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WELCOME ADDRESS FROM THE HEAD OF DEPARTMENT

An address presented by the head of the Department of Agricultural and Bioresources Engineering, University of Nigeria, Nsukka, Prof Emmanuel A. Echiegu, on the occasion of the first international conference of the Department held at the UNESCO International Centre for Biotechnology, University of Nigeria, Nsukka.

Protocols

It is my pleasure to warmly welcome you all to this maiden edition of the International Conference of the Department of Agricultural and Bioresources Engineering of the University of Nigeria, Nsukka. This conference is planned as part of the activities marking the occasion of the first alumni homecoming of the department.It is hoped that this departmental international conference will be an annual event henceforth. Once again, on behalf of the staff, students and alumni members of this department, I welcome you to this one-day conference.

The theme of the conference is "*Emerging Trends in Agricultural Engineering for Sustainable Development and Food Security*". This theme is very apt. As global populations continue to increase, agricultural productivity will continue to face the serious challenge of keeping pace with the trend without placing undue stress on environmental resources. Enough food, feed and industrial raw materialsmust be sustainably produced to meet society's needs of food security, among others.Agricultural engineering plays a vital role towards the achievement of global food security.

From the traditional core areas of Farm Power and Machinery, Soil and Water Engineering, Food and Bioprocessing/Postharvest Engineering as well as Structures and Environmental Control Engineering, the profession has since faced some rapid changes in response to the changing needs of the society by incorporating new discipline and changing to such names as biological engineering, bioresources engineering, food engineering, biosystems engineering, bioenvironmental engineering, etc. Some of the new discipline introduced include precision agricultural technology, biotechnology, big data application in farming, mobile application for agriculturist, as well as aquacultural, forestry, environmental,renewable energy and biomassengineering, etc.

Widely adopted by agricultural engineers in developed countries, precision agricultural technology is a novel approach applied in managing farms using Information Technology as a primary tool, along with specialised software equipment, to ensure that the optimum requirements to grow the plant are fulfilled. Satellite agriculture and site specific crop management is part of this new trend.The application of big data information and communication technologies to farm management has made smart farming a reality.Combines and tractors can now track every inch of land, calculating soil type, seed placement, chemical application, etc. which are used to create personalized recommendations using softwares.The Internet of Things (IoT) and cloud computing are some of the innovations that is leveraging the introduction of robotic technologies into farming. Sensors, robots, drones and the establishment of a cyber-physical system hooked up to smart devices are already quite popular in use.

Mobile applications are now available which can be installed in smartphones and used by farmers to reduce the cost of services, maximize yield and earn higher profits. From apps providing information regarding weather, to market prices for crops and updates on the field, everything is becoming just a click away. In the application of biotechnology, scientific tools are now used in the transformation of plants and sometimes animals allowing the farmer to produce crops that possess specific desirable characteristics such as higher yield, resistance to diseases, etc. therefore enabling higher profit margins and reduced waste.

From the quality of the participants, especially the lead paper presenters, I expect that the conference will be highly engaging. I expect that the application of some of these new innovations towards

improving food production and ensuring food security in Nigeria, in particular, and the world, in general, will be thoroughly discussed and communique issued.

I cannot end this address without expressing our profound gratitude to our collaborators. They include the UNESCO International Centre for Biotechnology, UNN; Africa Technology Policy Studies Network (ATPS), Kenya; and World Bank-assisted Africa Centre of Excellence for Sustainable Power and Energy Development (ACE-SPED), UNN. We owe the success of this conference to your collaboration.

I enjoin all the participants to play active role and make useful contributions as papers are being presented and discussed. I wish you a very fruitful deliberation!

E.A. Echiegu, Ph.D, R.Eng, FNIAE, FRAES
Professor and Head of Department 26th May, 2022

PREFACE

We heartily welcome all dignitaries, the conference chair, invited lead paper presenters, special guests and distinguished participants to this maiden international conference of the Department of Agricultural and Bioresources Engineering, University of Nigeria, Nsukka with the theme: "Emerging Trends in Engineering for Sustainable Agricultural Development and Food Security (ETE4A)".

Sustainable development in agriculture and food systems is one of the surest pathways to economic growth, development and self sufficiency, especially for Sub-Saharan African countries. Engineering and emerging technologies have made available quantum resources which can boost and speed up agricultural growth and development, if properly adopted. The 2022 ETE4A conference is intended to bring together stakeholders in both the academia and industry to jointly examine, explore and critically engage on the issues of emerging trends in engineering for sustainable agricultural development and food security, with particular focus on our environment. We hope that this will result in very useful and sustained collaborations between the academia, industry and the government; and that the research outputs, discussions and networks that will be so created will precipitate into increased impact of engineering and emerging technologies on agriculture and food security in the country.

The conference is organized into two sub-themes: field machinery, post harvest and emerging technologies as Track A; soil, water and environmental engineering as Track B. A total of 34 papers were accepted after a peer review process and they will be presented in two concurrent parallel sessions as Track A and B, to be chaired by suitable professionals. The concurrent sessions will follow immediately after the plenary sessions.

The ETE4A conference committee wishes all participants very fruitful deliberations and a happy conference.

Engr. Prof. Ozoemena Ani
Chairman, Technical Committee
May 2022

CONFERENCE TECHNICAL COMMITTEE

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EFFECTS OF BLANCHING TEMPERATURE, BLANCHING DURATION AND OVEN TEMPERATURE ON PROXIMATE COMPOSITION OF UNRIPE FALSE HORN (OKPURUKPU) PLANTAIN FLOUR.

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Abstract

Proper drying of food materials favours extended shelf life and improved quality. In this study, the effects of blanching water temperature (BT) (50 and 90^{o}C), blanching duration (BD) (5 and 15 min) and hot air-oven drying temperature (OT) (50 and 90^{o}C) on proximate compositions of false horn plantain flour were investigated. False horn plantain fingers were washed, peeled, sliced, blanched and dried to constant weights in an air-oven. The dried slices were milled into flour using a grinder. The flour samples were analyzed for proximate composition. Statistical analyses were done on generated data using Design Expert 12 software at (p = 0.05) significance level. Statistical analyses of results showed that within the range of variable values studied BT, BD, and OT had effect on proximate composition of false horn plantain flour. However, as a result of factors interaction, plantain flour with highest carbohydrate content (85.32%) resulted from slices blanched at 90oC for 15 min and dried at 50oC. Plantain flour with highest protein content (7.13%), and MC of 10 % came from slices blanched at 90oC for 5 min and dried at 90^{o}C.

Keywords*: *Plantain flour, Blanching temperature, duration, air - oven drying, proximate Composition

1. INTRODUCTION

Agricultural processing refers to any operation that preserves, improves, or modifies the shape or features of a crop. A produce goes through several processing methods between harvesting and consumption. Physical structure and, in some cases, chemical composition are transformed as a result of these processing methods.

Plantains are members of the *Musaceae* family and belong to the genus Musa (Abiodun and Falade, 2010). *M. acuminate* and *M. balbisiana* are two wild species from which almost all palatable plantain cultivars originated (Robinson, 1996).In the tropical rainforest regions of Africa, Asia, and South America, plantain (Musa spp.) provides an essential carbohydrate source (Robinson, 1996). Vitamins A, C, B, and minerals like calcium and iron, are high in plantain (Marriott & Lancaster, 1983). Musa spp. are valuable as human foodstuff in the form of flour for confectioneries, jams & jellies, crackers, and other products. Its peels are also used to raise livestock. Despite their numerous advantages of Musa spp. and the large volumes gathered annually, some issues exist, such as poor access to production areas, long expanses connecting production regions and buyers, poor harvesting machineries, and negligence on the part of farmers and processors, to name a few, all of which contribute to the increasing percentage of post-harvest waste, necessitating the demand for processing of this vital commodity. Plantains, when processed, help to increase the fruit's value and availability yearly, allowing for greater usage (Abiodun and Falade, 2010).

Plantains are a key food crop in Nigeria, Africa, and the rest of the globe. It also provides a plethora of medical benefits. Plantain has high fiber content, is rich in proteins, and has a low sodium content. Nigeria is the world's fifth largest grower of plantains, amounting to almost

9% of worldwide plantain productivity, according to data. This indicates that raw materials are easily accessible in Nigeria. Delta, Edo, Enugu, Lagos, Osun, Oyo, Akwa-Ibom, Cross

River, Ondo, Imo, Benue, and Abia State are among Nigeria's plantain-growing states (Ogazi, 1996).

Because plantain flour is better than cassava flour, many households now choose it as a healthy alternative to cassava flour.

Aside from being utilized as cassava flakes alternative, particularly for diabetics, plantain flour isalso utilized as raw resources in the making of pastries, puff-puff, biscuits, bread, and pan pastries. Plantain flour is made from unripe plantain fruit that has been dried and mashed. Retrieval of fingers from bunches, skinning, rinsing, chopping, curing, grinding, and repackaging are all steps in the production of plantain flour (Ayodeji, 2016).

Every year, over 63 million tons of plantain are harvested, with up to 90% of that being utilized domestically in the growing regions, leaving only 10% for international monetary benefit via exports (Awodoyin, 2003; Baiyeri et al, 2011). This is mainly due to the crop's inadequatestorage state, which is worsened by lack of preservation and manufacturing facilities (Adenijiand Empere, 2001). Certain times, processed foods are not appreciated among the populace due to textural differences, arising from the processing (Yarkwan,2004). As a result, research into theeffects of drying, blanching temperatures, and durations on the nutritional composition and quality of unripe plantains is needed.

Few researches have been done on unripe plantain. Arinola et al(2016)investigated the physicochemical, textural, and operational qualities of unripe plantain (*Musa paradisiaca*) flour from Ado-Ekiti, Nigeria. In addition, Yarkwan and Uvir (2015) investigated the nutrient content of unripe plantain flour from Makurdi, North-Central Nigeria, using different drying processes. But much work has not been done on unripe false horn plantain variety from Nsukka, South- Eastern Nigeria. As a result, the focus of this research is on proximate compositions of false horn*(okpurukpu)* plantain flour as a result of oven drying temperature, blanching temperature, and blanching duration.

2. MATERIALS AND METHODS

This research was conducted at the University of Nigeria, Nsukka, in Nsukka Local Government Area of Enugu State, Nigeria. Freshly cut matured unripe False horn (*Okpurukpu*) plantain was procured from a local farm in Ovoko Community, Igbo-Eze South Local Government Area, Enugu State, for this research.

2.1 Experimental Design

The experimental design was a 2^3 complete factorial experiment with 2 replications (blanching temperatures (50^0 C, 90^0 C), blanching durations (5 mins, 15 mins) and oven temperatures (50^0 C, 90^0 C) (Table 1).

Table 1: Experimental design setup

SAMPLE	BLANCHING TEMPERATURE (^{0} C)	BLANCHING DURATION (Mins)	OVEN DRYING TEMPERATURE(^{0} C)	NO OF REPLICATIONS
S1	50	5	50	2
S2	90	5	50	2
S3	50	15	50	2
S4	90	15	50	2
S5	50	5	90	2
S6	90	5	90	2
S7	50	15	90	2
S8	90	15	90	2
S: Specimen number				

2.2 Sample Preparation and Drying

Plantains were rinsed in clean water, skinned with a stainless kitchen knife, and cut into a circular f o r m with a thickness of 2mm. The sliced plantain was blanched using hot waterblanching method according to the experimental setup and cooled with cold water to halt the cooking process and drained using plastic sieve.

Each blanched plantain was dried in an Oven dryer (model: VWR Scientific) with the appropriate temperature according to the experimental design setup until a constant weight was obtained. The dehydrated samples were ground and placed in nylon bags that were closed and kept in tightly closed containers with proper labeling after drying. The proximate analyses of the unripe false horn plantain flour samples were carried out.

2.3 Determination of Proximate Analysis

The AOAC (2005) standard approach was used to determine the proximate compositions of the False horn (Okpurukpu) Plantain flour. The carbohydrate content was obtained using Pearson (1976) method by subtracting the sum total of % moisture, %ash, % Protein, %fiber, and % fat from 100.

$$\text{Carbohydrate content} = (100 - (\%\text{ of moisture} + \%\text{ Ash} + \%\text{ Protein} + \%\text{fiber} + \%\text{Fat})) \quad (6)$$

2.4 Statistical Analysis

The data (results) were statistically analyzed using Design – Expert 12 software at p = 0.05significance level.

3. RESULTS AND DISCUSSION

3.1 Effect of BT, BD and OT on proximate composition of plantain flour

The proximate composition of the plantain flour as influenced by BT, BD, and OT are shown in Table 2. This result showed that the values of the compositions ranged as follows: protein (4.23±0.19 – 7.13±0.16%), crude fiber (0.12 - 0.79%), carbohydrate (78.31 – 85.52%), crude fat(0.94 – 2.72%), ash (2.15 – 2.99%) and moisture (4.96 – 9.69).Yarkwan and Uvir (2015) who worked with plantain grown at Makurdi, Benue State, Nigeria reported that plantain flour milled from 5 mm thick slices dried for 24 h at 105^{o}C in an oven was composed of moisture (9.01±0.01%), ash (5.44±0.01%), fat (1.55±0.01%), crude fiber (10.43±0.01%), crude protein (3.6±0.01%), and carbohydrate (70.19±0.01%). Arinola et al. (2016) who worked with plantain grown at Ado-Ekiti, Ekiti State, Nigeria reported the following compositional values for flour milled from 3 mm thick slices blanched in Sodium metabisulphite solution (70 ppm) for 15 min and dried in Arm field tray dryer at 70^{o}C and blower speed of 1.5 m/s for 8 h: moisture (3.24±0.04%), ash (3.11±0.06%), fat (1.15±0.04%), crude fiber (1.04±0.02%), crude protein (3.82±0.03%), and carbohydrate (87.64±0.4%). Fadimuh et al. (2018) who worked with plantain grown at Abeokuta, Ogun State, Nigeria reported the following results for flour milled from plantain slices blanched in hot water at 50°C for 7 minutes, sulphited with 1 percent potassium metabisulphite, and dried at 60°C for 24 hours in a Gallenkamp oven: moisture (8.18±0.76%), ash (3.00±0.08%), fat (2.15±0.28%), crude fiber (3.21±0.03%), crude protein (2.89±0.68%), and carbohydrate (80.49±2.46%).

Table 2: Proximate Composition

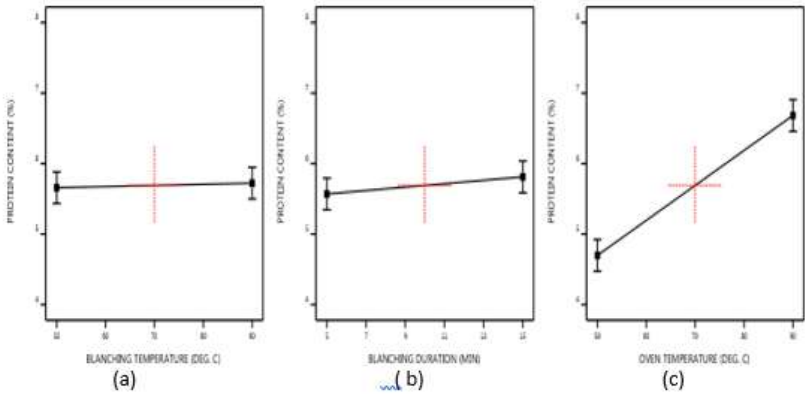
Samples	Protein (%)	Crude Fiber (%)	Carbohydrate(%)	Crude Fat(%)	Ash (%)	Moisture Content (%)
S1	4.92 ± 0.59	0.79 ± 0.01	83.06 ± 0.5	0.94 ± 0.04	2.99 ± 0.01	6.69 ± 0.31
S2	4.23 ± 0.19	0.42 ± 0.01	84.27 ± 0.33	2.23 ± 0.23	2.93 ± 0.01	5.93 ± 0.04
S3	5.13 ± 0.07	0.43 ± 0.02	84.11 ± 0.16	2.47 ± 0.01	2.15 ± 0.19	5.73 ± 0.31
S4	4.72 ± 0.13	0.34 ± 0.01	85.52 ± 0.73	1.08 ± 0.08	2.89 ± 0.03	5.46 ± 0.48
S5	6.21 ± 0.09	0.61 ± 0.01	82.92 ± 0.68	2.72 ± 0.24	2.86 ± 0.02	4.96 ± 0.54
S6	7.13 ± 0.16	0.62 ± 0.02	78.31 ± 0.01	2 ± 0	2.27 ± 0.04	9.69 ± 0.21
S7	6.38 ± 0.29	0.12 ± 0	81.31 ± 0.54	1.84 ± 0.15	2.97 ± 0	7.39 ± 0.98
S8	7.02 ± 0.34	0.2 ± 0	81.99 ± 0.34	1.78 ± 0.2	2.94 ± 0	6.86 ± 0.98

S1 = (BT = 50^{o}C, BD = 5min, OT = 50^{o}C); S2 = (BT = 90^{o}C, BD = 5min, OT = 50^{o}C); S3 = (BT = 50^{o}C, BD = 15min, OT = 50^{o}C); S4 = (BT = 90^{o}C, BD = 15min, OT = 50^{o}C); S5 = (BT = 50^{o}C, BD = 5min, OT = 90^{o}C); S6 = (BT = 90^{o}C, BD = 5min, OT = 90^{o}C); S7 = (BT =50^{o}C, BD =

15min, OT = 90°C); S8 = (BT = 90°C, BD = 15min, OT = 90°C); values are mean of 2 replicates ±standard deviation

3.2 Effect of BT, BD and OT on protein content of plantain flour

Statistical analysis of variance showed that within the range of values studied; BT, BD and OT had positive effect on the protein content (Fig.1). However, only OT had a positive significant ($p<0.05$) main effect (Table 3). Plantain flour of highest protein content (7.13%) resulted from slices blanched at 90°C for 5 min and dried at 90°C while that with lowest protein content (4.025%) was milled from slices blanched at 90°C for 5 min but dried at 50°C



(Fig.2

Fig.1 Plots of main effect of BT (a), BD (b), and OT (c) on protein content of processed plantain flour

Table 3 ANOVA for Protein

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	18.41	7	2.63	17.39	0.0003	significant
A-Blanching temperature	0.0169	1	0.0169	0.1118	0.7467	
B-Blanching duration	0.2352	1	0.2352	1.56	0.2476	
C-Oven temperature	15.76	1	15.76	104.23	< 0.0001	
AB	0.0100	1	0.0100	0.0661	0.8035	
AC	2.06	1	2.06	13.62	0.0061	
BC	0.1764	1	0.1764	1.17	0.3116	
ABC	0.1482	1	0.1482	0.9802	0.3511	
Pure Error	1.21	8	0.1512			
Cor Total	19.62	15				

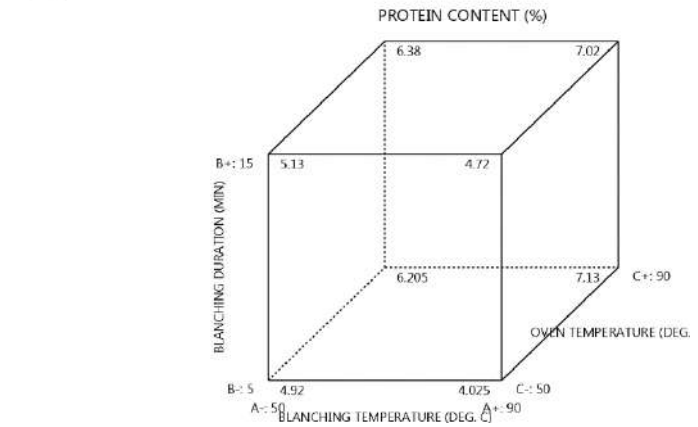
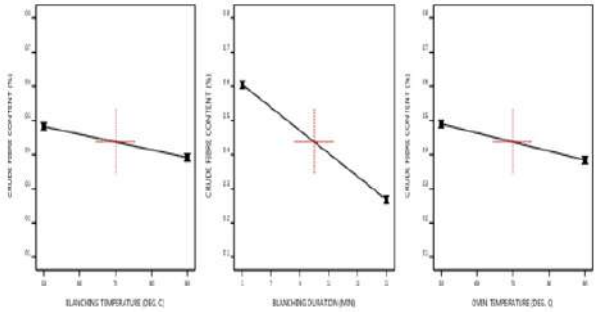


Fig.2 Cube plot of effect of BT, BD and OT on protein content of plantain flour

3.3 Effect of BT, BD and OT on crude fiber of plantain flour

Statistical analysis showed that the fiber content of plantain flour was significantly ($p<0.05$) affected by BT, BD, and OT, as well as their interactions. Within the range of values studied,BT, BD and OT had negative effect on the crude fiber with BD having the highest effect (Fig.3). Plantain slices blanched at 50°C for 15 minutes and dehydrated at 90°C to constant weight provided flour with the lowest (0.12%) fiber content, whereas slices blanched at 50°C for 5 minutes and dried at 50°C provided flour with the highest (0.79%) fiber content.



(a) (b) (c)

Fig.3 Plots of main effect of BT (a), BD (b), and OT (c) on crude fiber content of processed plantain flour

3.4 Effect of BT, BD and OT on carbohydrate content of plantain flour

Statistical analysis of variance showed that only OT had significant ($p<0.05$) effect on the carbohydrate content of the plantain flour. Within the range of values studied, BT and OT had negative effect on carbohydrate but BD had positive effect. Plantain flour with highest (85.32%) carbohydrate content was produced from slices blanched at 90°C for 15 min and dried to constant weight at 50°C whereas the lowest value (78.3%) resulted from slices blanched at 90°C for 5 min and dried at 90°C in the oven.

3.5 Effect of BT, BD and OT on crude fat content of plantain flour

Statistical analysis showed that only OT had significant ($p<0.05$) effect on crude fat content of the flour. However, BT/BD and BT/BD/OT interactions also had significant effect on the crude fat. Generally, BT and BD had negative effect while OT had positive effect on it. The flour with the highest crude fat content (2.72%) was made from chunks blanched at 50°C for 5 minutes and dried at 90°C, while the flour with the lowest value (0.94%) was made from slices blanched at 50°C for 5 minutes and dried at 50°C in the oven

3.6 Effect of BT, BD and OT on ash content of plantain flour

Statistical analysis of variance showed that BT, BD and OT singly had no significant ($p>0.05$) effect on ash content of the plantain flour. However, BT/BD, BT/OT and BD/OT interactions had significant effect on it. Generally, BT and OT had positive effect on the ash content; while BD had a negative effect. The flour with the lowest ash content (2.15%) was made from slices blanched at 50°C for 15 minutes and dried at 50°C, while the flour with the highest value (2.99%) was made from slices blanched at 50°C for 5 minutes and dried at 50°C.

3.7 Effect of BT, BD and OT on moisture content of plantain flour

Statistical analysis of variance showed that BT and BD had no significant ($p>0.05$) main effect on moisture content of the plantain flour. However, OT, BT/BD, BT/OT and BT/BD/OT interactions had significant ($p<0.05$) effect on it. BT and OT had positive effect on the moisture content; while BD had a negative effect on it. The flour with the lowest moisture content (4.96%)came from slices blanched at 50°C for 5 minutes and dehydrated at 90°C, while the flour with the highest moisture content (9.69%) came from slices blanched at 90°C for 5 minutes and dehydrated at 90°C.

