced health impacts like hypertension, vasoconstriction and cardiovascular problems (USSPWC, 1972). Apart from the potential of producing hearing loss, noise exposure has been reported to illicit a number of non – auditory or extra – auditory responses and can have some predictable effects on performance (Dobbs, 1972). Raju (2003) and Kryter (1971), reported a variety of physiological changes that can occur in human body which can be related to noise to include release of adrenaline into the blood stream, increase in blood pressure, heart rate and respiration, inhibited gastrointestinal motility, peripheral blood vessel constriction and tension of muscles

In most agricultural operations; tillage; harvesting, processing and packaging etc., high intensity noise is produced due to the use of large machines. Sometimes these machines are old and are not properly maintained and as such produce noise far above safe limits. Milling of agricultural produce such as dried yam, cassava, and potatoes tubers, grains, dried plantain, etc., is associated with enormous noise. Operators of these milling machines are exposed to these noise levels for long hours and are mostly without any form of protection.

Considering the hazard associated with excessive noise, it is imperative to ascertain the level of noise these mill operators are exposed to in order to develop an effective noise control programme.

This Study was aimed at conducting a noise survey in Agricultural Milling Shops located at old Gwadabe and Kure markets, Minna, Niger State, Nigeria and to evaluate the level of noise agricultural milling operators at these shops and their immediate neighbours are exposed to.

MATERIALS AND METHODS

The Study Area

The areas under study are the Old Gwadabe and Kure Markets located in Minna the capital of Niger State, North Central, Nigeria. The Markets are popular for food and farm produce. They both play host to large agricultural milling centres which are very common with such markets. The Agricultural milling centre is a large building partitioned into four unequal parts A, B, C, and D hereafter referred to as Mills A, B, C and D respectively. Each of the mills has two to three milling machines.

Method

At first, all the machines in the milling shop were shut down and the sound levels were taken at the ear level of the operators. Thereafter, one milling machine was operated at Mill A while all other milling machines were shut down and the sound measurement was taken at the ear level of the operator of the operating milling machine and at different distances up to 25m in 5m steps. This process was repeated for Mills B, C and D. Thereafter, two milling machines were operated at Mill A while all other milling machines in the milling shop were shut down and sound measurements were taken at the operator's ear level and at different distances up to 25m in 5m steps. This process was also repeated for Mills B, C and D.

One milling machine was then operated in each of Mills A, B, C, and D simultaneously and sound measurements were taken at the ear level of the operators of the operating machines. Two milling machines were thereafter operated in each of the Mills A, B, C, and D simultaneously and sound measurements were as well taken from the ear level of the operators and at different distances up to 25m in 5m steps.

The sound level was measured using a sound level meter manufactured by Cell Instruments Limited, England with model number CEL593. The meter was used to take sound measurements while a 50-meter measuring tape was used in taking distance measurements of the machine location to the points where noise measurements were taken. Also using the measuring tape, the dimensions of the buildings in which the milling machines were housed were taken. Noise level measurements were taken at equal distances in all accessible directions from the mill and an average of these measurements was used to develop Polar Diagrams.

RESULTS AND DISCUSSION

Gwadabe Market

Table 1 shows the dimensions of the entire milling shops. The following Polar Diagrams show the results of the noise measurements conducted at the Agricultural milling centre located at Gwadabe market. Fig. 1 shows the noise level measurement at the operator's ear level and at varying distances up to 25m in 5m steps when one milling machine was operated separately in each of the milling shops. Fig. 2 shows the noise level measurements at the ear level of the operators and at varying distances up to 25m in 5m steps when two milling machines were operated separately in each of the milling shops while Fig. 3 shows the noise level measurements at the ear level of the operator and at varying distances up to 25m in 5m steps when all the machines in the milling center were operated simultaneously.

Table 1: Milling Shops and their Dimensions

S/No	Mill No.	Length (m)	Width (m)	Height (m)
1.	Mill A	4.60	5.00	3.15
2.	Mill B	4.78	5.00	3.15
3.	Mill C	5.50	5.00	3.15
4.	Mill D	4.71	5.00	3.15