4. CONCLUSIONS

This work investigated the effects of blanching water temperature (50 and 90°C), blanching duration (5 and 15 min) and hot air-oven drying temperature (50 and 90°C) on proximate composition of false horn plantain flour. Based on the results and analyses, the following conclusions were

reached:

1. Blanching water temperature (50-90^{o}C) was found to have insignificant ($p>0.05$) positive effect on protein and moisture contents; insignificant negative effect on carbohydrate and crude fat contents; but significant negative effect on crude fiber content of the flour.
2. Blanching duration (5 – 15 min) was found to have significant ($p<0.05$) negative effect on crude fiber and significant positive effect on carbohydrate content; but insignificant negative effect on crude fat, ash and moisture contents of the flour.
3. Oven temperature (50 – 90^{o}C) was found to have significant ($p<0.05$) positive effect on protein, crude fat and moisture contents; significant negative effects on crude fiber and carbohydrate; but insignificant positive effect on ash content of the flour.
4. As a result of factors interaction, plantain flour with highest carbohydrate content (85.32%) could be obtained from slices blanched at 90^{o}C for 15 min and dried at 50^{o}C. Plantain flour with highest protein content (7.13%) and moisture content of 10 % could come from slices blanched at 90^{o}C for 5 min and dried at 90^{o}C

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PHYSICOCHEMICAL, HEAVY METAL AND MICROBIOLOGICAL PROPERTIES OF HONEY FROM SOUTH EAST NIGERIA

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Abstract
The objective of this study is to characterize honey samples in South East Nigeria on the basis of their floral location and its effects on the physicochemical, heavy metal and microbiological properties. Floral location had effect on the physicochemical, heavy metal and microbiological properties of honey from South East Nigeria. The moisture content of the honey samples ranged from 16.96% to 22.03%. Honeys from Ebonyi State has the lowest values electrical conductivity (0.08 mS/cm). All samples except for Ebonyi State (0.0 mg/l) and Anambra State (0.0268 mg/l) recorded very high Lead concentration, above the international permissible limits. Honey samples from Imo State had very high bacterial (1.8×10^2cfu) and yeast (22 cfu/ml) load due to the very high moisture content 22.03% which created conducive environment for microorganism infestation. The results would be vital for the authentication of honeys from South East Nigeria for large scale processing and exportation.**s**
Keywords: *Honey, Floral Location, Heavy Metals, Physicochemical Properties, Microbial Property*

1.0 INTRODUCTION

Honey is a sweet, viscous and highly nutritious sweet substance which is produced from honey bees gotten from the nectar of flowers which the bees collect, transform and store in honey combs. It comprises of numerous elements and nutrients, although the main components of honey are almost identical in all honeys, yet the chemical composition and physical properties of natural honey depends on the floral location, the processing, storage and climatic condition (Lazarerić *et al.*, 2012; Boussaid *et al.*, 2018). There are over 20,000 species of honey bees throughout the world and they are taxonomically known as the super – family Apiadae (Agrolads, 1998). The most commonly-known honey in the world comes from the sting bee species. In Nigeria the most common honey bees are the *Apis mellifera and asonii*. Honey is a concentrated aqueous solution of invert sugar that contains a mixture of other carbohydrates, amino and organic acids, minerals, aromatic substances, pigments, waxes and pollen grains to make it complex (Alvarez-Suarez *et al.*, 2010; Ajlouni and Sujirapinyokul, 2010; Manzanares *et al.*, 2011; Rashed and Soltan, 2004). Many studies have demonstrated that honey serves as a source of natural antioxidants, which are effective in reducing the risk of heart disease, cancer, immune system deficiency, cataracts, different inflammatory processes etc (National Honey Board, 2002). Where honeys are produced affects the quality of the sample which arises as a result of different activities carried out in that floral location. Consumers of honey take interest in finding out the geographic origin of the honey samples before purchasing them. Adam (2020) had earlier established in the production of honey that botanical origin of honeys is one of its main quality parameters. It has been reported that its composition and antioxidant capacity depend on the geographical origin, floral source, seasonal and climate factors as well as production process. Bueno-Costa *et al*. (2016) had earlier determined the antibacterial and antioxidant activity of honey. Many studies have demonstrated that honey serves as a source of natural antioxidants, which are effective in reducing the risk of heart disease, cancer, immune system deficiency, cataracts, different inflammatory processes, etc. (National Honey Board, 2002).

In the world, 1.5 billion kilograms of honey was produced from 2005 to 2010. China is the world largest producer (436,000,000 kg), followed by Turkey (88,162,000 kg). India is the 7th largest honey producer (6,100,000 kg) while Central African Republic is the least producer (1,600,000 kg) (FAOSTAT, 2016). There are lots of honey samples produced and sold in different parts of the South East Nigeria. However, in recent years, unadulterated honey production is declining due to high labor costs and low profits from

the honey business. Therefore, to overcome this decline pure honey is adulterated with chemicals and water (Anthony and Balasuriya, 2016). Knowledge of the various properties can help in identifying the authentic and adulterated honeys. Knowledge of honey properties is helpful to consumers, researchers, industries and the government for quality assurance, safety and improvement of local honey production in the South East region of Nigeria. The main objective is to characterize honey samples from South East Nigeria at varying floral location. Other specific objectives are to determine the effects of floral location on physicochemical, heavy metal and microbiological properties of honey sample from South East Nigeria.

2.0 Materials and methods

2.1 Sample collection

The samples were purchased from Aba in Abia State; Orlu in ImoState, Opi in Enugu State, Ikwo in Ebonyi State and Alor in Anambra State of South East Nigeria. The samples collected were tagged according to the different states for easy identification. The collected samples were placed inside plastic bottles of each 750 cm^3, tightly sealed, tagged and kept for subsequent analyses. Anambra State has a co-ordinate of 6º05ˈN 6º57ˈE. (Alor/Nigeria facts 2007); Abia State lies between the Longitude 7º30ˈ0 East and the Latitude of 05º25ˈ0 North (Sub-National Area Database, 2018); Ebonyi State Ebonyi State is located within latitude of 7º30ˈN & 8º30ˈN and longitude 5º40ˈE & 6º45ˈE (Ofomata, 1975); Enugu State has a coordinates of 6º27ˈ10ˈˈN 7º30ˈ40ˈˈE (Sanni, 2007) and Imo State lies in the co-ordinates of 05º47ˈ47ˈˈN 07º02ˈ20ˈˈE (Climate & weather, 2017).

2.2 Determination of the physicochemical characteristics

2.2.1 Determination of pH

The term pH is used to measure the amount of hydrogen ion concentration (H^+) of a solution. It is therefore described as a measure of the acidity or alkalinity of the solution. The Hanna pH meter (Hanna pH meter Model H12214, China) was standardized with pH 4, 7 and 10 buffer solutions and used for the evaluation of the pH. It was then washed with distilled water, wiped and immersed in the honey sample and retained for a short while until the reading stabilized. The reading was then recorded from the display.

2.2.2 Determination of moisture content

The AOAC (1990) method was used in determining the moisture content of honey. After the anlysis Equ (1) was used in computing the moisture content

$$\% \text{ moisture} = \frac{A-B}{A} \times \frac{100}{1} \quad (1)$$

A = Original weight of sample and B = Weight of dried sample.

2.2.3 Determination of electrical conductivity

The method by Kavanagh *et al* (2019) was used to determined the electrical conductivity of honey by using the electrical conductivity meter (Conductivity meter. Model LF. 90, China). The reading displayed on the screen was then recorded in milli Siemens per centimeter (*m*S/cm).

2.2.4 Determination of sugar content

Sugar content was analyzed using the Brix method according to Lawal and Adekalu (2009) using the Abbe Refractometer (Model: WYA-2S, Made by Search tech Instruments, England).

2.2.5 Determination of ash content

AOAC (1990) method was employed in determining the ash content of honey samples. Equ (2) was used in computing the ash content after analysis

$$\% \text{ Ash} = \frac{A-B}{C} \times \frac{100}{1} \quad (2)$$

A = Weight of crucible + ash, B = Weight of crucible and C = Weight of original sample

2.2.6 Determination of protein

The Micro-Kjedahl digestion flask (500 cm^3 capacity) (Barloworld U.K, model Fk 500/3l) as described in Pearson (1976) was used to determine the protein content of honey. Using a conversion factor of 6.25, the actual percentage of protein in the sample was calculated using Equations (3)

$$\% \text{ crude protein} = \% \text{ Nitrogen} \times 6.25. \quad (3)$$

Titration was carried out with 0.01M standard HCl to first pink colour.

$$\% \text{ Nitrogen} = \frac{Titration\ vol. \times 0.014 \times M \times 100x}{wt.ofsample} \frac{100}{10} \quad (4)$$

Where M= molarity of HCl, % crude protein =% N x 6.25

2.3 Determination of heavy metals

The method according to Osuagwu *et al* (2020) was employed for the analyses of Iron (Fe), Magnessium (Mg), Manganese (Mn), Lead (Pb), Sodium (Na), Cupper (Cu), Zinc(Zn), Calcium (Ca), Potassium (K), Alluminium (Al) and Phosphorus (P) by using Atomic Absorption Spectrophotometer (Atomic absorption spectrophotometer Model AA-7000, Japan)

2.4 Determination of microbiological content

Adenekan et al. (2012) was employed in the determination of the microbiological content of the honey samples. Developed colonies were counted from the equation (6) & (7) below

$$\text{Mean count} = \frac{\text{number of colonies in each segment}}{8} \quad (6)$$

$$\text{Total viable count} = \frac{\text{mean count} \times \text{dilution factor}}{\text{Vol. per drop}} \quad (7)$$

Volume per drop = 0.015ml

3.0 Results and Discussion

3.1 Results

Table 1 represents the physicochemical properties of South East honey samples while Table 2 shows the international permissible limit for honey physicochemical properties.

Table 1: The physicochemical properties of South East honey

State	pH	Moisture content (%)	Electrical conductivity (mS/cm)	Sugar content (%)	Ash content (%)	Protein (%)
Abia	6.0	19.90	0.39	80.1	0.38	0.88
Anambra	5.9	18.53	0.30	75.7	0.16	0.96
Ebonyi	4.9	16.69	0.086	38.7	0.08	0.74
Enugu	6.2	21.19	0.79	81	1.03	0.99
Imo	6.0	22.03	0.43	79.4	0.48	0.92

Table 2: The Codex Alimentarius International Standard of Honey

Parameters	Limits of Int'l standards
pH	3.40 – 6.10
Electrical conductivity	Not > 0.8mS/cm
Ash Content	Not > 0.5%
Sugar Content	Not < 60%
Moisture Content	Not > 20%
Protein	0.2% - 1.6%

3.2 Discussion

3.2.1 Effects of floral location on the physicochemical properties of honey

The physicochemical properties of honey are different due to the plant species on which the bees forage (Ebenezer and Olubenga 2010) and also climate and vegetative conditions. The production of honey in the South East is a well-known business, but the information about its qualities is rare.

pH

From the results obtained the pH values of the honey samples were acidic. They ranged from 4.9 to 6.0 as shown in Table 1, which was within the international standard limit for pH (3.4 - 6.1) (Codex Alimentarius 2001), except for Enugu State samples which had a value of 6.2. This may be due to harvesting, handling or poor hygiene employed. Osuagwu and Oyerinde (2020) had earlier determined the pH of honey samples by using glass electrode pH meter method (AOAC, 1990). Buba et al. (2013) also determined the pH values for honey using pH meters.

Moisture content

In this present studies, it was observed that the honey samples had a moisture content ranging from 16.96 to 22.03% as shown in Table 1, which are within the standard limit of the Codex Alimentarius (2001) and the European honey regulatory commission (2000), except for Imo State which had a value of 22.03. This might be an indication of adulteration. The water content of honey sample had earlier been established by Osuagwu*et al* (2020) by hot air-dried oven method (AOAC, 1990). Ribeiro *et al.* (2017) had earlier determined the moisture content of honey by the method of reading on refractometer, obtaining the corresponding percentage of moisture through the relation between the refractive index and the water content in percentage according to the conversion of AOAC (2012). Kavanagh *et al.* (2019) had also earlier determined the moisture content of honey sample using a VWR® handheld refractometer (VWR International Ltd., Ireland), and the mean refractive value for readings was recorded.

Electrical conductivity

The electrical conductivity ranges between the values of 0.39 to 0.89 for honeys from Africa and Tunisian country according to Chakir *et al.* (2011). The measurement depends on the ash and acid contents of honey: the higher their content, the higher the resulting conductivity (Piazza *et al.*, 1991). The honey samples had electrical conductivity ranging from 0.30 mS/cm to 0.79 mS/cm however for Ebonyi State the value for the conductivity was 0.086 which has a corresponding low value with its ash content (Figure 1). This proves the relationship between the electrical conductivity and ash content. The IHC recommended that electrical conductivity should not be more than 0.8 mS/cm.

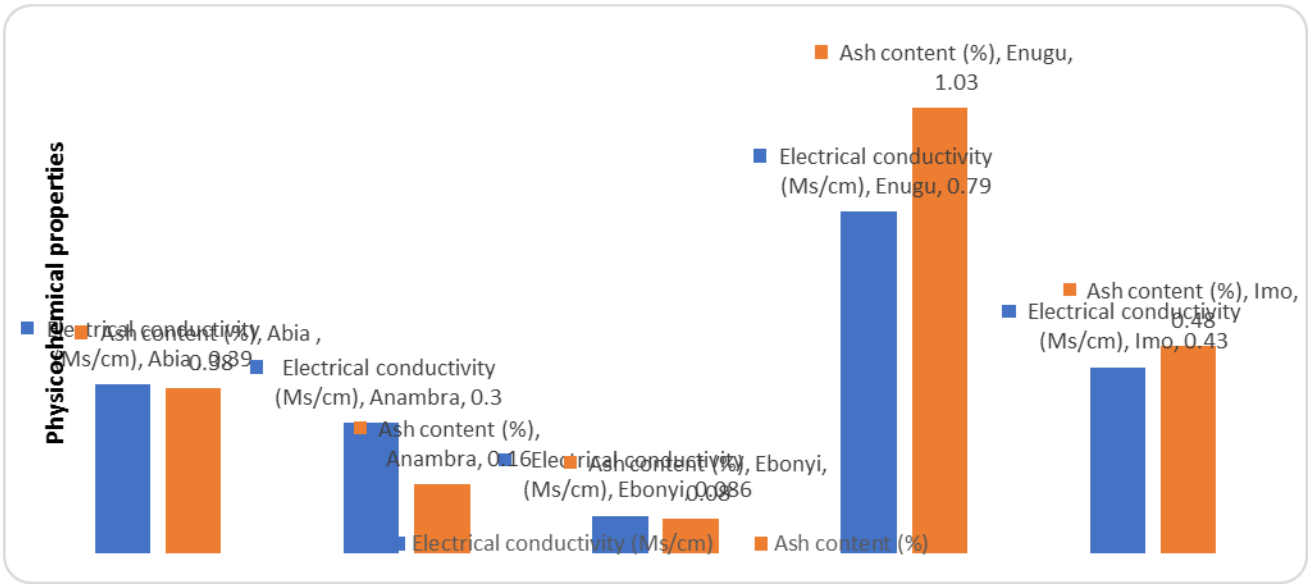

Figure 1.Bar chart showing the relationship between ash content and electrical conductivity.

Ash content

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The value for Abia State is 0.38%, Anambra State was 0.16%, Ebonyi State was 0.08, Enugu State was 1.03 and Imo State was 0.48. From Figure 1 there is a relationship between electrical conductivity and ash content. It was observed that the ash content for Enugu State is at the high side with a corresponding high value for electrical conductivity 0.79. The International Honey Commission set the ash content threshold at not more than 0.5 g/100 g for a good quality honey. The results obtained from this work also correspond to the results of some other researchers (Osuagwu *et al.*, 2020). According to the international Standard of honey ash content should not be more than 0.5 g/100 g. Osuagwu and Oyerinde (2020) had earlier determined the ash content of honey using the Furnace ash method (AOAC, 1990).

Sugar content

From the results obtained above, the percentage values obtained for sugar content in the samples ranges from 75.7 to 83.0. Sugar content was measured in brix, according to (Kirkwood *et al.*, 1960: Adebiyi *et al.*, 2004). The brix content of the various honey samples were shown on Table 1.The values ranged from 75.7 to 83.0% which is not within the acceptable range. The acceptable range is within 25 to 40 and only Ebonyi State had an exception with a value of 38.7. This shows that the honey samples were adulterated and that sugar was added to the honey samples with higher values. According to the International Honey Commission a good quality honey should have a sum of both fructose and glucose that is not less than 60%/100 g, sucrose content that is not more than 5 %/100 g. Lawal and Adekalu (2009) had also established the sugar content of honey (Brix content) using the hand refractometer.

Protein content

From the results obtained the percentage value of protein in the different honey samples ranges from 0.74 to 0.99. It was observed that Enugu State had the largest percentage of protein followed by Anambra, Imo and then Abia State. Osuagwu et al (2020) had earlier determined the protein content of honey by using the method of Kjeldahl (AOAC, 1990). The crude protein content was calculated using the conversion factor of 6.25 ($N \times 6.25$).

3.2.2 Effects of floral location on the heavy metal contents of honey.

The concentration for lead for Ebonyi, Anambra and Enugu States were within the acceptable levels of 25u̧kg^{-1} by the world health organization (WHO) and the Food & Agricultural Organization (FAO) (Alqarni*et al.*, 2012). Imo and Abia States had very high levels of lead 0.1489 and 0.2957 respectively, which indicates that the chemical composition of the soil is very toxic. The remaining elements Fe^{2+}, Zn^{2+} and Al^{2+} were all below 0.7mg/l. This reflected the botanical origin of the studied honey samples which also corresponds to Hungarian honey based on some of its mineral content (Ajtony *et al.*, 2007). Osuagwu *et al*. (2020) had earlier analyzed honey samples for mineral elements according to AOAC (1990). Magnesium (Mg), Iron (Fe), Calcium (Ca), Manganese (Mn), Cadmium (Cd), Nickel (Ni), Copper (Cu) and Lead (Pb) were determined using Atomic Absorption Spectrophotometer, PG-990F, model 990F.

Table 3. Heavy metal composition of honey samples from five South-East States in Nigeria

Mineral (mg/l)/State	Fe	Mg	Mn	Pb	Na	Cu	Zn	Ca	K	Al	P
Abia	0.6114	11.5846	0.0324	0.2957	1.314	0.1293	0.1905	14	4.6409	0.411	5
Ebonyi	0.5336	2.36	0.0324	0	2.0648	0	0.2424	27.3333	13.0718	0.146	4.8
Anambra	0.7336	4.9807	0.0972	0.0068	1.5598	0.0323	0.2078	12.607	2.6298	0.187	5.5
Imo	0.2445	9.9418	0.1944	0.1489	1.314	0.097	0.1905	19.3333	3.558	0.129	4.4
Enugu	0.6556	11.8063	0.0972	0.0468	1.3229	0.097	0.1818	16	4.7956	0.142	6.2

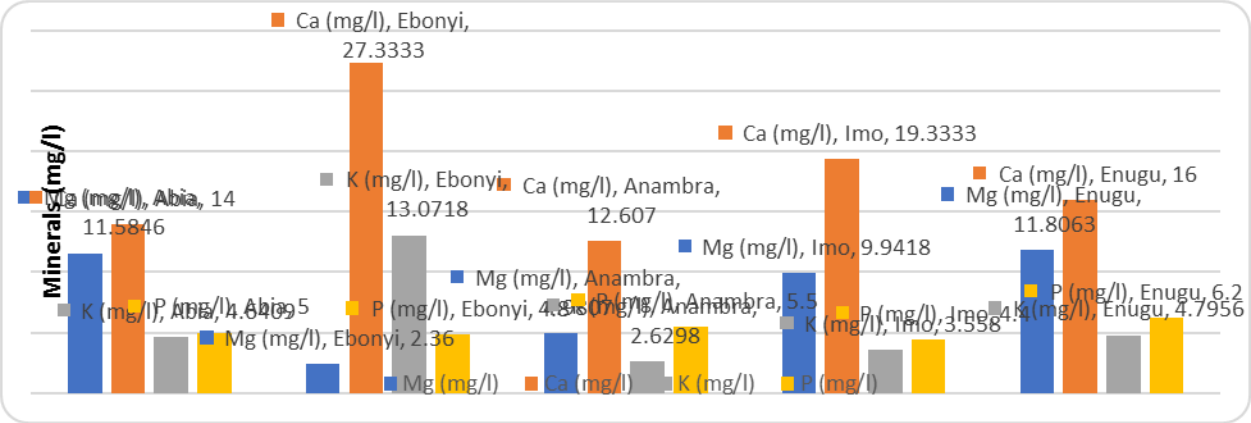

Figure 2:Bar chart showing the graphical illustration of different mineral against each South East State

3.2.3 Effects of floral location on the microbiological composition of honey

Microbial analysis of honey samples obtained in Table 4 showed the presence of viable bacteria, mold and yeast. Bacteria were detected in the honey samples and had values ranging from 0.7×10^2 to 1.8×10^2 with Imo State having the highest viable bacteria value. Microbiological analysis of the honey samples helps reveals the coliform counts present in the different locations where the honey was gotten form. Total viable bacteria for Abia, Anambra, Ebonyi, Enugu and Imo State were 1.5×10^2, 1.4×10^2, 0.7×10^2, 1.2×10^2 and 1.8×10^2 respectively. In honey, microorganisms may originate from pollen, the digestive tract of bees, dust, air, earth and nectar. These are primary sources of contamination and are very difficult to control.

Table 4: Microbiological concentration of South East honey.

Microorganisms/State	Abia	Anambra	Ebonyi	Enugu	Imo
Yeasts (cfu/ml)	36	20	8	14	22
Mould (cfu/ml)	12	8	Nil	6	8
Viable bacteria (cfu)	1.5×10^2	1.4×10^2	0.7×10^2	1.2×10^2	1.8×10^2

4.0 Conclusions and Recommendations

4.1 Conclusions

The results of this study indicated that physicochemical, heavy metal and microbiological contents of honeys from the South East Nigeria vary with floral location. Results also show that most physicochemical properties of South Eastern honeys were within recommended limits of international standards. The floral location showed a major effect in the mineral composition of the honey sample. The trace amount of heavy metals like lead (Pb^{2+}) in Imo and Abia States shows how toxic the soil and environment was. Sugar content for Abia, Anambra, Enugu and Imo States were very high exceeding the required standard limit for honey, which indicates adulteration by addition of other sweeteners such as glucose syrup, sugar and caramel.

4.2 Recommendations

For subsequent work, it is recommended that hydroxymethylfurfural, diastase, invertase, total acidity, free latonic, prolein and color content should also be looked into. It is recommended that honey samples from other region in Nigeria should also be investigated for their mineral, microbiological and physicochemical properties.

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LOCAL BIOREACTORS FOR SELECTED INDIGENOUS CROPS

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Abstract
A review of some of the existing local bioreactors for bioprocessing of indigenous crops was carried out. The reviewed local bioreactors mainly of Ethiopian and Nigerian origins showed their principles of operations and some of the key microorganisms aiding the processes. The major natural factors affecting the output from the bioreactors were also briefly discussed. A number of merits and demerits associated with using local bioreactors in the bioprocessing of indigenous crops were highlighted. The major findings and recommendations for future studies were also not left out.
Keywords: *Indigenous crops, Unsterilized materials, Local bioreactors, Natural inoculants*

1. INTRODUCTION

According to Ayanwale *et al.* (2016) as revealed by Akinola *et al.* (2020), "indigenous food crops are defined as those crops that originated in a particular region as well as those crops that were introduced into the same region but have become naturalized and recognized as traditional crops." They are either cultivated or found naturally producing in the wild, under diverse climatic conditions. Indigenous crops provide much more diversity of dietary and nutritional benefits than foreign food crops of which up to seven thousand species have been used from the Neolithic time, for both food and other applications (Jaenicke and Höschle-Zeledon, 2008; Bharucha and Pretty, 2010). They require low inputs, better remotely adapted and as well acquire more draught, disease and pest resistances than the exotic crops.

Iwuoha and Eke (1996), mainly classified the Nigerian indigenous crops as cereal, fruit, legume and seed, tree sap and as well root and stem tuber crops. The common cereal based crops are maize (*Zea mays*), sorghum (*Sorghum guineese*), millet (*Pennisetum typhoideum*). Fruit based crops are soft, over ripe banana/plantain (*Musa species*), ripe cocoa pod seed (*Theobroma cacao*), oil palm (*Efaeis guineensis*) fruits, oil bean (*Pentaclethra macrophylla*) seeds. The legume and seed-based crops are soya bean (*Glycine max Merrill*), African locust bean *(Parkia filicoidea Welw)*, melon (*Rullus wlguris Schrad*), African oil bean seed-melon mix, castor seeds (*Ricinus cummunis*), fluted pumpkin (*Telfairea occidentalis*) beans. The tree sap-based crops are raphia palm (*Raphia hookeri., R. vine-fera*) and oil palm tree (*Efaeis guineensis*). The tube based indigenous crops are cassava root tuber (*Manihot esculenta Crantz*), cocoyam tubers - the tannia variety (*Xanthosoma sugittlfolium*).
However, indigenous crops are mostly not regarded as main crops, and consequently experience insufficient research, reduced consumption and under-utilization (Azam-Ali, 2010). Emphasis has mostly been on improved productivity without necessarily investigating how to enhance the nutritional and health benefits of these indigenous crops (Agulanna, 2020). Most of the indigenous crops are perishable and contain some certain anti-nutritive compounds as well as toxic substances. For them to be preserved and made fit for human consumption, the toxic substances need to be broken down and removed through the process of bioreaction.
Local bioreaction processes make use of natural microbes in the processing of various indigenous crops, in order to enhance their palatability and shelf life (Anukam & Reid, 2009). It can also probably enhance the nutritional status and digestibility of the food (Ukwuru & Monday, 2018; Anukam & Reid, 2009; Adesulu & Awojobi, 2014).

2. SOME COMMON LOCAL BIOREATORS

Local bioreactors can be regarded as those traditional containers or materials normally used in the traditional bioreaction or fermentation of indigenous crops based on cultural practices and traditional procedures to produce foods and beverages with the help of natural microbes. The process is however, usually qualified with the employment of unsterilized local material, unprepared inoculant and uncontrolled process conditions.

Bioreactors can be historically traced as far back as 500 B.C. in the Babylonian cities where beer and wine were produced in tanks and wineskins respectively (Spier *et al*., 2011). The materials used as local bioreactors then, were merely selected based on their capacity to create food or beverage that cut the desire and approval of the king and his co sensory evaluators. Some locally available materials that normally function as local bioreactors and their principle of operations are briefly described in the subsequent sections.

2.1 *Insera*

This is a clean, smoked traditional bioreactor that is normally used in the traditional fermentation of *Tella*, an Ethiopian alcoholic beverage produced from cereals and fruits (Fentie et al., 2020). First of all, barley grains get wetted for one full day at room temperature to form a traditional malt known as B*ikil*, after which they are removed and secured in a dry area with freshly harvested banana leaves for about 36 hours as reported by Tafere (2015). The resulting grain is then spread under the sun with some *R. prinoides* (*Gesho*) leaves and stems, which are separately milled to form *Bikil* flour and *Gesho* powder before being thoroughly blended with water inside the *Insera*. Here, the blended matter is allowed for a 24-hour fermentation to result to a fermented product known as *Tejet* (Tekluu et al., 2015). Afterwards, unleavened bread, traditionally referred to as *ye Tella kita* (Berza & Wolde, 2014) is baked from dough formed from blending the same quantities of guinea corn, millet and *E. tef* (*teff*) flours with water, which is now pieced and included in the *Tejet* previously formed. Then the whole blended substance is completely covered for about one week of which anaerobic fermentation takes place to form *tenses* (Andualem et al., 2017).

Within the period of *tenses* formation, grains of maize are wetted for about 36 hours, after which they are dried-roasted, and milled into dark maize flour known as *Asharo*, which normally characterizes the actual *Tella's* colour (Tekluu et al., 2015). The *Asharo* is then included in the blend inside the *Insera* and also allowed to ferment anaerobically for a period of about two to three weeks. At the end, a thick substance traditionally known as *Difdif* results, and water is added to it again and allowed to further ferment for about six hours after which the formulated solid is filtered out and the *Tella* is now ready for consumption.

2.2 Drums, earthenware pots, enamel pots, Jute sack and/or plastic containers

i. In the preparation of fufu, freshly harvested cassava tubers are first of all peeled, washed and soaked in water (Aworh, 2008). Afterwards, the larger chunks are reduced into smaller chunks of various sizes, and submerged in drums and earthen pots for less than seven days in order to create room for fermentation (Braide et al., 2018). Submersion of the substrates kick-starts fermentation as a result of *Geotricum candidia* action on the solid substrates which breaks down the pectin in their cell walls, hence producing pectinase and increasing the acidity (Adesulu and Awojobi, 2014). This leads to eventual death of the organisms due to sudden manifestation of unconducive environment. Thereafter, other bacteria known as *corynebacteriumlactis* emerge; which can withstand the environment and help in causing softening, pH drop, flavour addition and reduction of cyanogenic glycoside level of the substrates (Braide et al., 2018; Egwim *et al*., 2013; Uyoh *et al*., 2009; Bamforth, 2005). Then, the softened tubers are finally squashed, sieved and left for sedimentation to take place and subsequent dewatering by squeezing or pressing.

ii. Jute sack and/or plastic containers serve as local bioreactors for bioprocessing of cassava tubers into 'garri'. Apart from raw cassava naturally containing very harmful substance known as cyanogenic glycoside; it also contains fibre, phytate, polyphenols, nitrate, oxalate and saponins substances which can potentially retard the bioavailability of nutrients (Montagnac *et al*., 2009; Chaves-Lopez *et al*., 2014). Therefore, bioprocessing by fermentation is required in order to detoxify these substances and keep the cassava fit for human consumption.

First of all, the cassava tubers are harvested, cleaned, peeled, washed and grated. The resulting grated substrate may be left to ferment inside a plastic container for a while, or immediately transferred to a porous jute sack and left to ferment (Ukwuru and Monday, 2018). The mouth of the jute sack is normally tired and the substrate is left for about 24 hours for fermentation to kick start before being subjected to heavy pressure under a screw jack with pressing dead load. The loaded bag is pressed for few days to dewater the substrate while fermentation is on-going. At the bagging stage, the substrate, adopts the characteristic sour taste of 'garri' which is introduced by the lactic acid bacteria (Ejiofor and Okafor, 1981). Hence, detoxification of the cyanogenic glycosides, linamarin and lotaustralin inherent in the cassava take place. That is, linamarin is hydrolyzed into β-D-glucopyranose and 2-hydroxy-iso-butyronitrile, while the cyanohydrin is hydrolyzed into HCN and acetone by the actions of endogenous enzymes (Uzogara *et al.,* 1990). After, about two to three days, the substrate is then sieved and roasted into "garri", with or without oil addition.

2.3 Porous raffia basket

This is a local bioreactor for the production of a fermented cocoa sap, which is a local wine beverage from ripe cocoa pods, mostly consumed in the major cocoa producing states of Nigeria. (Uzogara *et al*., 1990). After harvest, the pods are opened and the pulps with the containing seeds are gathered in porous raffia baskets and covered with plant leaves, for about one week. This allows the fresh cocoa pulps to ferment and release droplets of sap into calabash pots placed under the porous raffia baskets, from where it is then collected and utilized.

2.4 Keg

Palm sap, which comes from either raffia palm (*raffia hookeri*) or oil palm (*Elaeis guinensis*) is tapped with a small special barrel, termed keg (Uzogara *et al*., 1990; Ukwuru and Monday, 2018). The keg as shown in Fig. 1, at the same time serves as a local bioreactor for the bioreaction of palm sap to form palm wine.

Fig. 1: Keg Containing Palm Wine

Freshly tapped palm sap is sweet and has no alcohol, but ferments naturally into wine with a sour taste just a few hours of tapping (Uzogara *et al*., 1990). Within the same day of bioreaction of sap, the pH drops from seven to less than four, with a corresponding rise in alcoholic level from zero to as much as four percent. The fermentation induced by the presence of yeasts and bacteria, which supposedly have emanated from the native flora of the palm tree and the tapping tools is concluded within two days (Okafor, 1975; Ojomo *et al*. 1984; Uzogara *et al*., 1990).

2.5 Plastic container/Cloth bag

When preparing fermented corn starch, popularly known as *ogi* or *akamu* by the Igbo and Yoruba speaking tribes of Nigeria respectively, dry maize (*Zea mays*) is first of all soaked in water inside a container (plastic) for few days, in order for fermentation to take place, thereby producing acids and distinctive flavour due to the actions of lactic acid bacteria and yeasts (Umo and Fields, 1981). After soaking, the already softened maize is then washed and ground into paste. The paste is mixed with water and sieved to separate chaff from the real starch and allowed to sediment for as much as 12 hours (Fig. 2a). Thereafter, decantation of supernatant takes place while the wet sedimented starch is transferred into a cloth bag for further fermentation and dewatering, thereby forming consolidated wet starch ready for consumption (Fig. 2b) (Uzogara *et at*., 1990).

Fig. 2a Sedimented Corn Starch After Sieving

Fig. 2b: Cloth Bag Harbouring Wet Corn Starch

2.6 Calabash container lined with blanched plantain/banana leaves

This collection of materials serves as local bioreactor for the fermentation of soya bean (*Glycine spp.*) into soup condiment known as *daddawa.* This is mostly common in some Northern parts of Nigeria, where soya beans productions are dominant (Uzogara *et at*., 1990). After pretreatment of the soya beans, which is carried out by sorting, cleaning, washing, soaking overnight, followed by removal and washing of the seed coat, and then boiling in an earthenware or aluminum pot for about two and half hours; the beans are separated and poured into a calabash container which is lined with blanched plantain/banana leaves to wrap and cover the beans. At this point, the calabash is concealed with its cover and the content allowed to ferment for about four days or more at the surrounding room temperature. This fermentation into *daddawa* is facilitated by *genera bacillus* and *Staphylococcus spp.* of bacteria. Thereafter, the condiment is suitable for utilization in soup or stew preparation.

3 FACTORS INFLUENCING THE LOCAL BIOREACTORS OUTCOMES

i. Oxygen

The availability or non-availability of oxygen defines the nature of the microorganisms that will be present during operation of a local bioreactor and energy discharged during the process. This also goes a long way to ascertaining the extent of substrate utilization within a process, as well as the kind and quantity of achievable bio-product and dischargeable energy (Lee et al., 2011). A good number of the lactic acid bacteria that are involved in local bioreactions are aerobics; with just few anaerobic ones (Oyewole & Isah, 2012; Wikipedia, 2012).

ii. Temperature

At temperatures beyond 290.15 K, but below 296.15 K, almost all the lactic acid bacteria such as the *Leuconostoc spp.* which kick-start bioreaction, exhibit their best. (Braide et al., 2018; Oyewole & Isah, 2012). However, due to the temperature tolerance levels of various bacteria, a wide range of bioprocessed products may be obtainable (Lee et al., 2011). In as much as, many bacteria operate maximally at temperature range slightly higher than the one above, the thermophiles enjoy much higher temperatures of

the range 322.15 K $\leq x \geq 327.15$ K; whereas the colder temperature admirers, optimally perform between 288.15 K to around 293.15 K (FDA, 2011; Oyewole & Isah, 2012).

iii. pH level

Many of the bacteria perform maximally at about pH of 7 (Braide, 2018). However, bioreactions which are mainly initiated by the acid-tolerant bacteria (Lactobacillus and Streptococcus spp.), actively participate in determining the output of the dairy and vegetable biotreated products (FDA, 2011).

iv. Water activity

Micro-bacteria ordinarily thrive under high water activity of about 0.9 or more. However, yeasts and fungi actively enjoy lower water activity food substrates (FDA, 2011).

v. Nutrient availability

Every bacterium needs nutrient for its metabolism (Egbere, 2008); of which the bioactive one acts on either simple or complex sugars. In addition, microbes require enormous energy to multiply and function well. However, limited availability of nutrient in the substrate, can hamper their activities (FDA, 2011), and invariably affect the outcome of the bio-product.

vi. Salt concentration

Lactic acid bacteria thrive excellently in high acidic substrates which gives them edge above the non-tolerant bacteria. High salt concentrations harbours lactic acid bacteria and allows them to kick-start bioreaction process, thereby creating more acidic environment which further hinders both the multiplication and activities of the unwanted microbes. This is major reason of adding salt for bioreaction processing of *ogili* (local Nigerian condiment), and its likes. Due to high salt tolerant by *Leuconostoc* spp., they normally kick-start most lactic acid bioreactions (FDA, 2011).

4 MERITS AND DEMERITS OF LOCAL BIOREATORS

The various local bioreactors are naturally associated with inherent merits and demerits which are briefly presented in the Table 1 below.

Table 1: Comparison of the Merits and Demerits of Most Local Bioreactors

Local bioreactors	Merits	Demerits
Preservative potentials	Adeyemi (2012) has revealed that some degree of preservations can be provided on food crops such as cereals and fruits by local bioreactors. These reduce the products pH, as a result of acid production which subdues the creation and viability of most other destructive microorganisms that cause food spoilage, hence extending food storability potentials (Olukoya *et al.*, 2011).	
Modification of sensory qualities	Local bioreactors leave unique palatability on bioprocessed foods, since their sensory qualities are somewhat enhanced, thereby creating more valuable and acceptable food commodity among wider potential consumers (Osungbaro, 2009; Chelule *et al.*, 2010).	
Improvement of nutritional potentials	Most common available staple foods such as cereals are nutritionally poor and not easily digestible (Chelule *et al*., 2010; Nout, 2009). Bio-processing of these food crops, practically creates room for microorganisms such as lactic acid bacteria and yeast to work on these basic foods, which bring about some modifications by hydrolyzing the polysaccharides, proteins, phytates and lipids (Nout, 2009; Adeyemi, 2008). The local bioreactor induces bioreaction which reduces the antinutritional factors inherent in the food products, thereby improving their mineral content availability (Santos *et al*., 2008; Murwan & Ali, 2011).	
Health implications		Many of the local staple foods and condiments at their raw states such as fresh cassava tuber and castor oilseed are toxic for human consumption. So, if not well-treated can pose a very serious health problem. Also, since the local bioreactor materials are not sterilized, there is every tendency that the bioprocessed products will be contaminated, thereby exposing the vulnerable consumers to some health challenges.

Uncontrolled operations		Local bioreactors lack the capacity to regulate the operating parameters such as temperature, pH, oxygen etc., as well as providing optimum conducive environment for prevailing expansion and viability of lactic acid bacteria. As a result, the end product may actually differ from the real desired product. At the same time, food spoilages and wastages may set in.

5 EVALUATIONS OF PERFORMANCE OF THE LOCAL BIOREATORS

i. Microbial evaluation: Studies on the prevailing microbes that are associated with some local bioreactor operations during the bioprocessing of indigenous crops are briefly carried out. Some of the key findings are presented in the Table 2.

Table 2: Prevailing Microbes with Optimum Conditions for Local Bioreactors' Performance on Bioprocessing of some Indigenous Crops

Type of local bioreactor	Prevailing microbes	Bioprocessed product	Optimum conditions	Reference
Plastic container/cloth bag	*Lactobacillus plantarum, Streptococcus lactis, Saccharomyces cerevisiae*	*Ogi*	pH range - 6.4 to $\leq$ 3.4; duration – 24h to 72h; temperature – averagely 27^{o}C$\pm$1^{o}C	Odunfa (1985); Fields *et al*. (1981)
Keg	*Sarcina lutea, Shizo-saccharomyces pombe, Lactobacillus plantarum, etc.*	Palm wine	pH range – 7.0 to 4.0; duration – 48h; 27^{o}C$\pm$1^{o}C	Uzochukwu *et al* (1991); Ojoma *et al* (1984)
Calabash container lined with blanched plantain/banana leaves	*Bacillus spp, Staphylococcus spp*	Daddawa	Duration – 96h; averagely 37^{o}C$\pm$2^{o}C	Popoola and Akueshi (1985)
Drums, earthenware pots, enamel pots, Jute sack and/or plastic containers	*Carynebacterium manihot, Geotrichum candida, Streptococcus lactis, Aspergilus niger, this, Rhodotorula spp, Penicillum spp, Leuconostoc spp, Klebsiella spp*	Fufu and garri	pH range – 4.2 $\leq$ 3.6; duration – 4days$\pm$1day; temperature - 28^{o}C $\geq$ 45^{o}C	Hahn (1989); Oyewole and Odunfa (1988)
Porous raffia basket	Yeast	Cocoa wine	-	**O**dunfa (1985)

ii. Evaluation of the toxicity and health-related issues: Local bioprocessing of cereal-derived bioproducts showed traces of anti-tumour and anti-leukenic due to the involvement of *Lactobacillus spp* and lactic

acid bacteria (LAB) (Iwuoha and Eke, 1996). Also, locally processed palm wine has been reported to possess traces of nitrates, nitrites, and dimethylamine which are likely carcinogenic (Maduagwu and Bassir, 1979). It has been also reported that inadequate local processing of cassava resulted to significant (above minimum limit) left over of cyanide (Cooke and Cock, 1989). However, garri has been known for its much safe level of cyanide ($<< 50$ppm) (Omueti *et al*., 1993).

iii. Nutritional evaluation: After local bioprocessing of palm sap into palm wine, its nutritional status (protein/yeast, amino acids and organic acids) was observed to have greatly increased (Uzogara *et al*., 1990; Uzochukwu *et al*., 1991). But, local bioreaction of cereal-derived crop into *ogi* revealed shortage of phosphorus from phytate and an increment in the quantities of niacin and riboflavin (Iwuoha and Eke, 1996). Also, an analysis conducted by Ebuchi and Akinwande (1991) on locally processed *ogi* has revealed lower nutritional percentages of lipid (9.33%), protein (13.86%), ash (38.46%) and fibre (53.95%); which also manifested when used to wean newly born rats by showing overall malnourishment and death of most of the rat samples.

iv. Evaluation of biochemical and other associated changes: In the local bioreaction of soya bean into *daddawa,* a chronological sequence of microbes has been evidently witnessed with *bacillus spp* being consistent and *Staphylococcus spp*. on appearing after three days of processing (Popoola and Akueshi, 1985). The biochemical and other changes such as unique sour taste and flavour witnessed in a cereal-derived product like *ogi* by the provision of lactic, acetic and butyric acids has been attributed to direct influence of *Lactohacillus planetarium* (Iwuoha and Eke, 1996).

6 CONCLUSIONS

Applications of local bioreactors for bioprocessing of indigenous food crops have been creating easy accessibility for the utilization these crops in different more acceptable forms especially amongst the local populations. Although, these local bioreactors may be regarded as a tool for introducing diverse organoleptic qualities on the bioprocessed products in the presence of certain microbes, however, their nutritional, toxicological and health-related status may still be questionable, considering their uncontrollable process of operations. So, it remains practically difficult to manipulate the process operating parameters in such a manner that optimum conditions for providing consistent products of desired high qualities can be achieved. Therefore, it is recommended that:

i. The effect of various local bioreactor materials on the bioprocessing of food crops and the resultant quality of bioproducts should be studied.

ii. The local bioreactor material should be sterilized before being used, at least to minimize the influence of the unwanted microorganisms from interfering in the process. Also, the operating environment should be hygienically secluded as much as possible, so that most of the organisms needed for improvement of the quality and healthy status of the bioproduct should be most predominantly present.

iii. To ensure safe local bioproducts from indigenous crops, especially those with high toxicity levels, adequate and strict measures must be taken, in order not to jeopardize the health and life of the bearing consumers.

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MATHEMATICAL MODEL FOR PREDICTING WHOLE KERNEL RECOVERY OF A PALM NUT CRACKING MACHINE USING MIXED VARIETY OF PALM NUT

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Abstract
This research work aimed at developing a mathematical model for predicting whole kernel recovery as a performance parameter for a palm nut cracking machine, using mixed variety of palm nuts. The drying temperature of 105°C; five levels of cracking speed (1200, 1400, 1600, 1800 and 2000rpm); six levels of moisture content (12.4, 14.0, 16.2, 18.1, 20.0 and 27.8% w.b) and five levels of feed rate (360, 400, 450, 514.29, 600kg/h) were selected for the study. Full factorial design was used in the design of the experiment with three independent variables; cracking speed (rpm), moisture content (%) and feed rate (kg/hr), set at five, six, five level factorial respectively. Four hundred and fifty (450) samples of 1000g each of fresh palm nuts were used for the experiment. 150 samples were selected for each experimental run. The samples after drying to specified levels of moisture content, were cracked at 5 different speeds with 5 levels of feed rate. Mean values for each variety was computed and used for statistical analysis. Models to predict whole kernel recovery were developed using the concept of Buckingham Pi theorem. The developed models were verified and validated by fitting them into experimental data. Method of regression analysis as computed using Microsoft Excel programme of Microsoft package was used to describe the relationships, plot the graphs and compute the coefficients of determination (R^2) between the predicted and experimental values.

Keywords: *Model, Whole Kernel Recovery, Palm Nut, Cracking Machine, Mixed Variety*

Introduction

The oil palm fruit (*Eleasis guineesis*) as one of the predominant agricultural products over the years, has gained much attention in the world due to its wide application as a major raw material in industries. It is one of the most essential cash crops grown in the tropics. Nigeria is one of the leading producers of palm oil obtained from the oil palm fruit. The oil palm is a unique crop with two distinct types of oil namely; palm oil and palm kernel oil. Palm oil is extracted from the mesocarp of the fruits and palm kernel oil from the kernels of the palm nuts. The palm kernel is an edible seed and its oil can be fractionated into a liquid (olein), solid (stearin), and intermediate as shortening. Palm kernel oil can be used for making glycerin, candle, margarine, pomade, medicine, polish, oil paint and cheaper raw material for biodiesel when produced in abundant quantity (Adebayo, 2004; Emeka and Olomu, 2007).
Palm nut shell has become an essential commodity in the oil palm industry. Many applications have been developed. Due to high calorific value of palm nut shell, this commodity has been considered one of the key biomass materials which may possibly replace fossil fuel for steam engines (Mohammad, 2005).

Basically, there are three distinct varieties of the oil palm fruit. These are the *Dura*, *Tenera* and *Pisifera*. *Dura* variety has a thin mesocarp, thick endocarp (shell) and the kernel tends to be large, comprising 7 - 20% of the fruit weight. The *Tenera* variety has a large mesocarp, thin endocarp (shell) and large to medium kernel. The *Pisifera* variety possesses thick mesocarp, small or no endocarp (shell) with small kernel where applicable. The endocarp (shell) of palm nut generally contains one or more kernels (Okokon *et al*., 2007).
The nuts are not useable until the kernels are sorted out from the shell (Hartmann *et al.*, 1993). The nut recovery is a unit operation that encompasses nut drying after separation from the pulps. This is followed by cracking, kernel separation from cracked nut mixture, kernel storage and kernel oil extraction. Therefore, cracking and sorting are two major operations that need serious development for drastic improvement in quantity and quality of palm kernel oil produced.

Statement of Problem

There are heaps of palm nuts in virtually all processing mills and in local markets as a result of cracking problems. Considering the economic importance of palm kernels, this is a great loss to farmers and industrialist. There is need to establish the moisture content that will increase the cracking efficiency, whole kernel recovery, reduce the percentage or possibly eliminate the broken kernels during cracking of fresh palm nuts. Drying temperature and drying time to get the expected moisture content must be ascertained.