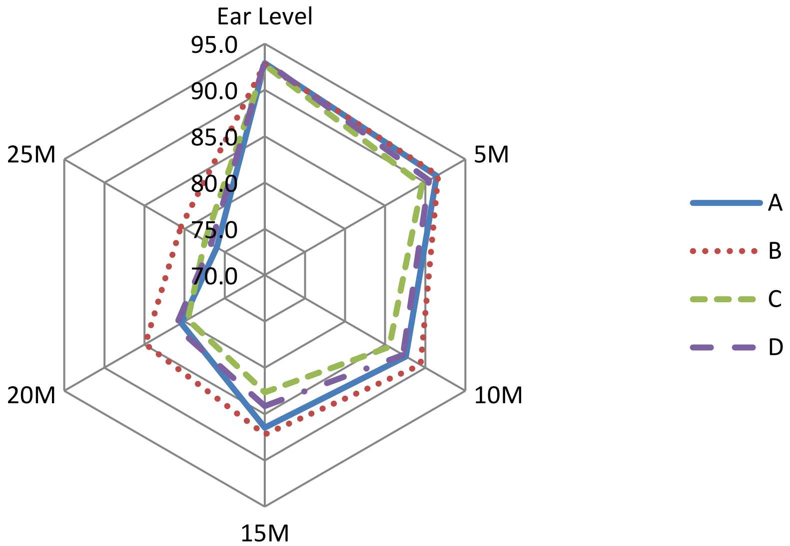

Fig. 1. Sound Level at different distances away from the milling machine when only one Milling Machine was operated at Milling Shops A, B, C, and D one after the other.

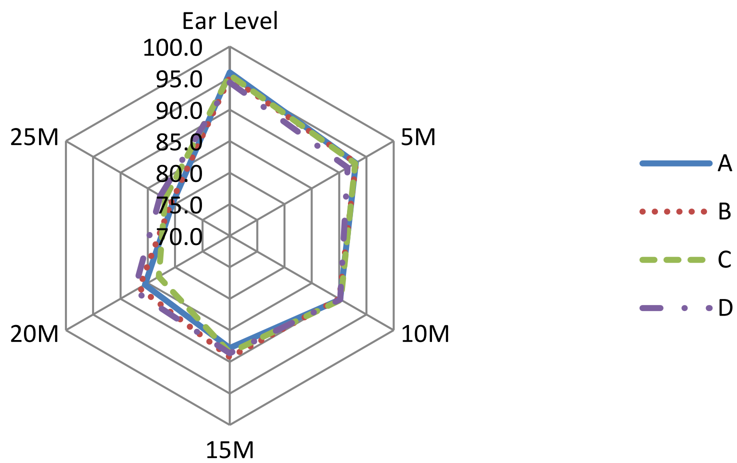

Fig. 2. Noise Level at different distances away from the milling machine when two Milling Machines were operated at Milling Shop A, B, C and D

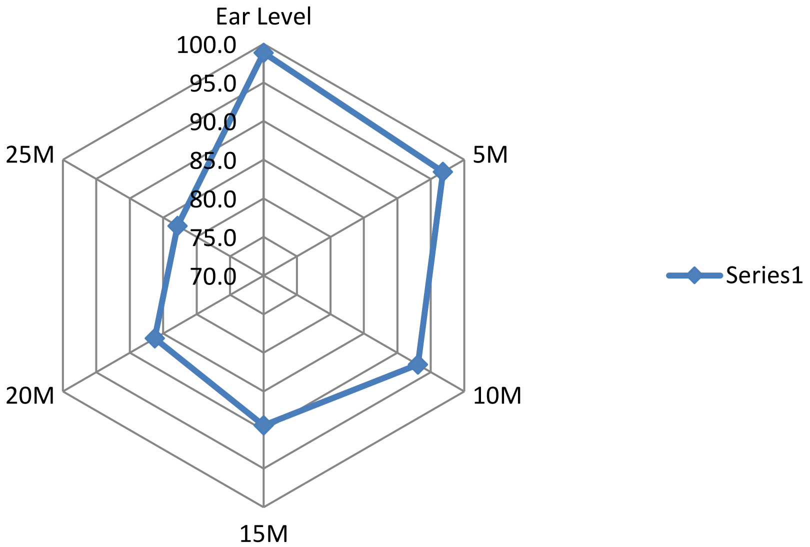

Fig. 3. Noise Level when all the machines in the Milling Center were operated simultaneously

Table 1 shows that the dimensions in each shop and the location of the milling machines differ. It was observed that the structure housing the mill was erected not on the basis of any standard, but on the availability of land within the area of interest as doors and windows were of different sizes and hence do not follow any architectural standard. The installation of the machines did not also follow any standard as machines were located in the mill haphazardly and ergonomic considerations for the mill operators were neglected.

For Gwadabe market, all the sound measurements taken at the ear level of the operators were higher than 90dB. This is consistent with Prasanna-Kumar *et. al.,* (2008). The results show that the sound level operators of agricultural milling machines are exposed to is far above the maximum allowable limit of 85dB recommended by Yisa (2005); Smith *et.al.,* (1994); and USEPA (1976). The results also show that going by the above recommendations; the safe place to stay around the mill is a minimum of 30m away from the mill. The results also show that the noise level kept reducing as the distance gets farther away from the mill which is consistent with the principle of noise propagation .

Kure Market

The following Polar Diagram show the results of the noise survey conducted at the Agricultural milling centre located at Kure market. Fig. 4 shows the noise level measurement at the ear level of the operator and at varying distances up to 25m in 5m steps when one milling machine was operated separately in each of the milling shops. Fig. 5 shows the noise level measurements at the ear level of the operators and at varying distances up to 25m in 5m steps when two milling machines were operated separately in each of the milling shops while Fig. 6 shows the noise level measurements at the ear level of the operator and at varying distances up to 25m in 5m steps when all the machines in the milling center were operated simultaneously.