Sorting out different varieties of palm nut also constitutes another major challenge in palm nut cracking. In most plantations, mixed varieties (Dura, Tenera and even Pisifera) of oil palm are planted, harvested and processed together in large quantities. To overcome the rigorous task of sorting and damages, the existing cracking machines need to be improved for effective cracking of mixed varieties of palm nuts simultaneously.

The various factors affecting the performance of cracking machine as presented by Ndukwu (1998) and Shahbazi (2012) include: the cracking time, nuts moisture content, feed rate, bulk density, throughput capacity, cracking speed and power. These factors if not properly controlled could reduce cracking machine performance. Therefore, modelling the performance parameters or contributing factors for cracking process of palm nut would provide better understanding of the fundamental relationship of these variables in order to identify the contribution of each variable. Also, optimization of the model will help to identify the best contribution of the variables that can be used to establish optimum conditions for palm nut cracking.

Materials and Methods

The materials/equipment used for the study are: Mixed varieties of fresh oil palm nuts; Impeller Palm nut cracker; Friction Absorption Dynamometer; Digital Tachometer – Photo type; Model: DT-2234B; Digital Stop watch; Vernier Calliper; Electronic Weighing Balance (Model: EK5350; Max.: 5kg/11lb with 0.01g accuracy); Desiccators and Air Oven – Model: MINO/50; Serial No.: 13C280

Sample Acquisition and Preparation

Mixed varieties of fresh oil palm nuts were purchased from VIKA Farm, Uyo and NIFOR, Abak Station palm fruits processing mill. Cleaning of nuts was carried out manually to remove immature nuts and other unwanted materials from the bulk sample. The nuts were sorted out and graded into large, medium and small nuts as shown in Figure 1.

Figure 1: (a) Large nuts (b) Medium nuts (c) Small nuts

Description of the Experimental Machine

Palm nuts were cracked in a cracker (Figure 2) developed by Etuk Tech. Engineering Company based on the design consideration and analysis by Ismail *et al.* (2015) and Stephen and Lukman (2015). The machine was coupled together with a Friction Absorption Dynamometer, for determining torque during each run of cracking**.** It consists of five major units: the in-feed unit, the cracking unit, the discharge outlet, the driven unit and the dynamometer.

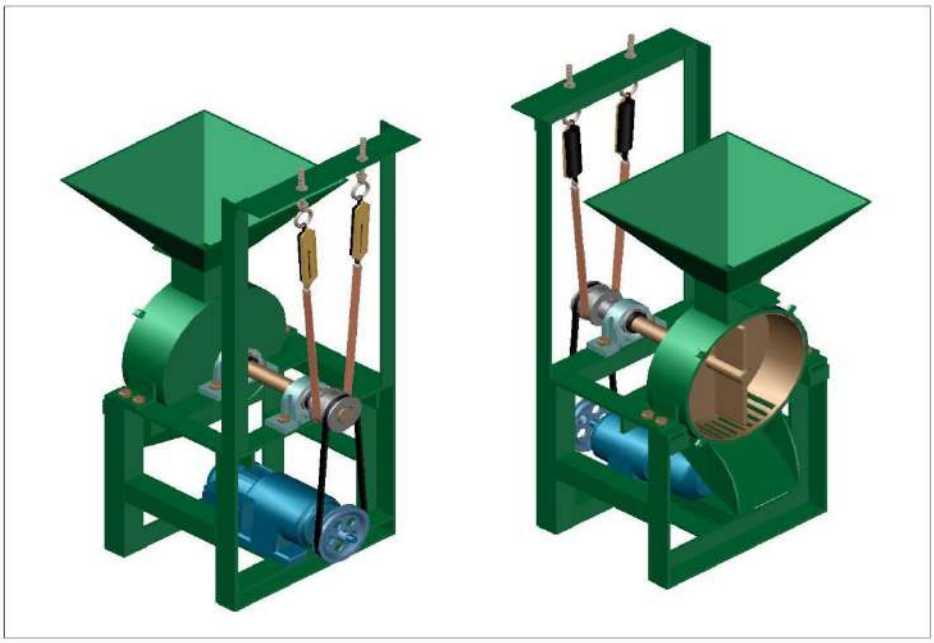

Figure 2: Isometric view of the palm nut cracker
Source: Sam, 2017

Working Principles of the Machine

The machine was put into operation by starting the electric motor, which provides the required power to drive the pulley of the cracking machine thereby causing the impeller blades to rotate. The cracking speed was adjusted by adjusting the power supplied to the electric motor. The cracked mixture falls by gravity through discharge outlet situated directly below the cracking chamber.

Model Development

Model to predict the percentage of whole kernel recovery of a palm nut cracking machine was developed using the concept of Buckingham Pi theorem.

The variables influencing the percentage of whole kernel recovery WKR are:

- Volume of the nut before cracking - - - - V_n
- Moisture content of nuts- - - - - α_{mc}
- Diameter of cracking drum (mm) - - - - D_{cd}
- Feed rate (g/s) - - - - - - - F_r
- Peripheral velocity of impeller (m/s) - - - - P_v
- Nut dimension (mm) - - - - - - d_n
- Nut density (kg/m^3) - - - - - - δ_n
- Cracking speed (rpm) - - - - - - S_c
- Speed of the nut (m/s) - - - - - - $\cap_s$
- Throughput (kg/h) - - - - - - T_p

The whole kernel recovery from the cracker is expressed in Equation (1) as:

$$WKR = f(V_n ; \alpha_{mc} ; D_{cd} ; F_r ; P_v ; d_n ; \delta_n ; S_c ; \cap_s ; T_p) \quad (1)$$

Adopting the $M\,L\,T$ system of dimension, the dimension of variables and the dimensional matrix are presented in Tables 1 and 2 respectively.

Table 1: Dimension of variables influencing whole kernel recovery of a palm nut cracking machine

S/N	Variables	Symbol	Unit	Dimension
1	Whole kernel recovery	WKR	%	$M^0 L^0 T^0$
2	Volume of the nut before cracking	V_n	m^3	$M^0 L^3 T^0$
3	Moisture content of nuts	α_{mc}	%w.b	$M^0 L^0 T^0$
4	Diameter of cracking drum	D_{cd}	mm	$M^0 L^1 T^0$
5	Feed rate	F_r	g/s	$M^1 L^0 T^{-1}$
6	Peripheral velocity of impeller	P_v	m/s	$M^0 L^1 T^{-1}$
7	Nut dimension	d_n	mm	$M^0 L^1 T^0$
8	Nut density	δ_n	kg/m^3	$M^1 L^{-3} T^0$
9	Cracking speed	S_c	Kgm^2/s	$M^1 L^2 T^{-1}$
10	Speed of the nut	$\cap_s$	m/s	$M^0 L^1 T^{-1}$
11	Throughput capacity	T_p	kg/h	$M^1 L^0 T^{-1}$

Table 2: Dimensional matrix of the variables influencing the whole kernel recovery of a palm nut cracking machine

S/N	Variables	Symbol	Dimension		
			M	L	T
1	Whole kernel recovery	WKR	0	0	0
2	Volume of the nut before cracking	V_n	0	3	0
3	Moisture content of nuts	α_{mc}	0	0	0
4	Diameter of cracking drum	D_{cd}	0	1	0
5	Feed rate	F_r	1	0	-1
6	Peripheral velocity of impeller	P_v	0	1	-1
7	Nut dimension	d_n	0	1	0
8	Nut density	δ_n	1	-3	0
9	Cracking speed	S_c	1	2	-1
10	Speed of the nut	$\cap_s$	0	1	-1
11	Throughput capacity	T_p	1	0	-1

Applying the Buckingham pi theorem to identify the dimensionless group to be formed, the following assertions were made:

The dependent variable = WKR

The repeating variables = V_n ; α_{mc} ; D_{cd} ; F_r ; P_v ; d_n ; δ_n ; S_c ; $\cap_s$; T_p

Total number of variables = 11

Number of fundamental dimension = 3

Number of dimensionless groups to be formed = 11-3 = 8

So the required terms is expressed in Equation (2) as:

$\pi_1 = f(\pi_2, \pi_3, \pi_4, \pi_5, \pi_6, \pi_7)$ (2)

The pi terms can be determined by considering the corresponding dimensional expression in Equation (3) as:

WKR ; V_n ; α_{mc} ; D_{cd} ; F_r ; P_v ; d_n ; δ_n ; S_c ; $\cap_s$; T_p = 0 (3)

From Table 2, α_{mc} is dimensionless and is therefore excluded from the dimensionless terms determination as shown in Equation (4); and is added when other dimensionless terms are determined (Simonyan *et al*., 2019).

$WKR = f(V_n ; D_{cd} ; F_r ; P_v ; d_n ; \delta_n ; S_c ; \cap_s ; T_p)$ (4)

The dimensionless equation is given in Equation (5) as:

$f(V_n ; D_{cd} ; F_r ; P_v ; d_n ; \delta_n ; S_c ; \cap_s ; T_p) = 0$ (5)

Nut dimension (d_n), speed of nut ($\cap_s$) and throughput (T_p) were selected as recurring set of variables since their combination does not form a dimensionless group.

With d_n, $\cap_s$ and T_p selected, the exponent a, b and c attached to each recurring set respectively as ${d_n}^a {\cap_s}^b {T_p}^c$

The component of the exponential recurring set is divided by the remaining variables: V_n ; D_{cd} ; F_r ; P_v ; δ_n ; S_c . So the dimensionless group π_1, π_2, π_3, π_4, π_5, and π_6 were obtained as given in Equation (6) to (11) according to Ndirika (2005); Ndukwu and Asoegwu (2010). These expressions form the basis of the Buckingham Pi theorem of dimensionless groups.

$$\pi_1 = \frac{V_n}{{d_n}^a {\cap_s}^b {T_p}^c} \quad (6)$$

$$\pi_2 = \frac{D_{cd}}{{d_n}^a {\cap_s}^b {T_p}^c} \quad (7)$$

$$\pi_3 = \frac{F_r}{{d_n}^a {\cap_s}^b {T_p}^c} \quad (8)$$

$$\pi_4 = \frac{P_v}{{d_n}^a {\cap_s}^b {T_p}^c} \quad (9)$$

$$\pi_5 = \frac{\delta_n}{{d_n}^a {\cap_s}^b {T_p}^c} \quad (10)$$

$$\pi_6 = \frac{S_c}{{d_n}^a {\cap_s}^b {T_p}^c} \quad (11)$$

In order to obtain values for the exponents a, b and c, the principle of dimensional homogeneity is used to equate the dimension on each side of the equations of the π groups.

So Equation (6) becomes; $M^0L^0T^0 = \frac{M^0L^3T^0}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (12)

From Equation (7); $M^0L^0T^0 = \frac{M^0L^1T^0}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (13)

From Equation (8); $M^0L^0T^0 = \frac{M^1L^0T^{-1}}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (14)

From Equation (9); $M^0L^0T^0 = \frac{M^0L^1T^{-1}}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (15)

From Equation (10); $M^0L^0T^0 = \frac{M^1L^{-3}T^0}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (16)

From Equation (11); $M^0L^0T^0 = \frac{M^1L^2T^{-1}}{(M^0L^1T^0)^a(M^0L^1T^{-1})^b(M^1L^0T^{-1})^c}$ (17)

Employing dimensional homogeneity for M, L and T, the exponents a, b and c were evaluated. Substituting the values of the components a, b and c into Equations respectively;

$$\pi_1 = \frac{V_n}{{d_n}^3 {\cap_s}^0 {T_p}^0} = \frac{V_n}{{d_n}^3} \quad (18)$$

$$\pi_2 = \frac{D_{cd}}{{d_n}^1 {\cap_s}^0 {T_p}^0} = \frac{D_{cd}}{d_n} \quad (19)$$

$$\pi_3 = \frac{F_r}{{d_n}^0 {\cap_s}^0 {T_p}^1} = \frac{F_r}{T_p} \quad (20)$$

$$\pi_4 = \frac{P_v}{{d_n}^0 {\cap_s}^1 {T_p}^0} = \frac{P_v}{\cap_s} \quad (21)$$

$$\pi_5 = \frac{\delta_n}{{d_n}^{-2} {\cap_s}^{-1} {T_p}^1} = \frac{\delta_n {d_n}^2 \cap_s}{T_p} \quad (22)$$

$$\pi_6 = \frac{S_c}{{d_n}^2 {\cap_s}^0 {T_p}^1} = \frac{S_c}{{d_n}^2 T_p} \quad (23)$$

And $\pi_7 = \alpha_{mc}$ (24)

Combining the expressions for π_1, π_2, π_3, π_4, π_5, π_6 and π_7, Equation (2) is expressed in Equation (25) as:

$$\frac{V_n}{{d_n}^3} = f\left\{\frac{D_{cd}}{d_n}, \frac{F_r}{T_p}, \frac{P_v}{\cap_s}, \frac{\delta_n {d_n}^2 \cap_s}{T_p}, \frac{S_c}{{d_n}^2 T_p}, \alpha_{mc}\right\} \quad (25)$$

Combining the dimensionless terms to reduce the Equation to a manageable level. The dimensionless terms is expressed in Equation (26) to (29) as:

$$\pi_{12} = \frac{\pi_1}{\pi_2} = \frac{V_n}{{d_n}^3} \times \frac{d_n}{D_{cd}}$$

$$\pi_{12} = \frac{V_n}{{d_n}^2 D_{cd}} \quad (26)$$

$$\pi_{34} = \frac{\pi_3}{\pi_4} = \frac{F_r}{T_p} \times \frac{\cap_s}{P_v}$$

$$\pi_{34} = \frac{F_r \cap_s}{T_p P_v} \quad (27)$$

$$\pi_{56} = \frac{\pi_5}{\pi_6} = \frac{\delta_n {d_n}^2 \cap_s}{T_p} \times \frac{{d_n}^2 T_p}{S_c}$$

$$\pi_{56} = \frac{\delta_n {d_n}^4 \cap_s}{S_c} \quad (28)$$

$$\pi_7 = \alpha_{mc} \quad (29)$$

The new dimensionless functional equation is expressed in Equation (30) as:

$$WKR = f(\pi_{12}; \pi_{34}; \pi_{56}; \pi_7) \quad (30)$$

$$WKR = f\left\{\frac{V_n}{{d_n}^2 D_{cd}}; \frac{F_r \cap_s}{T_p P_v}; \frac{\delta_n {d_n}^4 \cap_s}{S_c}; \alpha_{mc}\right\} \quad (31)$$

$$WKR = f(A; B; C; D) \quad (32)$$

Equation (31) gives the whole kernel recovery, WKR with all variables in Equation (1) as a function of four efficiency components which are presented as A, B, C and D respectively in Equation (32).

Model input parameters for whole kernel recovery

The average experimental results, machine input, crop and design parameters for mixed varieties of palm nut are presented in Tables 3

Table 3: Experimental results of the effects of different crop and cracking machine parameters on whole kernel recovery for Mixed variety of palm nut.

S/N	V_{nc}	$\propto_{mc}$	D_{cd}	F_r	P_v	d_n	δ_n	S_c	$\cap_s$	T_p	WKR_e
1	0.0016	12.4	0.385	360.00	20.73	0.0165	710.55	1200	7.54	277.78	58.37
2	0.0016	14.0	0.385	400.00	24.19	0.0165	710.55	1400	8.79	187.92	62.29
3	0.0016	16.2	0.385	450.00	27.65	0.0165	710.55	1600	10.05	177.84	86.00
4	0.0016	18.1	0.385	514.29	31.10	0.0165	710.55	1800	11.31	156.63	80.71
5	0.0016	20.0	0.385	600.00	34.56	0.0165	710.55	2000	12.57	141.36	70.61

Development of the prediction equation

The prediction equation was established by allowing one π-term to vary at a time while keeping the other constant and observing the resulting changes in the function. This was achieved by plotting the values of experimental whole kernel recovery against dimensionless constants shown in Tables 4. The values of experimental whole kernel recovery were plotted against dimensionless constant π_{12}, while keeping π_{34}, π_{56} and π_7 constant; π_{34}, while keeping π_{12}, π_{56} and π_7 constant; π_{56}, while keeping π_{12}, π_{34} and π_7 constant; and π_7, while keeping π_{12}, π_{34} and π_{56} constant as illustrated in Figures 3 to 6.

Table 4: Experimental whole kernel recovery values (WKR_e) and calculated values (π_{12}, π_{34}, π_{56}, π_7) of whole kernel recovery for Mixed variety of palm nut in an impeller-type nut cracker

S/N	WKR_e	$\pi_{12} = \frac{V_{nc}}{{d_n}^2 D_{cd}}$	$\pi_{34} = \frac{F_r \cap_s}{T_p P_v}$	$\pi_{56} = \frac{\delta_n {d_n}^4 \cap_s}{S_c}$	$\pi_7 = \propto_{mc}$
1	58.37	15.26	0.4714	0.03309	12.4
2	62.29	15.27	0.7735	0.03313	14.0
3	86.00	15.32	0.9197	0.03327	16.2
4	80.71	15.33	1.1941	0.03329	18.1
5	70.61	15.34	1.5438	0.03330	20.0

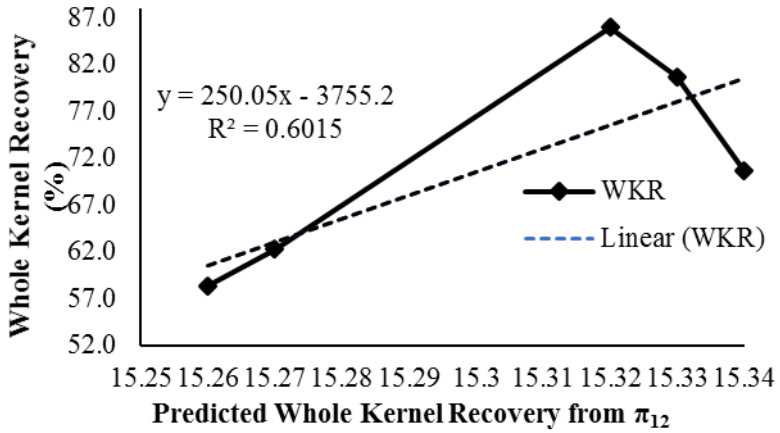

Figure 3: Variation of experimental whole kernel recovery against π_{12}, keeping π_{34}, π_{56} and π_7 constant

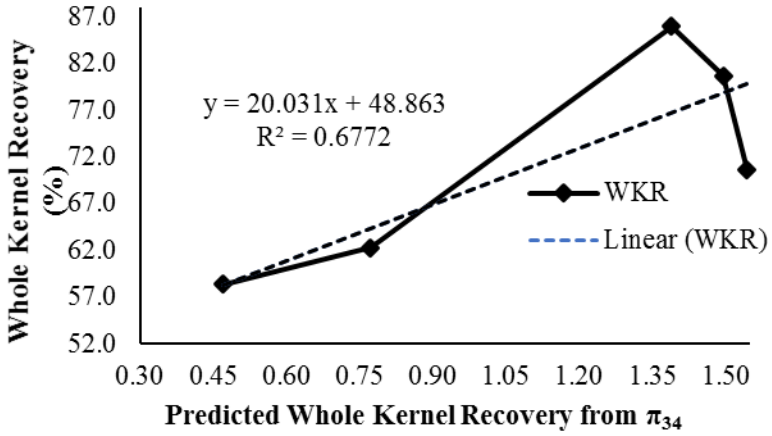

Figure 4: Variation of experimental whole kernel recovery against π_{34}, keeping π_{12}, π_{56} and π_7 constant

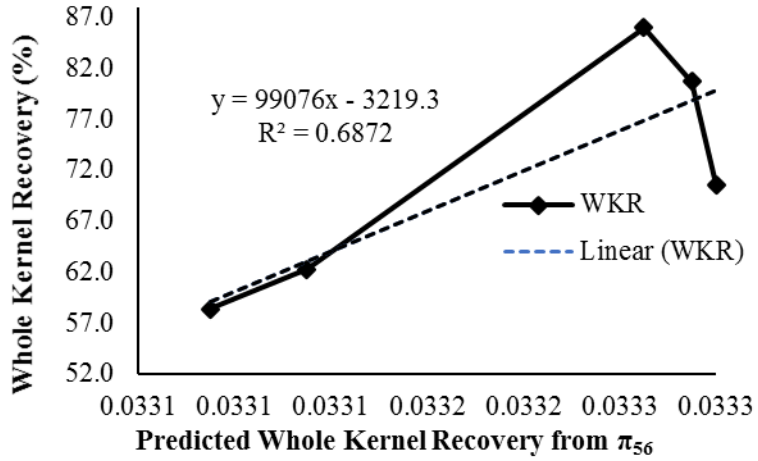

Figure 5: Variation of experimental whole kernel recovery against π_{56}, keeping π_{12}, π_{34} and π_7 constant

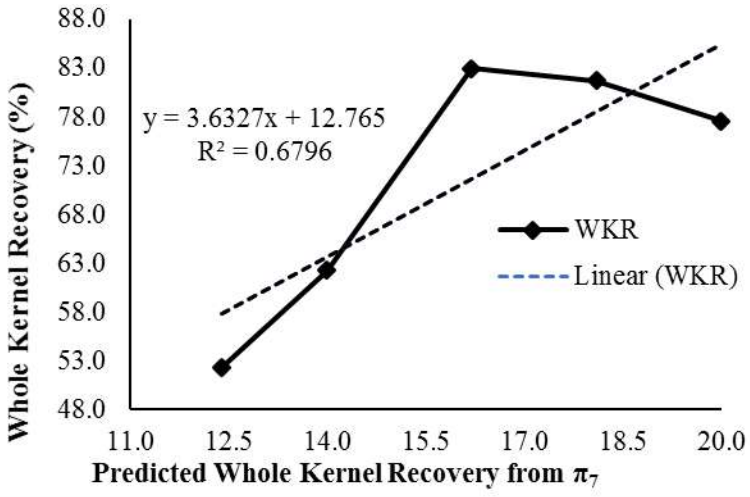

Figure 6: Variation of experimental whole kernel recovery against π_7 keeping π_{12}, π_{34} and π_{56} constant

The model equations obtained from the linear functions and R^2 values for mixed variety of palm nut are expressed in Equations 33 to 36 as:

$$WKR_{s/\pi_{12}-MIXED} = 250.05\pi_{12} - 3755.2 \qquad R^2 = 0.6015 \qquad (33)$$

$$WKR_{s/\pi_{34}-MIXED} = 20.031\pi_{34} + 48.86 \qquad R^2 = 0.6772 \qquad (34)$$

$$WKR_{s/\pi_{56}-MIXED} = 99076\pi_{56} - 3219.3 \qquad R^2 = 0.6872 \qquad (35)$$

$$WKR_{s/\pi_{7}-MIXED} = 3.633\pi_{7} + 12.77 \qquad R^2 = 0.6796 \qquad (36)$$

The plot of the π terms (Figures 3 – 6) forms a plane surface in linear space, and according to Mohammed (2002), Ndukwu and Asoegwu (2011) and Musa (2012), it implies that their combination favours summation or subtraction. Therefore, the component equation was combined by summation. The component equation was formed by the combination of the values of Equations 33 – 36 and expressed in Equation (37) as:

$$WKR_p = f_1(\pi_{12};\pi_{34};\pi_{56};\pi_7) + f_2(\pi_{12};\pi_{34};\pi_{56};\pi_7) + f_3(\pi_{12};\pi_{34};\pi_{56};\pi_7) + f_4(\pi_{12};\pi_{34};\pi_{56};\pi_7) + K \qquad (37)$$

Substituting Equations (33) to (36) into Equation (37), WKR_p for mixed varieties were obtained in Equation (38) as:

$$WKR_{p-MIXED} = 250.05\pi_{12} + 20.03\pi_{34} + 99076\pi_{56} + 3.633\pi_7 - 6912.87 \qquad (38)$$

A further manipulation as permitted under the rules of the Burkingham pi theorem is manipulating with a constant factor. Therefore, Equation (38) was divided with a constant factor of 3.65, which yields the predicted model Equation expressed in Equation (39) with values close to the actual ones.

$$WKR_{p-MIXED} = 68.51\pi_{12} + 5.488\pi_{34} + 27144.11\pi_{56} + 0.995\pi_7 - 1893.94 \qquad (39)$$

Substituting the values of dimensionless π terms ($\pi_{12};\pi_{34};\pi_{56};\pi_7$) into Equation (39), the predicted equation for whole kernel recovery was obtained as expressed in Equation (40) as:

$$WKR_{p-MIXED} = 68.51\left(\frac{V_{nc}}{{d_n}^2 D_{cd}}\right) + 5.488\left(\frac{F_r \cap_s}{T_p P_v}\right) + 27144.11\left(\frac{\delta_n {d_n}^4 \cap_s}{S_c}\right) + 0.995(\propto_{mc}) - 1893.94 \qquad (40)$$

Model validation

The mathematical model was validated using the data generated from the impeller-type palm nut cracker. The model validation was carried out at five levels of cracking speed (1200, 1400, 1600, 1800 and 2000 rpm), nut moisture content (12.4, 14.0, 16.2, 18.1 and 20.0 % w,b) and feed rate (360.00, 400.00, 450.00, 514.29 and 600.00 kg/h). The method of regression analysis as computed using Microsoft Excel

programme of Microsoft package was used to describe the relationships, plot the graphs and compute the coefficients of determination (R^2) between the predicted and experimental values. Experimental values of parameters were substituted into Equation 40 to yield the predicted whole kernel recovery as presented in Table 5.

Table 5: Experimental (WKR_e) and calculated (WKR_p) values of whole kernel recovery for Mixed varieties of palm nut in an impeller-type nut cracker

S/N	Cracking Parameters			Whole Kernel Recovery	
	S_c	$\propto_{mc}$	F_r	$WKR_{e-Mixed}$	$WKR_{p-Mixed}$
1	1200	12.4	360.00	58.37	64.61
2	1400	14.0	400.00	62.29	68.03
3	1600	16.2	450.00	86.00	76.06
4	1800	18.1	514.29	80.71	78.80
5	2000	20.0	600.00	70.61	81.67

The predicted and experimental whole kernel recovery values were evaluated on a regression curve in order to obtain the coefficients of determination (R^2) and the Root Mean Square Error (RMSE). Figure 7 present the regression curves between the predicted and experimental whole kernel recovery, with their linear Equations and R^2 values.

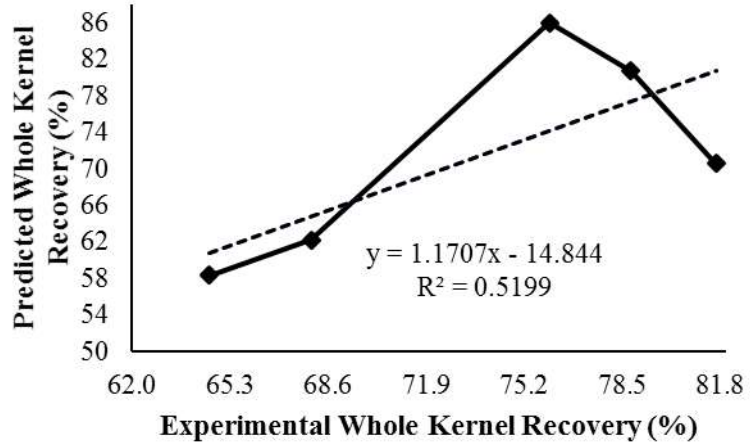

Figure 7: Graph of predicted (WKR_p) against experimental (WKR_e) whole kernel recovery for mixed variety of palm nut

From figures 7, it was observed that the predicted and experimental values have a very high correlation with R^2 values of 51.99% with a standard deviation of 11.76 and 13.77 as presented in Table 6.

The linear equations relating the predicted and experimental values of the whole kernel recovery is given in Equation (41) as:

$$WKR_{p-MIXED} = 1.17076 WKR_{e-MIXED} - 14.844 \quad (41)$$

Equations 41 express the relationship between the predicted and experimental whole kernel recovery with R^2 values of 51.99%, with RMSE of 3.18 (Table 6) between the experimented and predicted whole kernel recovery values which is less than 5% of the average value of the experimental whole kernel recovery of palm nut using the impeller-type palm nut cracker. The validity of the models was examined by testing to know if the intercept and the slope were significantly different at 5% significance level.

Table 6: Experimental (WKR_e) and predicted (WKR_p) values of whole kernel recovery for mixed varieties of palm nut

S/N	Cracking Parameters			Whole Kernel Recovery	
	S_c	$\propto_{mc}$	F_r	$WKR_{e-Mixed}$	$WKR_{p-Mixed}$

1	1200	12.4	360.00	58.37	53.49
2	1400	14.0	400.00	62.29	58.08
3	1600	16.2	450.00	86.00	85.84
4	1800	18.1	514.29	80.71	79.64
5	2000	20.0	600.00	70.61	67.82
Standard deviation				11.76	13.77
RMSE				3.18	

Conclusion

Models to predict whole kernel recovery for mixed varieties of palm nut cracking machine were developed using the concept of Buckingham Pi theorem. The developed models were verified and validated by fitting them into experimental data. The method of regression analysis as computed using Microsoft Excel programme of Microsoft package was used to describe the relationships, plot the graphs and compute the coefficients of determination (R^2) between the predicted and experimental values. The simulated and experimental results during the cracking process and the best combination for optimum whole kernel recovery for mixed varieties was obtained

The developed model satisfactorily predicted the whole kernel recovery as performance parameters of the cracking machine during the cracking process with < 5% relative error.

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QUALITY ENHANCEMENT OF *MASA*: A REVIEW

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Abstract
Masa is a Spanish terminology known as waina, it is majorly reffered to as all kind of dough. Masa is usually round in shape and brown in colour with smooth surface, it is a cereal fermented based product that is eaten as snacks and breakfast porridges. Some of the common cereals used in the production of masa include; maize (Zea mays), rice (Oriza sativa), millet (Pennisetum typhoideum) or sorghum (sorghum vulgare). Masa is a single cereal diet and no single cereal contain all the required nutrients in the required proportion, hence there is need to fortify in order to enhance the quality of masa production. Fortification of masa will not only supply the essential micronutrients needed for daily consumption but will also provide a balanced nutritional content with minimal health risk. Thus, the use of agricultural crops to fortify masa is an effective method with less cost to enhance the quality of masa towards combating micronutrient deficiency.

Keywords: *Masa, Quality, Cereals, Fortification., Enhancement*

1.0 Description of *Masa*

Masa is a Spanish word mostly referred to as all kind of dough. It is also known as *waina* which is a cereal-based spontaneously fermented cake popularly consumed in developing countries as snack or adjunct to breakfast porridges (Owusu-Kwarteng and Akabanda, 2014). It is a bread-like product that is round in shape with brown colour and smooth surface made from different types of cereals (Nachana'a *et al.*, 2018). It can be eaten with granulated sugar or honey or soup because of its sour taste (Sanni and Adesulu, 2013). *Masa* is a very popular staple food consumed by over 80% of the Northern Nigeria population of about 47 million; it is also consumed in Ghana, Niger, Burkina Faso and Mali (Ayo *et al.*, 2008). *Masa* is mainly produced from common cereal such as maize *(Zea mays)*, rice *(Oriza sativa)*, sorghum *(sorghum vulgare)* or millet *(Pennisetum typhoideum)*. The processes involved in *masa* production includes cleaning, steeping, wet milling, fermentation and frying of the fermented dough in a pan containing little oil with individual cuplike depression to obtain *masa* - which is round in shape with brown smooth surface and crippling edges (Ayo *et al.*, 2008). The shelf life of *Masa* is a maximum of Three (3) days if stored in a cool dry place but can only store for about 12 hours at room temperature (Jeff, 2021).

2.0 Common Cereals Used for *Masa* Production

One viable strategy for improving public health is appropriate modification of the food supply to give products that deliver substantiated health benefits while retaining consumer appeal. Cereals grains are prime targets in this regard. As dietary staples, relatively small improvements in grain composition especially in starch and fibre have the potential to translate into significant health gains at the population level when incorporated into food (Regina *et al.*, 2007). Some of the commonly used cereals in the production of *masa* include; maize, rice, sorghum and millet.

1. Maize

Maize (*Zea mays*) is a member of the cereal family, it is the third most important cereal in the world after rice and wheat and ranks fourth after millet and rice in Nigeria (Jeffery *et al.*, 2013). Cereal grains are

fruit of cultivated grasses of the monocotyledonous family and are used for production of different classes of foods. The cereal family are potential sources of vitamins, minerals, carbohydrates, fats, oils and proteins in its natural form. Other examples of the cereal family include: oat, rye, rice, sorghum. Breakfast meals like cornflakes, bread, and pastries, brewing of both alcoholic and non-alcoholic drinks can be made from cereal (Abegunde *et al.,* 2014). The average maize grain is 8–17 mm long, its width is 4–6 mm (Collin *et al.,* 2017). The combination of maize with many other indigenous crops has generated highly varied foods and dishes that are still used in modern cuisine like *masa.* It is a cereal with economic significance and in the global production of cereals crops, maize rank first after rice and wheat. In the developing countries of Africa, maize production is estimated to 33.3 million tonnes yield per 1.5 tonnes per hectare. Nigeria is one among the largest producers of maize with 4.7 million tonnes per 4.1 hectare (Food and Agricultural Organization Statistics (FAOSTAT), 2002). Some of the health benefits derived from maize include;

i. It contains valuable B vitamins and other essential minerals such as zinc, magnesium, copper, iron manganese that are vital to human health.
ii. It is also a good source of antioxidants *carotenoids*, *lutein* and *zeaxanthin* which promote eye health.
iii. The insoluble fibre in maize may also help to lower the risk of colon cancer.
iv. Its high fibre content helps aid with digestion.
v. The fibre content present in maize also assists in weight management by increasing post meal feelings of fullness.

2. Rice

Rice is a staple food that is broadly produced and consumed around the world to more than half of the world's human populace (Adanse *et al.*, 2019). After maize, rice is one of the most produced cereal in the world with Asia, Africa and America ranking the world top producers (FAOSTAT, 2012). According to Sharif (2009), 645 million tonnes of rice is produced within 114 nations of the world including Nigeria. Rice is an economic crop, which is important in household food security, ceremonies, nutritional diversification, income generation and employment (Perez-consesa & Periago, 2002). Hence, its consumption is increasing faster than that of any other food staple in Africa at about 5.5% per year. In developing countries like Africa, production of food is grossly inadequate and if something is not done to abate the situation, hunger and malnutrition will sweep through the population (World Health Organization (WHO), 2004). Rice as a cereal will be an alternative to combat hunger as malnutrition continues to be a major public health problem throughout sub-Saharan Africa and the populace (FAO, 2004). Rice is eaten boiled by humans or can be processed into flour however it is relatively uncommon.

3. Millet

Millets are one of the cereals beside wheat, rice, and maize. It is a major food sources for millions of people, especially those who live in hot and humid areas of the world. Millets are excellent sources of carbohydrates, protein, fatty acids, minerals, vitamins, calcium, dietary fibre and polyphenols (Devi *et al.,* 2011). The different varieties of millet are Pearl millet *(Pennisetum glaucum),* which comprises 40% of the world production, Foxtail millet *(Setariait alica)* (Yang *et al.,* 2012), Proso millet or white millet *(Panicum miliaceum),* and Finger Millet *(Eleusin ecoracana).* Pearl millet produces the largest seeds and it is the variety most commonly used for human consumption (Mariac *et al.,* 2006). In 2007, global millet production reached about 32 million tonnes with the top producing countries being: India (10,610,000), Nigeria (7,700,000), Niger (2,781,928), China (2,101,000), Burkina Faso (1,104,010), Mali (1,074,440), Sudan (792,000), Uganda (732,000), Chad (550,000) and Ethiopia (500,000) (FAO, 2009). Millet can be used as unique staple food with biodiversity in Agriculture and as food security system to millions of populace across the Sub-Saharan Africa. In Ghana, millet grains serve as the raw material for the processing of various foods such as *koko* (Lei and Jakobsen, 2004), *fura* (Owusu-Kwarteng *et al.,* 2012), and *masa* (Owusu-Kwarteng and Akabanda, 2013).

3.0 Fortification of *Masa*

Masa is usually produced from cereals which are from a monocot family whose nutritive value is mainly carbohydrate. The consumption of this diet can lead to deficiencies in nutrients since no single food item

contains all the required nutrients in its proportion; therefore the need to fortify *masa* with other food crops. Hence, fortification of *masa* is therefore, the practice of deliberately increasing the content of essential micronutrients in *masa* to improve the nutritional quality of the food supply that will be of health benefit with minimal risk to human health. *Masa* fortification is essential because with the increase in knowledge of the complexity of human nutrition, there are still cases in which food security is conceptualized as simply the supply of foods to provide metabolic energy (Omar and Michael, 2008). This implies that, food fortification has being considerably on advance because it provides the needed supplement with minimum cost that help combat deficiency of vital micronutrients such as vitamins, minerals and trace elements. These micronutrients are essential for the mental and physical development of both children and adults.

Fortified composite *masa* production is important because of the increment in prominent cases of micronutrient deficiency been on the rise as reported by World health organization in 2002. The report identified iodine, iron, vitamin A and zinc as some of the most common deficiencies faced by the global populace. Therefore, fortification of *masa* will aid in supplementing the dietary needs of the populace.

Ayo *et al.,* (2008) investigated the effect of different cereals (rice, maize and millet) on the quality of *masa.* The studies revealed that there were no significant difference in the length, volume and volume index of rice and maize based *masa.* The none significant differences could be due to similarity in the molecular weight and structures of carbohydrates which are the principal functions of volume development during fermentation on the physical quality of *masa.* Also, the average protein content of *masa* produced from rice, maize and millet are 8.59, 9.60 and 9.21%, respectively where the relative difference could be due to the chemical composition of the raw cereal.Carbohydrate contents were 64.99, 65.16 and 66.66% for rice, maize and millet based *masa,* respectively, which suggest that the relatively high carbohydrate content could make the product of significant source of energy to the consumers.

Nachana'a *et al.* 2018 studied on microbial quality evaluation of *masa* processed and sold within University of Maiduguri campus, and *masa* was identified as one of the meal mostly consumed by student because it is one of the common ready-to-eat foods. It is also a fast food with low cost compared to other foods. However, higher amount of microbial contaminant of *masa* could emerge as a result of the use of contaminated water and utensils during the production of *masa*.

Méndez-Albores *et al.* (2012) studied on the technological properties of maize tortillas produced by microwave nixtamalization with variable alkalinity. The research was conducted to determine the quality, physicochemical, textural, compositional, nutritional, viscoamylographic and sensory properties of maize tortillas produced with a modified tortilla-making process (MTMP) of variable alkalinity. The evaluated qualities were significant. However, the process of nixtamalization was achieved by the use of microwave oven.

Owusu-Kwarteng and Akabanda, 2014 researched on the effect of soybean fortification of *maasa:* a Ghanaian fermented millet-based cake. The study revealed that fortification of commonly consumed cereals with inexpensive plant protein sources such as soybeans can be used to improve the protein quality of staple foods like *masa* through a mutual complementation of their limiting amino acids. The cereal and legume fortification show that soybean fortification accelerates the production of total acids and the growth of lactic acid bacteria during the fermentation of millet dough to produce *masa*.

Schaarschmidt and Fauhl-Hassek 2019 carried out a review on mycotoxins during the processes of nixtamalization and tortilla production, this review study showed that nixtamilization is a processing technique that improves the nutritional properties of *masa*. The review also found average reductions of total aflatoxin concentrations in *masa* and tortillas of 94% and 95%, respectively, at 0.6% lime without significant diff erence compared with the use of 1.87% lime.

Conclusion

A lot of works has being carried out on *masa,* however there are readily available agricultural crops that have not been used for quality enhancement of *masa*. It is therefore important to enhance and improve the nutritional quality of *masa* through fortification using readily available crops that have not been used such as sweet potato, Irish potato and cocoyam as well as other cheap protein sources such as egg.

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DEVELOPMENT OF GROUNDNUT CAKE PRODUCTION MACHINE

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Abstract
This paper presents the development of a kulikuli making machine and optimization of its functional parameters that is inexpensive and for use in the production industry for producing kulikuli (groundnut cake) of different shapes. The components of the machine are the hopper, screw, the barrel assembly, and the injection nozzle. The machine is a batch processing machine and fabricated using locally sourced materials. The machine was tested. Temperatures of 200ºC and 300ºC were used to test the rate of melting of the groundnut paste. The performance test of the machine indicated average throughput and injection efficiency, of 15,662.4kg/mins and 92.2% respectively at a displacement time of 2.1204mins. Therefore, this innovation is recommended for small scale industries.
Keywords: *Optimization; Kulikuli; Machine, Efficiency, Groundnut Cake*

1.0 INTRODUCTION

Processing of agricultural products is generally accepted as the efficient method of maintaining the shelf-life of produce. Such processed products provide local foods for consumption among the rural population (Zuberu et al., 2013). Hence, the importance of crop processing industries especially in Nigeria cannot be over emphasized. Processing of groundnut cake, locally called *kulikuli* is largely dominated by the traditional methods in Nigeria and often carried out using a mortar and pestle or using grinding machine if the quantity is large. The process involves dehulling and winnowing of chaff from fried groundnut. The groundnut is mixed with some spices like salt, dry pepper and ginger and grounded into paste. Oil is then extracted from the groundnut paste to avoid it looking crispy when fried in hot oil, the paste is moulded using hand to give the kulikuli different shape and finally, the moulded groundnut paste is fried using groundnut oil obtain from the groundnut cake (Davis et al., 2016). Peanut meal is a high protein feed. Its protein content is usually about 50-55% of dry matter (DM), and ranges from 42% to more than 60%, depending on the amount of oil, skins, and hulls. Peanut cake processed on-farm, including shells and more residual oil, can have a protein content of less than 40% of DM. Peanut meal is deficient in lysine, and low in methionine and tryptophan. Mechanically extracted meal may contain more than 5 to 7% fat, and thus tends to become rancid if stored more than 5 to 6 weeks during summer, and 8 to 12 weeks during winter (Cunha, 1977 and Seerley, 1991). In the Northern part of Nigeria, apart from being consumed raw, edible groundnuts are processed into many local foods or included as an ingredient in a wide range of other products which includes groundnut paste which is fried to obtain groundnut cake (kuli kuli), salted groundnut (gyada mai gishiri), a gruel or porridge made with millet and groundnut (kunun gyada), groundnut candy (kantun gyada) and groundnut soup (miyar gyada).

This research is focused on the development of a Kuli-kuli making plant as well as constructing different moulds or shapes (Oval, Triangular, Circle, and Rectangular) to give the kuli-kuli an appetizing look before consumption.

Statement of the Research Problem

The process of molding groundnut paste using traditional method is stressful and time consuming because it can take up to 5 hours to mold a 5kg of kulikuli to different desired shapes. This leads to decrease in quantity produced. During molding, the groundnuts cake breaks frequently and does not have uniform shape because of the inconsistency of using hands to mold into desired shapes, this eventually consumes time because of the repeated nature of molding it.

Aim and Objectives

The aim of the research is to develop a kulikuli making machine and optimization of its functional parameters.

The specific objectives are:-

1. To review the traditional method of kulikuli production.

2. To design and fabricate the kuli-kuli making machine
3. To optimize the functional parameters.

Nutritional Features of Groundnut

The groundnut is particularly valued for its protein content (26%). On equal weight basis (Kg for Kg), groundnuts contain more protein than meat and about two and a half times more than eggs. Being an oil seed crop, it contains 40 to 49% oil. In addition to protein, groundnuts are a good source of calcium, phosphorus, iron, zinc and boron. The groundnuts also contains vitamin E and small amounts of vitamin B complex. High in calories, 5.6 calories nut -1 (calorific value of 567). The table below shows the food value and nutritional content of groundnuts.

Table 1.0: Food value of Groundnut

S/N	CONTENT	PERCENTAGE
1	Protein	25.2
2	Oil	48.2
3	Starch	11.5
4	Soluble Sugar	4.5
5	Crude Fibre	2.1
6	Moisture	6

Table 1.1: Nutritional Characteristics of Groundnut

S/N	Characteristics	Raw	Roasted
1	Calories(g)	564	582
2	Protein(g)	26	26
3	Fat(g)	47.5	48.7
4	Carbohydrate(g)	18.6	20.6
5	Calcium(mg)	69	72
6	Phosphorus(g)	401	401
7	Iron(mg)	2.1	2.2
8	Thiamine(mg)	1.14	0.32
9	Riboflavin(mg)	0.13	0.13
10	Niacin(mg)	17.2	17.2

(Source: USDA National Nutrient data base)

2.0 MATERIALS AND METHODS

2.2 Description of the machine

The machine is designed for small scale industries purposes with main considerations as follows: inexpensive, small size, capable of producing a small number of products for prototype testing, able to accommodate up to medium size specimens, and have a standard operational procedure. Fig. 3.1 shows a sectional view of the machine.

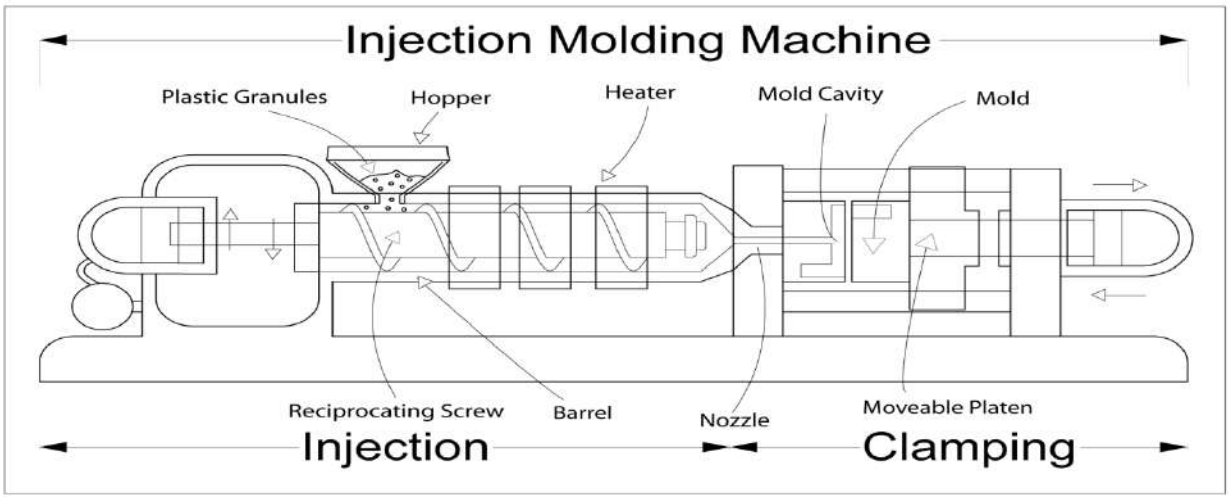

Fig 3.1: Sectional view of machine

The hopper is fabricated with 3mm flat metal sheet, this part helps direct the groundnut paste into the barrel for melting and injecting. A circular pipe of 55mm internal diameter was used for the construction of the injection moulding barrel, where the screw is given 0.1mm tolerance so it can rotate and move linearly in the barrel. Also, 55mm thick shaft was used to construct the injection moulding screw by threading operation in a lathe machine. The torpedo consists of an assembly of valve and a locking ring for preventing backward movement during the injection process. These parts were constructed by machining using a lathe machine. In addition, the injection nozzle was fabricated. This part is connected to the end of the barrel in which the paste come out from and then goes into the mold cavity. The platen is constructed from a flat metal sheet. Next is the heater band which is an electric device that generates the amount of heat required to further melt the paste, it is of different sizes and capacities. The type used is called the Mica heater band. The selection of the heater band depends on the amount of heat needed in a system. Mica heater bands provide excellent thermal conductivity. These bands are basically of mica insulator a nickel-chrome resistant ribbon wire. Mica bands are capable of attaining a 8 temperature up to 90^{o}F and a normal watt density of 20-45W on a barrel. This rotating handle was constructed with a circular pipe. Its function is to help in rotating the screw manual by hand. The frame was also constructed with angle iron bars, which act as support and carrier for the other machine components.