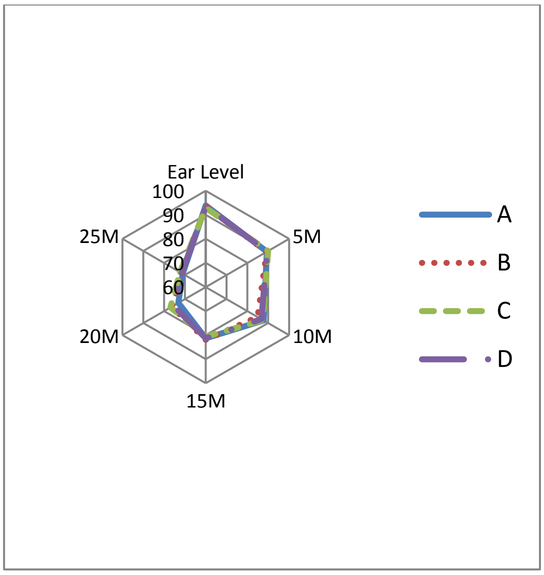

Fig. 4 Noise Level at different distances away from the milling machine when only one Milling Machine was operated at Milling Shop A, B, C and D one after the other.

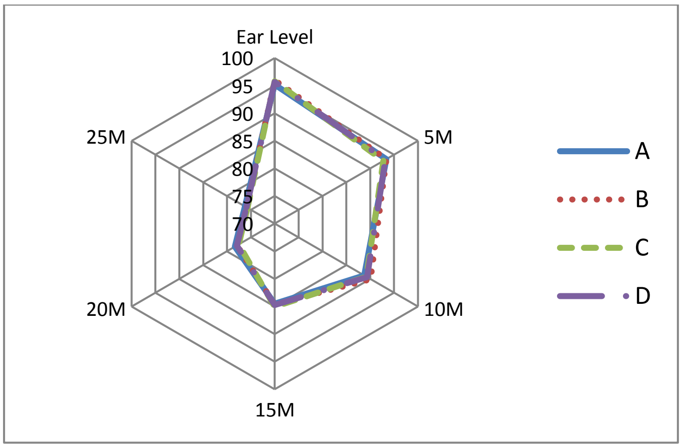

Fig. 5 Noise Level measurements at different distances away from the milling machine when two Milling Machines were operated at Milling Shop A, B, C and D one after the other.

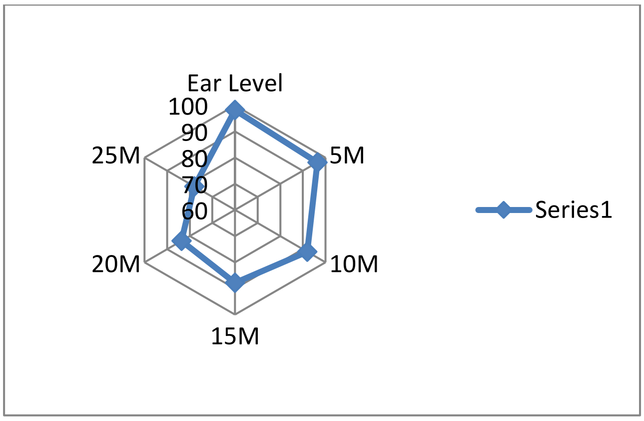

Fig. 6 Noise Level when all the machines in the Milling Center were operated simultaneously

For Kure market, all the noise measurements taken at the operators ear level were also higher than 90dB. This is also consistent with Prasanna-Kumar *et. al.,* (2008) who reported that the noise level in Indian Oil Mills and Indian Rice Mills both exceeded 90dB at the ear level of the operator. The results show that the noise level operators of agricultural milling machines are being exposed to is far above the maximum allowable limit of 85dB recommended by Yisa (2005); Smith *et.al.,* (1994); and USEPA (1976); they all asserted that exposure to noise levels greater than 85dB for eight hours daily or 40 hours per week seriously damages health and that a maximum outdoor noise level of 60 to 65 dB is safe. The results also show that going by the above recommendations; the safe place to stay around the mill is a minimum of 30m away from the mill. Furthermore, noise level kept reducing as the distance gets farther away from the mill which is consistent with the principle of noise propagation.

CONCLUSION

The study shows that workers at the Agricultural milling centres in both Gwadabe and Kure markets are exposed to noise level greater than 90dB for more than 10 hours daily. Hence, they face the potential danger resulting from exposure to excessive noise if nothing is done urgently. The traders around the mill are also exposed to noise level above 85dB for more than 10 hours daily and are also liable to the negative consequences of exposure to excessive noise. In the light of the above, government at all levels should come out with clear regulations and guidelines on environmental noise for manufacturers and enforce its strict adherence.

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