Principle of the machine

The principle of the machine process starts with the feeding of groundnut paste through the hopper. The groundnut paste is processed by using a grinding machine to grind the groundnut and a extractor to extract the oil from the grinded groundnut. The hopper functions as the inlet point and holder of the paste. Groundnut paste is then fed from the hopper to the barrel through gravity. The barrel is a housing that gives support to the screw and consists of heater bands that function as heat source for each section of the barrel. The screw, also known as the reciprocating screw is used in compressing, melting and conveying the paste. The screw consists of three zones: the feeding zone, the compressing/transition zone, and the metering zone. In the feeding zone, there is no change to the orientation of the paste and are transferred to the next zone which is the transition zone. In this zone, melting of the paste occurs and the paste is transferred to the next zone which is the metering zone. Here, the paste is ready for injection. Also, there is the nozzle, with the main function of connecting the barrel to the sprue bush. This forms a seal between the mold and the barrel. It is essential that the nozzle temperature should be set to the materials melting temperature, depending on the recommendation (Rosato et al., 2000). After injection, pressure is applied to both platens of the injection molding machine (moving and fixed platens) to hold the mold tool together until after cooling and solidification. After this process, the product gets its shape and the two platens are moved away from each other to separate the mold tool which is known as mold opening. Finally, the moulded product is ejected or removed from the mold marking the end of the process (Siregar et al., 2017).

3.2 Design equations

Design calculations of injection screw conveyor. Rauwendaal (2013):

Total length of screw (L) = 10D (1)

Length of feeding zone section L_f = 2D (2)

Length of transition zone section L_t = 3D (3)

Length of melting zone section (L_m) = L - (L_f + L_t) (4)

Helix angle = (φ) = 18^0 (5)

Flight pitch = D/2 (6)

Flight width = 0.1D (7)

Barrel internal diameter = D = R_C (8)

Where, D = Screw diameter (mm), R_C = Radial clearance (mm)

Vol. of barrel = V= $\pi R^2 L$ (9)

Where, R = barrel radius, L = barrel length and π = 3.142

Vol. of hopper = $\left(\frac{1}{2}(a+b)h\right)h$ (10)

Mass flow rate = D^2 x N x h x *Pbuik* (11)

Volumetric flow rate = V_Z x w x h (12)

Vz (Channel Velocity) = π x D x Ncos φ (13)

Where *W*= Metering channel width, *h* = Metering channel depth, *D* = Screw diameter, *N* = Screw speed, φ = Helix angle, and $\rho bulk$= Bulk density.

Determination of total flow output from barrel (Jassim *et al.*, 2016):

$$Q_T = \frac{1}{2}\pi^2 D^2 N h sin\varphi cos\varphi - \frac{\pi D h^3 (sin\varphi)^2}{12\eta}\frac{P}{L} \quad (14)$$

Where;

Q_T = Total output, D = Diameter of the screw, N = Screw Revolution (rpm), h = Channel dept of the screw (m), φ = Helix angle of screw, L = Length of screw (m), P = Operational pressure (Pa), and η= Viscosity (Pa.s)

Determination of heat transfer through barrel (Shigley, 2006; Eastop and McConkey, 2009):

$$Q = \frac{2\pi K(T_1 - T_2)}{In\left(\frac{R_2}{R_1}\right)}$$

Where Q = Amount of heat transfer (W),

R_1 = Inner cylinder radius (m), R_2 = Outer cylinder radius (m), (T_1-T_2) = Temp. Difference,

K = Proportionality constant known as Thermal conductivity W/m^0C.

3.0 RESULT AND DISCUSSION

3.1 Performance Evaluation

Test parameter of melting time with temperature was tested and a simple mould was fabricated and the machine was tested. The injection machine was feed with groundnut paste through the hopper. Its rotating handle was rotated for the paste to travel forward. The heat generated by the heater band to the barrel was sufficient to melt the paste and then the injection lever was then pulled for the injection of groundnut paste out from barrel into the mould cavity. The machine was connected to electric power to power the heater bands and heat up the barrel through which the paste passed to the nozzle where it was pressurised into mould cavity and it was also super-heated before getting to the nozzle in order to enhance injection pressure and to avoid cold short before getting into mould cavity. The machine temperature controller was set at 200^{o}C and then 300^{o}C for the experimental runs undertaken. For the temperature measurements, a thermocouple was used.

The injection machine performance as seen in table 3.1 was further tested by the evaluation of the Machine injection efficiency (IE) and Throughput (TP). The performance test was carried out after the

fabrication and assembly of the machine. The machine was fed with samples of equal-weighted mass of the plastic materials used through the hopper per time. A stopwatch was used to record the time taken for the processing of each experimental batch.

$$Mach\ ine\ injection\ ef\ ficiency, IE\ (\%) = \frac{\text{Output mass from injection machine, Om (kg)}}{\text{Input mass of plastic pellets, Im (kg)}}$$

$$Th\ rough\ put, TP\ (kgh\ r) = \frac{\text{Output mass from injection machine, Om (kg)}}{\text{Time taken, T (hr)}}$$

Table 3.1: Performance test responses for the Injection machine

Experimental runs	Input mass (Im) (kg)	Time taken (T) (min)	Output mass (Om) (kg)	Machine injection efficiency (IE) (%)	Throughput (TP) (kg/min)
1	10	2.082	9.7	97	16,770
2	10	2.136	8.6	86	14,496
3	10	2.136	9.5	95	16,014
4	10	2.100	9.4	94	16,116
5	10	2.148	8.9	89	14,916
Average	**10**	**2.1204**	**9.22**	**92.2**	**15,662.4**

4.0 CONCLUSION

A mini injection moulding machine for kulikuli processing was designed and fabricated which melts and injects (pressurizes) groundnut paste into mould cavities with ease. This machine is inexpensive and can be used as learning equipment in school or laboratories and also could be used in the production industry for producing small size plastic products. The components design of the machine was properly undertaken and fabrication followed by assembling of the parts. The machine was tested with Temperatures of 200ºC and 300ºC were used to test the rate of melting of the paste and. Performance test of the machine indicated average throughput and injection efficiency of 15,662.4kg/mins and 92.2% respectively at displacement time of 2.1204mins, 10 average input and output masses of 10kg and 9.22kg respectively. Therefore, this innovation is recommended for small-scale manufacturing industries.

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A REVIEW OF THE UTILIZATION OF BAMBARA NUT AND SWEET POTATO FLOUR FOR CONFECTIONARY PRODUCTS

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Abstract
Confectionary products are a wide range food product including soft, hard, jelly, gummy and aerated confection, chocolate and derivatives such as chewing gum. Other products such as bread, biscuits, cakes and doughnuts are also a derivative of confectionary products. Over the years, wheat have been a suitable flour of choice in the confectionary industries for baking and its high level of utilization has resulted in overdependence especially in developing countries like Nigeria. Hence, utilization of local agricultural crops such as sweet potato and Bambara nut for composite flour in the confectionary industries will reduce the importation of wheat flour and encourage the use of locally grown crops as flour. These Composite flours are being developed which consist as substitute to primarily wheat flour in the production of baked products. The composite flour will enhance nutritional content of confectionary products in addition to being gluten-free. These composite flours enhance the utilization of local and underutilized local and inexpensive food raw materials in the production of bakery products.

Keywords: *Confectionary Products, Utilization , Flour, Bambara Nut, Potato*

1.0 Introduction

Confectionery products are integral part of the human diet which can serve as a high density food energy source and improves the feeling and mood of consumers (Juhaniakova *et al*., 2014). Confectionary foods products are a wide range food whose category include soft, hard, jelly, gummy and aerated confection, chocolate and derivatives and chewing gum respectively. Other food diet derivative from confectionary products include; biscuits, cakes, cookies and doughnut.

1.1 Bread

Bread is a universal food that is popularly consumed in Nigeria and other parts of the world. In most European cultures, it is the single inevitable presence at the table during all the three meals of the day (Kent, 2000). It is a bakery product that is a constant daily element in the diets of most people. In Nigeria, it is consumed by people in every socioeconomic class and it is acceptable to both children and adults. Bread has gained wide consumer acceptance for many years in Nigeria because it is consumed by almost every household in Nigeria (Badifu *et al.*, 2005; Abulude, 2005). Bread consumption has increased continuously in many developing countries due to changing eating habits, a steadily growing population and a large proportion of the overall increased incomes can now be spent on foods (Seibel, 2011). However, the demand for wheat flour needed for making bread had to be imported, since the climatic conditions and soil did not permit wheat to be grown locally in most developing countries such as Nigeria (Seibel, 2011). Hence, finding composite blend of non-wheat bread-making alternatives in order to reduce non-wheat-producing countries' dependence on imported wheat is a suitable remedy (Mepba *et al.*, 2007).

Baking of bread involves; dough-mixing (flour, water, yeast, and salt), dough fermentation, and baking. During the baking process, the starch is gelatinized and the proteins denatured at an internal temperature of 60-80 °C and then the raw dough is transformed into a light, porous, and readily digestible product. During baking, the most apparent phenomenal changes are volume expansion, crust formation, inactivation of yeast and enzymatic activities, protein coagulation, partial gelatinization of starch in dough and moisture loss (Therdthai and Zhou, 2003). Hence, it is highly desirable to establish optimum baking conditions to produce bread with lowest

moisture loss and consistent quality attributes including texture, colour, and flavour (Piperno *et al.*, 2004).

1.2 Biscuit

Unlike yeast leavened baked products, high quality and acceptable biscuits are reported to have been produced from wheat-non-wheat composite flours containing 50% and above non-wheat flours. Iwe and Egwuekwe (2010) produced biscuits from the composite flour blends of wheat-*Xanthosoma sagitifolum* and wheat-*Colocasia esculenta* flours. The research study blended the wheat flour with each of the cocoyam species flours at the ratio of 100:0, 50:50, 25:75 and 0:100. The sensory evaluation results showed that the products were acceptable to the panelists.

1.3 Pasta

Pasta is a stable food product that is produced mainly by mixing durum wheat semolina and water (Sozer, 2009). In recent years, pasta has become recognized as a healthy food, with a low fat content, no cholesterol and a low glycaemic index (Cleary and Brennan, 2006).

2. Importance of Composite Flour

The concept of composite flour technology is important because it is considered advantageous in developing countries as it reduces the importation of wheat flour and encourages the use of locally grown crops as flour. Also, it provides a medium through which local raw materials can be substituted for wheat flour. Since there is an increasing demand of wheat due to the growing market for confectioneries. The following advantages can be derived from using composite flour:

i. It aid savings of hard currency.
ii. It promote and encourages the cultivation of high yielding native plant species.
iii. With the various blends from different crops there is a sufficient supply of protein needed for balanced human nutrition.
iv. Better overall use of domestic agriculture production.

Flour blends are used for partial substitution of wheat flour to reduce the import of cereal. Thereby improving the nutritional quality of food products to meet consumers` needs, this has been a focus of various studies worldwide (Pierarski, 2009). Hence, bread production has increased every year with a wide variety of formulations for optimum quality.

In Nigeria, reliance on wheat flour has over the years limited the use of local cereals and tuber crops in the pastry and bakery industries. Wheat does not grow well in the tropics and has to be imported by countries in these regions. Incessant increases in the cost of wheat have in turn led to constant increases in the price of confectionery products which will be too expensive for an average person from a developing country to afford.

3. The use of Sweet Potato Flour in confectionary products

Sweet potatoes (*Ipomoea batatas L.*) are rich in calories, dietary fiber, good sources of antioxidants and polyphenols (Ahmed *et al*., 2010), zinc, potassium, iron, sodium, calcium, magnesium and manganese (Antia *et al*., 2006). The sweet potato flour is used as a dough conditioner for bread, biscuit, and cake processing. It may substitute for up to 20% of wheat flour, as well as in gluten-free pancake preparation (Shingh *et al.*, 2006). Sweet potato flour can add natural sweetness, colour, and flavour to processed food products. It can also serve as a source of energy and nutrients and minerals and contributes to the daily nutrient needs for β-carotene, thiamine, iron, vitamin C, and protein. Sweet potato flour provides 14%-28% of the dietary reference intake (DRI) for magnesium and 20-39% for potassium. However, sweet potato alone

cannot be used totally for bread production. Anton, 2008 reported that an attempt at total substitution of flour by root crop flours in bread, in which various starch binders are incorporated to maintain loaf volume in the absence of gluten and of protein additives to sweet potato flour, were investigated and result shows a poor loaf volume.

Baljeet *et al.* (2014) stated that blends of refined wheat flour with *colocasia*, sweet potato and water chestnut flours respectively at a replacement level of 25 g/100 g were assessed for suitability in noodles making. Limroongreungrat and Huang (2007) used protein sources such as soy flour and soy protein concentrate to enhance the nutritive quality of pasta. The sample pasta fortified with 15 g/100 g defatted soy flour or 15 g/100 g soy protein concentrate had approximately five times higher protein content compared to pasta made from 100 g/100 g alkaline-treated sweet potato flour.

Saeed *et al.* (2012) reported that a proportion of 90:10 of plain wheat flour and sweet potato flour produced good results without any adverse effect on the physical and sensory characteristics of biscuits. It has been established that cookies' spread is strongly correlated to the water absorption capacities of the flour (Vieira *et al*., 2007). Since the water absorption capacity of sweet potato flour (2.375 ml/g) is higher than that of wheat flour (1 ml/g), rapid partitioning of free water to hydrophilic sites of sweet potato flour is presumed to be higher than that of wheat flour (Saeed *et al*., 2012). It was also noted that sweet potato flour improved the flavour and texture of cookies and can significantly improve the dietary fibre and mineral contents of the product (Saeed *et al*., 2012).

4. The use of Bambara nut Flour in confectionary products

Bambara nut *(Voandzeia subterranean L. Verdc)* is one of the underutilized legumes in Nigeria. This is partly due to limited information on its nutritional value, potential food uses and hard to cook nature (Stephen and Omolare, 2020). Its cultivation has several agronomic advantages; it is drought tolerant, it has ability to grow well in poor soil and unfavourable environmental condition (Oyeyinka, 2016). It contains appreciable quantity of minerals that are essential to human nutrition. Bambara nut is eaten in several ways and at different level of maturity (Bamshaiye *et al.,* 2011), it has been used to supplement flours of other crops (Olapade *et al.,* 2014, KiinKabari *et al.*, 2015). Bambara nut is a suitable legume used as supplement for the production of bread with nutritional quality for consumption. Bambara nut (*Vigna subterranean* L.) has been used by researchers as composite flour for baking because of its nutritional value. It contains high protein content that plays important role in human nutrition. Study shows that it contains 20-26% crude protein (high in lysine; 6.6%); and makes an excellent source of supplementing proteins in the diet (Nwosu, 2013). Bambara nut is a good source of fibre, calcium, iron and potassium; unusually high in methionine (Awolu *et al*., 2017).

A lot of research has being carried out on produced bread formulated from different flours of agricultural crops. Research has shown that Flour blends produced from breadfruit and Bambara nut showed variant functional and pasting properties and could be adopted to replace relatively expensive flours such as whole wheat flour, yam flour commonly used to produce dumpling dough. Olaleye *et al*. (2013) also recommended that soybeans flour could be added to rice flour to improve its nutritional quality. Since fortification of rice flour with 20% soybeans flour will give an acceptable, nutritional and aesthetic "rice-soy flour blend". The addition of soybean flour increases the protein content but decreased the sensory qualities of rice flour. Igbabul *et al*

(2014) produced composite flour of bambara nut, cassava, and soybean at different levels (100:0:0, 80:20:0, 80:0:20, and 70:15:15) and reported protein content varying between 14.25% and 16.25%; the high protein content of the product is as a result of bambara nut and soybean but more from bambara nut due to its high proportion.

5 Conclusion

Since wheat is popular and unique among other crops for making bread and other aerated baked products, bread production from composite flour blends will not only be a suitable diet made available for people. It will also minimise the cost of wheat importation since imports are paid for with scarce foreign currency. And this, no doubt, is depleting Nigeria's external currency earnings and reserve thereby improving the country's economy. Also, there will be extension of the shelf life of the flours for a longer period – a measure to food security.

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OPTIMIZATION OF FLUIDIZED BED DRYING PARAMETERS ON THE PROXIMATE COMPOSITION AND CAROTENE CONTENT OF DRIED TOMATOES

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Abstract

Tomato (*Lycopersicon* esculentum L.) is a popular and widely grown vegetable crop in the world as well as in Nigeria. The cultivation and production of tomato have been widely practiced due to its nutritional and medicinal value. Tomato is seasonal and highly perishable after harvest in its natural state, leading in huge post-harvest losses during the production season which brings about serious scarcity during off-season because of its short post-harvest life and traditional ways of managing the post-harvest system (inadequate processing, handling and storage systems). Drying is one of the most convenient methods in extending the shelf life and minimize postharvest loses. During drying, some physicochemical quality may be degraded and thus affect general quality characteristic of the dried tomato. However, fluidized bed dryer has proven to be an important and valuable way of preserving tomato since it has great outcome on the quality of the dried product.The optimization of some parameters of the fluidized bed dryer was carried out with the view to establish the optimum parameter for the production of quality dried tomato. This study examined some drying conditions on proximate composition of tomato in a fluidized bed dryer. The parameters examined were temperature, air velocity and slice thickness. Seventeen (17) experimental data sets were generated using response surface methodology randomized box-Behnken design of design expert 11.0 within the process boundary of (55-70°c) for temperature, hot air velocity (0.8-1.2m/s) and slice thickness (3-7mm). The result of the optimization solution shows that 70°c drying temperature, 0.96m/s hot air velocity and slice thickness of 4.9mm produced dried tomato with an optimum proximate composition of 5.96% moisture, 15.92% protein, 54.12% carbohydrate, 17.1% ash, 4.47% fat, 3.95% crude fibre, 22.53% lycopene and 7.360% β-carotene with highest desirability of 0.697

Keywords: *Tomato, fluidized Bed Dryer, Drying Conditions, Optimization, Proximate Composition*

1.0 Introduction

Tomato (*Lycopersicon esculentum* Mill) belongs to family "Solanaceae" and is a worldwide important agricultural commodity. In terms of area, tomato is the second horticultural product cultivated. It is regarded as one of the most important vegetable crops grown all over the world and Nigeria in particular, after pepper and onions. The leading tomato-producing countries are: China, United States of America, India, Egypt, Turkey, Iran, Mexico, Brazil and Indonesia (FAO, 2012). In Nigeria, tomato accounts for about 18% of the average daily consumption of vegetables (Ibitoye *et al.*,2009). Tomatoes are a good source of vitamin C and vitamin A equivalents (in the form of β-carotene) and provide some vitamin E, folic acid, potassium and other trace elements. One of the benefits of tomato is its lycopene content. Lycopene is a vital anti-oxidant that helps in the fight against cancerous cell formation as well as other kinds of health complications and diseases. Diets that include tomato have been linked with reduced risk of obesity and some neurological diseases including Alzheimer's disease (Adegbola *et al.*,2019). Tomatoes and tomato based foods are considered healthy foods for several reasons. They are low in fat and calories, cholesterol free and a good source of fiber and protein (Shi, 2000). It is a seasonal and highly perishable vegetable, deteriorating few days after harvest which affect their nutritional and qualitative characteristics (Nakhasi *et al*., 1991).

Tomatoes which is extremely valuable in nutritional qualities, especially ripe tomato is not suitable for long term storage after harvest. Due to high content of water, tomato can deteriorate very quickly because of either chemical or microbiological effects. This situation leads to significant losses in terms of both nutritional and economic (Demiray and Tulek,2008). The shelf life of tomato is within 4 to 6 days after harvest, and this is dependent on the variety and storage

conditions. The short shelf-life of tomato, coupled with improper packaging and storage equipment, as well as lack of effective transport means has been one of the bottlenecks affecting the tomato industry (Idah *et al*., 2007).

Nigeria is ranked the second largest producer of tomato in Africa and 13th in the world (Brushlyanova *et al. 2013)*. Due to lack of post-harvest enterprise and poor post-harvest storage plans, Nigeria is unable to meet its domestic demands for tomatoes even though it ranks 13th on the world tomato production hierarchy. The high moisture content of tomato makes their handling, transportation and marketing a problem especially in the tropics. Tomatoes deteriorate rapidly after harvest, requiring preservation and/or processing in other to extend its shelf life (Anyaogu , 2013). The predominant method of preservation of fresh tomato in most homes is by storing at low temperatures. This however, often results in poor and uneven ripening, and in some instances, high fungal spoilage (Alam *et al*., 2009).

Dehydration is one of the most widely used methods for fruits and vegetables preservation. Drying tomatoes is one of the easiest known preservation methods. The amount of time it takes to dry tomatoes depends on the tomato variety, the air's humidity during the drying process, the thickness of the tomato slices or pieces, and the efficiency of the dehydrator or oven. Drying basically removes moisture from food and this inhibits the growth of bacteria and fungi. Moreover, it slows down the enzyme action without deactivating them. These factors (bacteria and fungi) when inhibited ensure that food does not spoil easily and hence, makes drying an effective food preservation technique (USDA 2010). It is important to develop suitable method for drying and preserving of tomato to reduce losses, maintain high nutrition and sensory quality, provide food security and increase productivity. Tomato can be dried using several drying methods such as sun, solar, spray and freeze-drying techniques. Since quality of the dehydrated product depends on factors such as tomato variety, the total soluble solid content of the fresh product, air humidity, air temperature and velocity, the size of the tomato segments and the efficiency of the drying system (Ghavidel and Davoodi, 2010). So, one promising method of preventing or minimizing quality losses during drying is by using fluidized bed drying technology to preserve tomato. It decreases the water content of the raw product to levels that minimize its biochemical, micro biological and chemical deterioration. Fluidized bed dryer is an attractive technology because it is very simple and can easily be adopted by the farmers, with low capital investments. (Shahnawaz *et al.*,2012).

Fluidized bed dryers offer advantages such as good mixing of solids, high heat and mass transfer rates, ease of operation and maintenance and lower capital costs (Puspasari *et al*.,2012). Drying in fluidized bed dryer results in shorter drying time and produces excellent product quality compared to other drying methods due to the intensive heat and mass transfer between gas and solids (Bakal *et al*., 2010)

Figure 1: Fluidized bed dryer

Aim of the Study

The aim of this work is to optimize some fluidized bed dryer parameters on the proximate composition and carotene content of dried tomato with the view to establish the parameters for the optimum production of quality dried tomato.

2.0 Materials and Method

The materials used for this research were, fluidized bed dryer, anemometer, tomato, cutting knife, distilled water, muslin bag, conical flask, Soxhlet extractor, desiccator, weighing balance. The tomato were purchased from Kure market, Minna, Niger state.

2.1 Experimental design

The study was conducted using response surface methodology, Box-behnken experimental design with three drying factors (drying temperature, air flow velocity and thickness as depicted in Table 1) of fluidized bed dryer. Each of the drying factors were optimized (consisting a total number of 17runs as depicted in Table 2) to get the best dried tomato in terms of nutritional qualities.

2.2 Sample preparation and drying process

Firstly prior to drying, the individual fresh tomato fruit were washed with distilled water and cut into (3, 5, and 7mm) slices of thickness using sharp stainless-steel knife and venier caliper to measure. Drying was conducted using fluidized bed dryer taken into consideration the optimized factors as depicted in Tables 1 and 2. Next the dried tomato slices were cooled inside desiccators to prevent formation of condensation moisture. The following proximate composition of the dried tomatoes were determined: moisture content, protein, carbohydrate, fat, ash, crude fibre, lycopene, and β-carotene as depicted in Table 3. The reagents and chemicals used for the various analyses were of quality and analytical grades. All data obtained were analyzed statistically using response surface methodology design expert 11.0. The best samples in terms of nutritional qualities was established as depicted in Table 5.

2.3 Proximate analysis

The proximate composition (moisture, protein, carbohydrate crude fibre ash and fat) were analysed as described by AOAC (2002). All chemicals used were of analytic grade. Each analysis was carried out in triplicates.

2.4 Determination lycopene and β-carotene

β-carotene and lycopene were determined following a procedure as outlined by (Barros *et al.* 2010) measuring the absorbance at 453, 505, 645, and 663 nm. The contents will be calculated according to the following equations: β-carotene (mg/100 ml) = 0.216 × A663 – 1.220 × A645 - 0.304 × A505 + 0.452 × A453; lycopene (mg/100 ml) = − 0.0458 × A663 + 0.204 × A645 - 0.304 × A505 + 0.452 × A453**.** Where A663, A645, A505 and A453 refers to the absorbance at 663, 645, 505 and 453 nm, respectively. The values will be expressed as (mg/100gm) of extract.

3 Results and Discussion

Table 1: Factors and levels used in the drying of experiments

Factors	**Level 1**	**Level 2**
	High	**Low**
Temperature(0C)	70	55
Hot air velocity(m/s)	1.2	0.8
Thickness (mm)	3	7

Table 2: Experimental design layout for experiment

Run	**Factors 1**	**Factor 2**	**Factor 3**
	A: Temperature (°c)	**Air Velocity(m/s)**	**Thickness(mm)**
1	**63**	**0.8**	**3**
2	**63**	**1**	**5**
3	**63**	**1**	**5**
4	**63**	**1.2**	**3**
5	**63**	**1**	**5**
6	**63**	**0.8**	**7**
7	**70**	**1**	**3**
8	**63**	**1**	**5**
9	**55**	**1.2**	**5**
10	**63**	**1**	**5**
11	**55**	**1**	**3**
12	**70**	**0.8**	**5**
13	**63**	**1.2**	**7**
14	**55**	**0.8**	**5**
15	**70**	**1.2**	**5**
16	**70**	**1**	**7**
17	**55**	**1**	**7**

Runs:17

Replicate: 3

Table 3: Average proximate composition and carotene content of fluidized bed dried tomato

	Factor 1	Factor 2	Factor 3	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6	Response 7	Response 8
Run	Temp°c	Hot air Vel	SLice Thickness	Moist cont.%	Protein%	carb. %	Ash Cont.%	Fat%	Crude fib.%	Lycopene	B-carotene

1	62.5	0.8	3	8.7	15.47	57.375	9.625	3.785	5.045	24.9678	8.87912
2	62.5	1	5	5.7	14.07	56.615	17.075	2.5	4.04	16.6659	7.69
3	62.5	1	5	5.2	13.17	56.03	18.5	2.61	4.49	17.4139	5.1914
4	62.5	1.2	3	4.5	12.07	60.71	12.025	2.845	5.85	16.0522	6.5601
5	62.5	1	5	4.97	12.27	50.82	15.875	2.45	5.615	16.8671	6.86885
6	62.5	0.8	7	9.4	10.97	58.52	13.075	3.6	4.435	15.056	6.58701
7	70	1	3	6.3	10.07	62.63	13.175	4.21	3.615	25.869	7.62105
8	62.5	1	5	7.4	13.62	54.3775	17.7875	2.55	4.265	17.0399	7.27192
9	55	1.2	5	9.2	13.02	50.615	14.875	3.845	4.445	12.1655	4.49327
10	62.5	1	5	6.01	13.72	56	17.6875	2.53	5.0525	17.1405	7.19399
11	55	1	3	7.05	11.52	64.39	7.55	6.505	2.985	22.8133	6.80272
12	70	0.8	5	7.25	13.37	53.865	18.275	3.24	4	22.1077	8.02509
13	62.5	1.2	7	7.95	12.51	63.865	9.675	1.825	4.175	14.2309	7.94009
14	55	0.8	5	10.7	14.37	54.885	14.8	4.775	4.47	13.8046	5.79337
15	70	1.2	5	6.64	14.02	54.995	11.075	5.19	4.08	24.3218	7.8848
16	70	1	7	7.55	13.17	55.23	13	6.75	4.3	17.5127	7.29198
17	55	1	7	8.75	14.92	50.865	14.875	3.745	5.745	8.67176	3.21954

Table 4: Optimization constraints

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A:Temperature	is in range	55	70	1	1	3
B:Hot Air Velocity	is in range	0.8	1.2	1	1	3
C:SLice Thickness	is in range	3	7	1	1	3
Moisture Content	minimize	4.5	10.7	1	1	3
Protein	maximize	10.07	15.47	1	1	3
carb.	minimize	50.615	64.39	1	1	3
Ash Cont.	maximize	7.55	18.5	1	1	3
Fat	maximize	1.825	6.75	1	1	3
Crude fibre	maximize	2.985	5.85	1	1	3
Lycopene	maximize	8.67176	25.869	1	1	3
B-carotine	maximize	3.21954	8.87912	1	1	3

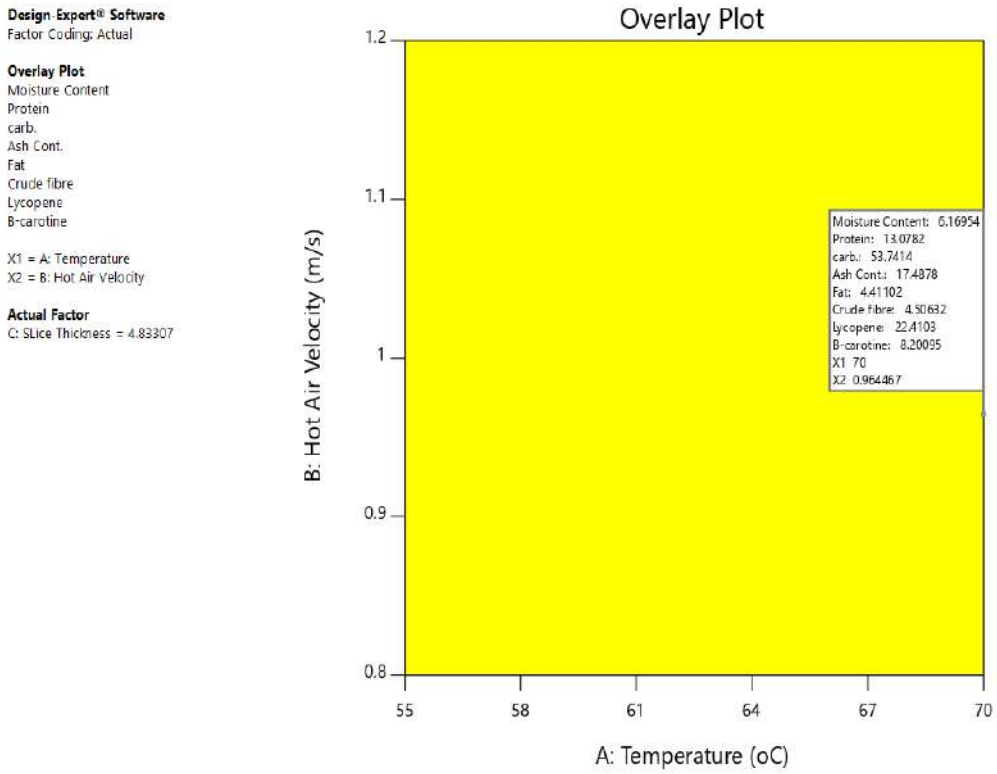
Table 5: Numerical optimization desirability solution for the dried tomato

No.	Tempt.	Hot Air Vel.	Slice thick.	Moisture cont.	Protein	carb.	Ash Cont.	Fat	Crude fibre	Lycopene	β-carotene	Desirability	
1	**70.000**	**0.964**	**4.933**	**6.170**	**13.078**	**53.741**	**17.487**	**4.412**	**4.506**	**22.411**	**8.201**	**0.697**	**Selected**
2	70.000	0.962	4.834	6.188	13.078	53.715	17.515	4.404	4.506	22.425	8.205	0.697	
3	70.000	0.968	4.846	6.150	13.078	53.767	17.449	4.430	4.506	22.363	8.192	0.697	

4	70.000	0.964	4.793	6.162	13.078	53.767	17.488	4.390	4.506	22.499	8.214	0.697	
5	70.000	0.959	4.839	6.206	13.078	53.689	17.540	4.399	4.506	22.429	8.207	0.697	
6	70.000	0.959	4.875	6.216	13.078	53.664	17.541	4.419	4.506	22.350	8.196	0.697	
7	69.700	0.958	4.836	6.218	13.078	53.674	17.557	4.392	4.506	22.444	8.211	0.697	
8	70.000	0.969	4.873	6.152	13.078	53.758	17.439	4.448	4.506	22.298	8.182	0.697	
9	54.980	0.972	4.784	6.110	13.078	53.847	17.407	4.409	4.506	22.476	8.205	0.676	
10	70.000	0.963	4.768	6.158	13.078	53.785	17.488	4.375	4.506	22.557	8.222	0.697	

3.1 Optimization process

Numerical optimization carried out on the produced dried tomato by setting goals on the investigated proximate composition and carotene content produced dried tomato based on the experimental design matrix. The desirability constraints of the produced dried tomato include minimum value of moisture content, carbohydrate with maximum value of protein, crude fibre, fat,ash content, lycopene and β-carotene depicted in table 4. The best set objectives of each of these parameters (maximum, minimum and within range) of the produced dried tomato was investigated and the responses and solution are presented in table 5. The optimization desirability best 10 solution with highest desirability prediction of 0.697 selected, revealed the best temperature of (70°c), air velocity of (0.965) and slice thickness of 4.93 for the drying of tomato in a fluidized bed dryer and this gives optimum proximate composition and carotene content of moisture content 6.17, protein 13.078, carbohydrate of 53.741, Ash 17.487, fat 4.412, crude fibre 4.806, lycopene 22.41 and β-carotene 8.201.



sFigure1 : Overlay plot showing optimum proximate composition and the desired parameters

Conclusion

It is concluded that temperature of 70°c, air velocity of 0.96m/s and slice thickness of 4.93mm with highest value of 0.697 in terms of minimum carbohydrate and fat and maximum protein, ash, crude fibre, lycopene and β-carotene produced the dried tomato with optimum proximate composition and carotene content. It can be concluded that drying fresh tomato using a fluidized bed dryer will improve its availability, quality and assist in reducing postharvest losses of tomato. Further studies should be carried out on effective ways of preserving the quality of dried tomato.

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EFFECT OF TIME, TEMPERATURE AND CALYX-WATER RATIO ON THE TITRATABLE ACIDITY OF ROSELLE CALYX (*zobo*) EXTRACT

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Abstract
The effects of time, temperature and mass calyx- water ratio on the titratable acidity of the extracts were studied. The time used was 5, 10 and 15 minutes; temperatures used were 30, 50, 75 and 100 ^{0} C and calyx-water mass ratio used were 1:50, 1:20, and 1:10. The titratable acidity was determined as oxalic acid; 0.1N Sodium hydroxide (NaOH) was used as the base and Phenolphthalein was used as an indicator. It was observed that an increase in the factors increased the titratable acidity of the extract. Analysis of Variance (ANOVA) showed that time, temperature and calyx-water mass ratio had a significant ($p \leq 0.05$), ($p \leq 0.0001$) and ($p \leq 0.0001$) linear effect on the titratable acidity of the extract respectively. Time, calyx-solvent ratio; and temperature, calyx ratio both have significant ($p \leq 0.05$) and ($p \leq 0.0001$) interaction effect respectively. Only temperature had a quadratic significant ($p \leq 0.01$) effect. Regression models were developed and validated to predict the titratable acidity of the extracts. These findings provide a better understanding of the dynamic changes in the acidity of the extract based on the processing condition.
Keywords: *Roselle Calyx (Zobo) Extract, Time, Temperature, Calyx Wate ratio, Titrable acidity*

1. Introduction

Roselle (Hibiscus Sabdariffa) popularly known as *zobo* in Nigeria is an annual crop grown in the its Northern part for its red calyx (Cissé et al., 2012). It is cultivated in several other Asian and south American countries. In these countries, most of the time, it is cultivated with the purpose of using the calyx of their flowers to produce a soft drink highly appreciated all over the world for the particular sensation of freshness conveyed and its ruby colour due to its high content in anthocyanin(Cissé et al., 2011; Lin et al., 2007; Wong et al., 2002). It is known for its sour and tart taste which is as a result of its acidic content. The calyx contains a lot of vitamins, minerals and antioxidants which makes it a very rich and sought after agricultural product. It is known for its medicinal values as it is used for medicinal purposes such as cancer, stroke (Juliani et al., 2009; Lee et al., 2009; Lin et al., 2007). The extracts which is gotten from the extraction of roselle calyces using a suitable solvent which is usually water is used for making beverages, snacks, wines etc. (Ismail et al., 2008; Tsai et al., 2002).

Titratable acidity is a better predictor of acid's impact on flavour than pH. However, total acidity does not give all relevant information on a food. The titratable acidity measures the total acid concentration in a food. Food acids are usually organic acids, with citric, malic, lactic, oxalic, tartaric, and acetic acids, being the most common(Tsegay, 2020). However, inorganic acids such as phosphoric and carbonic (arising from carbon dioxide in solution) acids often play an important and even predominant role in food acidulation. The organic acids present in foods influence the flavour (i.e., tartness), colour (though their impact on anthocyanin and other pH-influenced pigments), microbial stability (via inherent pH-sensitivity characteristics of organisms), and keeping quality (arising from varying chemical sensitivities of food components to pH) (Tyl & Sadler, 2017). While organic acids may be naturally present in the food, they also may be formed through fermentation, or they may be added as part of a specific food formulation (Yadav & Chakravarty, 2013).

Titratable acidity is determined by neutralizing the acid present in a known quantity (weight or volume) of food sample using a standard base. The endpoint for titration is usually either a target pH or the colour change of a pH-sensitive dye, typically phenolphthalein. The volume of titrant used, along with the normality of the base and the volume (or weight). Sugars or sweeteners are usually used to neutralize the taste. The titratable acidity level of the extract determines the quantity of the sweeteners required to offset the tarty taste.

The aim of this study is to determine the effect of extraction time, temperature and calyx-water ratio on the titratable acidity of roselle extract.

2. Materials and Methods

Sample Preparation

Dried roselle calyces were obtained from Ogbete main market in Enugu State, Nigeria. Figure 1 shows the sample preparation setup; the calyces were weighed and portioned into 20g, 50g and 100g in 12 places were placed in a conical flask; 1 litre of distilled water was used for each extraction cycle; each portion was subjected to different extraction condition (time 5, 10, 15 minutes and temperature 30^0 C, 50^0 C, 75^0 C and 100^0 C) and labelled accordingly. A total of 36 samples were produced, bottled and stored at 4^0 C for further analysis.

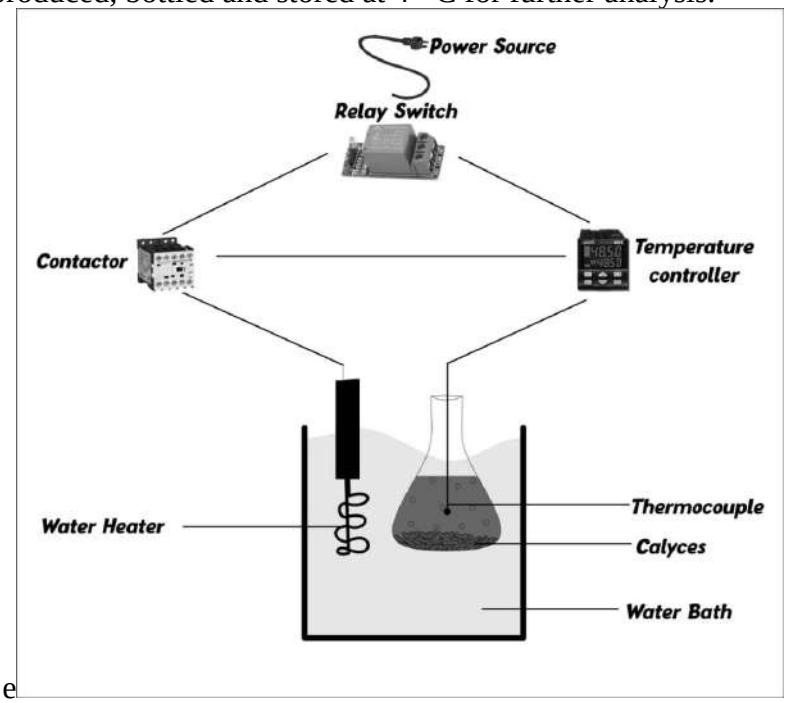

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Fig. 1 Sample preparation setup

Titratable analysis of samples

Total titratable acid was determined as oxalic acid. 10 ml of the samples was diluted with 20 ml of distilled water and titrated against 0.1 N sodium hydroxide. Phenolphthalein was used as an indicator (Sadler & Murphy, 2010).

$$\%acidity = \frac{vol.of\ titrant \times conc.of\ titrant \times meq\ wt\ acid}{sample\ wt} \times 100 \quad (1)$$

Experimental design and Statistical Analysis of Results

Analysis of Variance (ANOVA), Response surface method combined with central composite rotatable design (CCRD) were employed to investigate the statistical analysis of effects of extraction time, temperature and calyx-water ratio on the titratable acidity of the extract as well as to develop experimental models for the design.

3. Results and Discussion

Titratable Acidity at different extraction conditions

Table 1 shows the results of the titratable acidity of the samples, it was observed that as temperature increased, titratable acidity increased. This is similar to what was observed by (Tsegay, 2020) who observed that increased fermentation temperature increased the titratable acidity in lantana camara fruit wine. This could be as a result of increased extraction of the solute in the calyces. Increased time increased the titratable acidity of the extract, this trait was also observed by (Yadav & Chakravarty, 2013) that increased keeping time increased the titratable acidity of fruits such as mangoes, oranges, pineapples etc. Increased calyx-water ratio increased the titratable acidity.

Table 1 Titratable Acidity of Roselle Extract at different time, temperature and calyx-water ratio

		Temperature(^{0} C)			
Time (mins)	**Calyx-water mass ratio**	**25**	**50**	**75**	**100**
5	1:50	0.06±0.005	0.09±0.003	0.12±0.002	0.21±0.006
	1:20	0.08±0.004	0.13±0.005	0.20±0.004	0.48±0.003
	1:10	0.22±0.001	0.29±0.006	0.41±0.007	0.71±0.031
10	1:50	0.09±0.003	0.11±0.01	0.12±0.005	0.26±0.012
	1:20	0.13±0.002	0.17±0.005	0.32±0.011	0.59±0.006
	1:10	0.24±0.002	0.33±0.007	0.56±0.005	0.82±0.007
15	1:50	0.10±0.006	0.12±0.003	0.16±0.005	0.28±0.005
	1:20	0.14±0.003	0.16±0.034	0.44±0.006	0.62±0.005
	1:10	0.29±0.004	0.38±0.007	0.70±0.007	0.93±0.006

Values are expressed as mean ± SD of triplicate determination

Polynomial equation developed for predicting total titratable acidity of the extract as a function of time temperature and calyx-water ratio is as shown in equation 2

$$Tit\ acidity \times 10^3 = 462.8 - 9.55t - 8.17T - 8.30m - 0.07tT + 0.22tm + 0.11Tm + 0.42t^2 + 0.07T^2 + 0.02m^2 \quad (2)$$

Where t is time, T is temperature and m is calyx-water ratio

Effect of extraction variables on titratable acidity

From the ANOVA, it was observed that time, temperature and calyx-water ratio all had a linear significant ($p<0.01$) effect on the titratable acidity of the extract, while only temperature had a quadratic significant ($p<0.01$) effect and time and calyx-water ratio and temperature and calyx-water ratio has an interaction significant ($p<0.01$) effect on the titratable acidity.

Table 2 ANOVA evaluation of linear, interaction, and quadratic terms for total titratable acidity variables and coefficients of the model prediction

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	5.99	9	0.6658	35.38	< 0.0001	significant
A-Time	0.0977	1	0.0977	5.19	0.0249	
B-Temp	3.42	1	3.42	181.87	< 0.0001	
C-Mass of calyx	1.58	1	1.58	83.81	< 0.0001	
AB	0.0061	1	0.0061	0.3266	0.5690	
AC	0.0927	1	0.0927	4.93	0.0288	
BC	0.9260	1	0.9260	49.20	< 0.0001	
A^2	0.0026	1	0.0026	0.1400	0.7091	
B^2	0.1548	1	0.1548	8.23	0.0051	
C^2	0.0303	1	0.0303	1.61	0.2076	
Residual	1.83	97	0.0188			
Lack of Fit	1.40	26	0.0540	9.06	< 0.0001	significant
Pure Error	0.4228	71	0.0060			
Cor Total	7.82	106				

3.1 Effect of Time

The time of extraction had a linear significant ($p \leq 0.05$) effect on the titratable acidity of the extract as shown in Table 2. It has a significant ($p \leq 0.05$) interaction effect with calyx-water ratio but no significant ($p \leq 0.05$) quadratic effect. Time is seen to have the least significant effect compared to the other variables under study. As extraction time increased, the titratable acidity in the extract increased. This more solute being leached as a result of increased exposure of the calyces to the solvent. Figures 1A and B show how extraction time affects the titratable acidity of the extract when interacting with temperature and calyx-water ratio respectively at calyx mass 60g and temperature 65^0 C respectively. At time 15 minutes and temperature 100^0 C, the titratable acidity was slightly above 0.6% and while at the same time but at calyx mass of 100g, the titratable acidity is about 0.55%. These are similar to the values gotten by (Yadav & Chakravarty, 2013)for apples and papaya.

3.2 Effect of Temperature

As it can be seen from Table 2, the extraction temperature has a significant ($p \leq 0.0001$) effect on the total titratable acidity of the produced extract linearly. Similarly, temperature had a interaction significant effect with calyx-water ratio but did not have with time. The quadratic effect of extraction temperature significantly ($p \leq 0.01$) influenced total titratable acidity of the extract. Temperature is seen to have the highest significant effect on the titratable acidity. This is expected because an increase in temperature increases the rate of diffusion of the solute from the calyces into the solvent thereby increasing the acids that are leached into the solvent. At temperature 100^0 C, the titratable acidity was seen to be the highest when other variables remain constant as seen in figures 1 A and C. This shows that high temperatures favour the extraction of organic acids from the calyces and they do not denature the acids.

3.3 Effect of Calyx-Water ratio

The calyx-water ratio had a linear significant ($p \leq 0.0001$) on the titratable acidity of the extract; it also has a significant ($p \leq 0.05$) and ($p \leq 0.0001$) interactive effect with time and temperature respectively as shown in Table 2. It does not have a significant quadratic effect on the titratable acidity of the extract. The trend is as shown in figure 2, the titratable acidity got as high as 0.93% at 100^0 C at 15minutes.

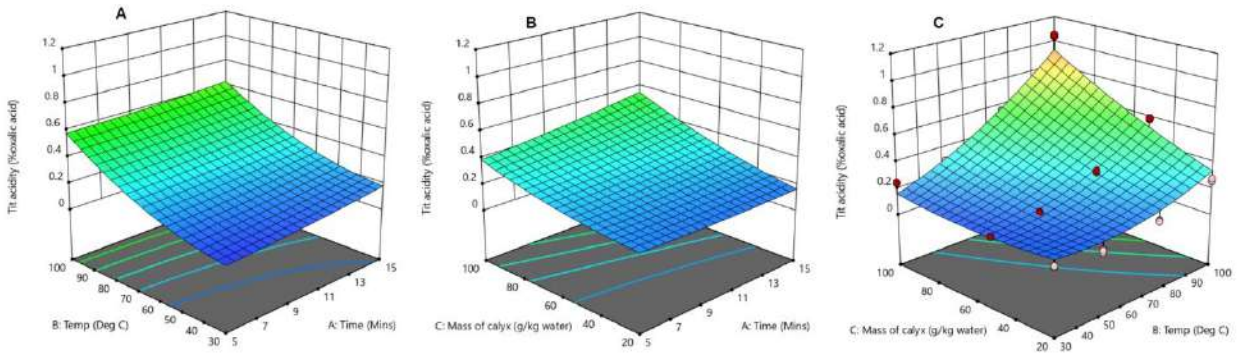

Fig 2 Response surface and contour plots for effect of time, temperature and calyx-water ratio on the titratable acidity of roselle extract.

4. Conclusion

The titratable acidity was seen to increase with an increase in time, temperature and mass ratio and this has a relationship with the tartness of the extract. This means that increased titratable acidity increases the quantity of sugar or sweeteners required to enhance the taste of the extract. It goes to show that increasing the temperature and time and calyx water ratio would increase the quantity of sweetener required to neutralize the taste of the extract. Depending on results required, the processing conditions can be adjusted to suit ones taste

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POTENTIALS AND CHALLENGES OF ADOPTING MACHINE VISION SYSTEMS IN MONITORING AGRICULTURAL FIELDS IN NIGERIA

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Abstract

The rising population and food security concerns which are aggravated by increase in climate change requires a technology that can curb the challenges facing agricultural production in Nigeria such as crop losses caused by inadequate monitoring of farms. A real time farm monitoring to boost agricultural productivity and achieve the United Nations Sustainable Development Goals (SDGs') 1, 2, 3 and 8 (i.e. No Poverty, Zero Hunger, Good Health and Well-being and Decent work and economic growth, such as machine vision systems. This paper reviewed the potentials and challenges of adopting machine vision in monitoring agricultural fields in Nigeria. The teeming unemployed Nigerian youth with huge appetite to get things done through technology is an enormous potential in adopting emerging technologies into agriculture. Research and gender inclusive training on how to develop, deploy and scale up machine vision systems in monitoring agricultural fields with adequate integration of farmers and stakeholders will overcome social economic factors, Resistance to change etc., that have been identified as challenges of adopting this technology.

Keywords: *Machine Vision, Monitoring, Agricultural Fields, ,Potentials and Challenges, Nigeria*

1.0. INTRODUCTION

Technological developments in agriculture have been seen as one of the fastest response to the challenges facing agricultural production. This necessitated the use of tractors, ridgers, planters and other agricultural production technologies for cultivation ((FAO, 2008) in Nigeria. The adoption of these technologies are geared towards reduction of drudgery in agricultural production, timeliness of operation and increased productivity. However, most of these technologies adopted are mostly for cultivation and harvesting. Little or no work has been done on the monitoring of the farm after cultivation and planting of the seedlings to know if they are growing as required (Asoegwu and Asoegwu, 2007). Hence enormous losses of crops due to weeds, pest and diseases infestation, nutrient deficiency and water availability et., plaque and affect the productivity of agriculture in Nigeria. Moreover, farm monitoring is one of the most tedious works for farmers in Nigeria. This is because their farms are most times located miles away from their residents, and the roads leading to these farms most times are not in good condition, causing most farmers to visit their farms once or twice a week. Farmers who cultivate more than five (5) hectares of land may not be able to effectively monitor and note what is happening in all the parts of the farm simultaneously. Hence, field monitoring and harvesting are seen as the major operations in the farm needing high rate of human power in Nigeria, since attempts have been made to mechanize other operations in the farm. Furthermore, hiring work force to take care of field monitoring, and crop harvesting over a large expanse of land are very costly and ineffective. This is because human inspection are tedious, time consuming and inconsistent (Raji and Alamutu, 2005). The resultant effect of ineffective monitoring is losses and notable reduction in crop yield.

The pressing need for a cost effective, automated farm monitoring technologies to aid subsistent and commercial farmers in reducing crop losses resulting from weed and pest and disease infestation, nutrient deficiency and water availability cannot not be over-emphasized. Because technology that can solve the aforementioned challenges will encourage the youth who have a huge desire to work and get things done through technology and invariably boost modern commercial agriculture. This will help Nigeria to achieve the United Nations Sustainable Development Goals (SDGs') 1, 2, 3 and 8 (i.e. No Poverty, Zero Hunger, Good Health and Well-being and Decent work and economic growth), and revive the glory of the sector as a major revenue earner of the 1960's – 70's. This paper is therefore aimed at reviewing the potentials and challenges of adopting machine vision systems in monitoring agricultural fields in Nigeria.

2.0. MACHINE VISION SYSTEM COMPONENTS

Most machine vision systems employed in agricultural operations normally acquire transmittance, fluorescence and reflectance images of the plants or materials under either an ultra-violet (UV), Visible Spectrum (VIS), or a near infra-red (NIR) illumination (Chen *et al.*, 2002). The two major aspects of machine vision are the image acquisition which includes the illuminating and capturing devices (Digital cameras) and Image analysis which is done using image analysis software. A conventional machine vision system is shown in Figure 1.

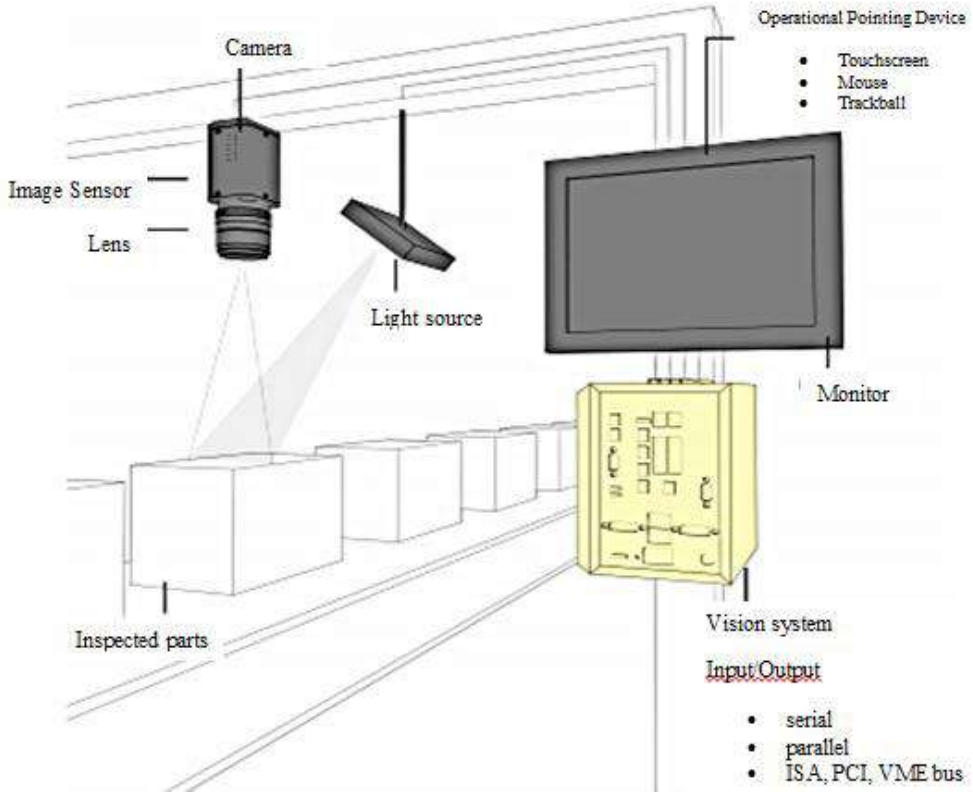

Figure 1: A conventional machine vision system setup
Source:(Sun, 2003; COGNEX, 2014)

The setup shown in Figure 1 is normally a setup for controlled environments, where the quantity of light incident on the agricultural materials to be observed can be controlled. The lighting in most Machine vision systems are used in controlled environment and it ranged from ultra-violet (200-400nm), the visible spectrum (400-700nm) or near-infrared (700-2500nm)(Chen *et al.*, 2002). The performance of most machine vision systems is affected by the quality of illumination just like the human eyes. Poor illumination will consequently affect the performance and the accuracy of the Vision system. Though in uncontrolled environments, the sun is the lighting source (Kittipong, 2012). Image capturing with digital cameras and pre processing using some software to optimize the image by suppressing some unwanted distortions in the image called noise and make sure all the important features are visible (Kurmtulmus *et al.*, 2011; Ramaraju and Kumar, 2014; Kumar and Thamizharasi, 2015).

3.0. APPLICATION OF MACHINE VISION SYSTEMS IN PLANT PROTECTION AND GROWTH MONITORING

Developed agricultural Countries have leverage on emerging technologies such machine vision, Artificial Intelligence (AI) and other innovations in agricultural field monitoring; in the agro-industries for disease detection, weed detection, yield estimation, nutrient deficiency detection and for checking remotely the activities of other pests in the farm with digital images gotten from the farm (Vibhute and

Bodhe, 2012). A review of the potentials of automatic weed detection and selective spraying of herbicides was carried out, and it was concluded that it will not just save the farmer the stress of going to the farm to know if his farm is being attacked, the farm can automate the spraying of the chemicals in the farm (Thompson *et al.*, 1991). Steward and Tian, (1999) worked on machine vision systems for weed density estimation in real-time (Tian *et al.*, 1999), Steward *et al.*, (2002) worked on a distance-based control system for machine vision-based selective spraying in the farm. They found that precise spraying of chemicals through automated spraying device can reduce the drudgery involved with the traditional approach (Steward and Tian, 1999; Steward *et al.*, 2002). Further study on weed detection using canopy reflection (Vrindts *et al.*, 2002), determination of crop rows by image analysis without segmentation (Søgaard and Olsen, 2003); and the management of spatial and temporal variability in irrigated agriculture through adaptive control were observed to reduce the cost of irrigation by knowing the actual areas in the farm to irrigate (Smith *et al.*, 2009).

The prospects of Machine vision automated grading for agricultural produce to detect the matured ones ready to be harvested has also been studied (Narendra and Hareesh, 2010). Since most of the researches carried out on field monitoring and its applications have to do with image processing, so many other works have been done to know the best method of classification that will give the accurate prediction and results, leading to the use of some classification algorithms like support vector machines (SVM), the Artificial neural network (ANN), Decision tree (DT) and the k-nearest neighbour (KNN) (Scotford and Miller, 2005; Sannakki *et al.*, 2011; Solomon and Breckon, 2011; Serafeim *et al.*, 2012) and Prototype selection algorithms for kNN classifiers (Shikha and Manoj, 2013; Ramaraju and Kumar, 2014). Some of these classifications are made based on colour, texture, and shape (Woebbecke *et al.*, 1995a; Saurabh *et al.*, 2011). The challenge of monitoring farms with just mounted cameras which seems not to cover adequately the whole farm led to the development of autonomous robots with cameras mounted on it to walk round the farm, and gather required information with ease. Some of the robots were also tasked to take actions based on the information gathered from the farm. This development has resulted to real-time precision sprayers (Sabanci and Aydin, 2013), and smart robotic weed control system for sugar beet (Sabanci and Aydin, 2017). Furthermore, machine vision system have been used in controlled environments like the green houses (for monitoring crop growth), poultry farms (for monitoring animal growth) and farm fields (Chao *et al.*, 2000; Kim *et al.*, 2000; Kim *et al.*, 2001), for monitoring the diseases, pests and growth of both plants and animals. More especially those crops that need special attention like apples, and tomatoes.

In Nigeria there has been a notable advancement in computer technology, and this have made several researchers to be aware of benefits of image analysis and computer vision in agriculture and many other disciplines. Raji *et al.*, (2000), reported the importance of image analysis and machine vision systems in guiding and controlling some agricultural machinery to work autonomously, in the improvement of the quality and quantity of agricultural produce in Nigeria. However, not much has been done on machine vision and its application in Nigeria. Hence, the benefits of deploying machine vision in agriculture for field monitoring and other agricultural operations in Nigeria which results to reduce yield loss, and improved quality and quantity of farm produce in Nigeria are yet to be harnessed. This can be attributed to low technological infrastructures, skills and poor education on emerging technologies, lack of state of the art sensing systems and data processing complexity that scares farmers (Raji *et al.*, 2000; Raji and Alamutu, 2005)

Different image analysis techniques using machine vision systems have been employed to carry out various tasks in agriculture. The development of machine vision based autonomous vehicles and robotic technology in bio-production systems has been examined by many research groups to optimize complex agricultural operations relevant to precision farm management. An autonomous platform is included in the examples for robotic weeding (Åstrand and Baerveldt, 2002; Bakker *et al.*, 2010), a precision sprayer (Gil *et al.*, 2013; Sabanci and Aydin, 2013; Tewari *et al.*, 2014), an automatic device for non-chemical control of pests (Tillett *et al.*, 2008; Perez-Ruiz *et al.*, 2012; Perez-Ruiz *et al.*, 2014). With technological advancements coming into play today, the automatic monitoring of the farm and classification of weeds and plants by computer vision have received increased attention (Arribas *et al.*, 2011).The development

of a machine vision system to sort sweet tamarind was done by (Jarimopas and Jaisin, 2008). Kurmtulmus *et al.,* (2011) also made use of an image analysis technique to distinguish green citrus fruits in Natural canopies in the natural daylight illumination. Image processing has the potential of a non-destructive evaluation of fruit's maturity, herbicide application, weed detection and control.

The checking of the spread of weeds and diseases based on human inspection is very demanding in large fields, more especially when management is required. Automated monitoring system based on machine vision has been considered a potential approach for monitoring the growth of plants, to check for nutrient deficiency (know when and where a particular type of nutrient/fertilizer is needed), detect weeds and diseases in the early stages of plant growth which in turn allow traceability of spatial and temporal progression of those weeds and diseases.

A large number of machine vision systems dependent on different image processing techniques have been invented for different operations in agriculture. For weed detection, success was recorded in making use of colour indices for the identification of weed under various soils, residue and lighting conditions (Woebbecke *et al.*, 1995a). Some other people made use of colour and shape analysis techniques for differentiating between crops, weeds and soil (Perez *et al.*, 2000). An invention of an image processing component for detecting and for mapping system based on the intensity of green colour (Kittipong, 2012). Hemming and Rath (2001) was successful in the classification of plants and weeds using colour indices (Wanrat *et al.*, 2011; Kittipong, 2012). Meyer et al. (1998) verified the colour vegetation indices for automatic threshold using plant-soil-residue images and Kittipong (2012) discriminated between weeds, crops and soil in real-time by machine vision.

In crop pests and disease diagnosis, machine vision has been widely applied in the identification of diseases in the farm. Carmago and Smith developed an algorithm for determining the threshold for disease detection in the farm (Camargo and Smith, 2009a; 2009b). Carmago and Smith again used the machine vision system to identify diseases on cotton. Another researcher made use of image processing based on multi-spectral image and quantitatively detected rust in soybean (Cui *et al.*, 2010)**.** Wanrat *et al.* (2011) proposed an image processing method for grading plant diseases. In Nigeria, Aduwo et al., (2010) developed a vision system for diagnosing cassava mosaic disease, and the identification of brown leaf spot in cassava (Wanrat *et al.*, 2011).

The researches done so far on machine vision is a clear indication that applying machine vision and image analysis techniques in Nigerian farms is a step in the right direction as it reduces the drudgery in the farm field and gives the farmer a serious assurance on the quality of crop to be produced.

4.0. Challenges of Machine Vision Adoption in Monitoring Agricultural Fields in Nigeria

There are many problems facing the adoption of machine vision system for field monitoring and other application in agriculture. These challenges include socio-economic factors, resistance to change and not willing to take the risk, political problems, and lack of adequate extension services.

a. Socio-economic factors:

Age, sex, and educational level of the farmers are being considered as some of the socio-economic factors affecting the adoption of not just machine vision systems, but most other emerging technologies in agriculture. Young farmers in Nigeria are always very keen to make use of new and emerging agricultural technologies in their farms faster than old farmers (Ibok *et al.*, 2015). The old farmers are not willing most times to take risks, and they are also less likely to be less flexible in their farming approach than the young farmers. With this lack of flexibility in their farming approach, old farmers tend to have lesser likelihood of utilizing technological information, and embracing new technology such as machine vision systems. Another important factor is the gender (Katungi, 2006; Ibok *et al.*, 2015). Considering the socio-cultural values in Nigeria, males are very free to take part in different types of meetings and trainings which make them to have a great deal of access to information. Women are normally ignored in the transfer of improved agricultural technologies with the assumption that they will receive the required information through their male counterpart (Yahaya, 2001; Ibok *et al.*, 2015). In understanding the importance of agricultural innovations and technological advancements, education is very important. An educated farmer knows the need to seek for information about new and emerging technologies in agriculture, and the need to make use of them. Most of the farmers in Nigeria are

illiterates making it difficult for the transfer of information about machine vision and other new technologies. Ekong (2003) was of the opinion that there is a positive relationship between being literate and making use of new agricultural innovation but there is no significant relationship between using agricultural innovation and formal education. A farmer having a low level education fosters unfavourable attitude towards making use of advancements in technology. A farmer will make use of an innovation like vision systems if people around him or her have been making use of it. If a farmer with a high level of education and large sized farm, and lives among illiterate and low level farmers who does not make use of new technologies, such a farmer will tend to live like those low level farmers over time (Ekong, 2003; Ibok *et al.*, 2015). Most of the farmers in Nigeria are subsistent illiterate farmers and are relatively poor. Therefore it is a very big task for an average farmer to have the required resources to procure or set up machine vision systems because they do not have collateral for loans (Zhou, 2016).

b. Resistance to change and not willing to take the risk

Most farmers in Nigeria are being very reluctant to change their conventional farming methods because it is their culture. Most of them might be interested in trying out the new technologies (machine vision systems) coming up but they are waiting for who will try it out first before they will join up. Most of them will like to see a working model before they will follow (Paras and Amongo, 2006; Zhou, 2016). One of the reasons for their reluctance to adopt new technologies according to Paras and Amongo (2006) might be as a result of their previous experiences with new farm technologies. It may also be the fear of whether they will be able to handle the maintenance issues accompanying these new machine vision technologies when they breakdown.

c. Political problems

The federal government of Nigeria has undoubtedly been making heavy investments on the procurement of new agricultural machineries and technologies to boost agricultural development in the country, but many politicians divert these monies for their selfish ends more especially where agricultural development is not the priority (Paras and Amongo, 2006). For big government farms that are supposed to be setting the pace for other farmers in Nigeria to follow, money released for agricultural mechanisation projects like the installation of these machine vision systems and technologies, may take time to implement, or sometimes the money allocated for it embezzled. This happens because a politician with no technical background might be put in charge of the implementation process.

d. Lack of adequate extension services

The new technologies and machineries provided sometimes by the federal or state government agricultural mechanisation programmes may end up packing in the government premises for a long time without making proper use of them because there is no formal training on how to use them or because there are not enough extension workers who will take care of the training of the farmers in that area. In some areas there might be just 10-15 extension workers as against 100-500 farmers (Paras and Amongo, 2006).

5.0. PROSPECTS OF MACHINE VISION SYSTEMS IN FARM MONITORING IN NIGERIA.

Adopting Machine vision for farm monitoring will play a very vital role in proper management of farms in Nigeria, considering the increased percentage of crop lost and poor yield that result from poor farm monitoring and management. More especially in large farms where hectares of land are to be managed at a time. This is possible as machine vision systems offers the generation of precise and descriptive data and reduces tedious human involvements in farm management and monitoring. Applying computer vision to monitoring in agriculture is a very promising approach to solving farm monitoring and inspection problems in large farms. Other benefits associated with adoption of machine vision systems for farm monitoring in Nigerian agriculture includes increased rate of production (this is achieved by

optimising equipment utilization), more efficient operation, increase in crop yield, increase in the quality of farm produce, and a reduction in the production cost of these farm produce. Furthermore, crop production in Nigeria will be enhanced immensely as the quantity of crop lost to pests, lack of nutrients, inadequate supply of required water and poor farm management in general during plant growth will be tackled. Introduction of this less tedious and effective ways of farm monitoring will also encourage farmers to cultivate large expanse of land and this will invariably lead to increased food production and an increase in the quality of farm produce. It will also encourage the youth to go into farming and improve livelihoods of the communities. The development of machine vision system technologies for farm monitoring, adoption and introduction of these technologies to agricultural operations will also develop the Nigerian Agricultural sector and make it ready for other more sophisticated machine vision technologies to be infused into the development of Nigerian Agricultural mechanization.

6.0. CONCLUSION

Development and application of image processing techniques for farm field monitoring was discussed in this paper. The conventional machine vision and image analysis techniques were also discussed; a technique used in the automatic monitoring and management of farms was highlighted. It was observed that the introduction of machine vision system for farm field monitoring solves majority of farm management problems faced in Nigeria. It reduces losses during plant growth occurring as a result of lack of nutrients in some part of the farmland, attack by pests, and poor management of the farm. The automated inspection and decision making process in the farm can be achieved by the use of machine vision systems for farm growth monitoring as they provide rapid, economic, consistent and objective assessment of different areas of the farm no matter how big the farm is. The adoption of machine vision in agriculture will also encourage the teeming unemployed Nigerian youth in getting involved with commercial agriculture, since they are interested in such technology.

7.0. RECOMMENDATIONS

Difficulties still exist, evident from the relatively slow commercial uptake of computer vision technology in all sectors. Although adequately efficient and accurate algorithms have been produced, processing speeds still fail to meet modern monitoring requirements. With few exceptions, research carried out in this field in Nigeria has dealt with trials on a laboratory scales thus this area of mechatronics has been neglected, and hence there is needs for more focused and detailed study on how to improve process time of these machine vision algorithms, and how to deploy and scale up these developed algorithms to autonomous systems.

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MODELLING THE THIN-LAYER DRYING CHARACTERISTICS OF CASSAVA CHIPS IN A HYBRID SOLAR DRYER

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Abstract
The study was aimed at determining the drying characteristics of Cassava (Manihot esculenta crantz) in a Solar/electric hybrid drying system and validating some existing drying models. The cassava was chipped into three different thickness layers of 1.0cm, 0.7cm, and 0.5cm, respectively. Thereafter, the Cassava chips were blanched at 100°C for 5 minutes and dried at 40°C, 45°C, 50°C, 55°C, 60°C, and 65°C using the hybrid dryer, equipped with an Arduino-based data logger. The drying rate of the cassava was calculated using the loss in mass and this was monitored with an electronic scale. HB Halogen (OHAUS) moisture Analyzer was used to determine the initial moisture content of the sample. The drying characteristics of moisture content (MC), moisture ratio (MR), and drying rate (DR), were determined at intervals during the drying process. The coefficient of moisture diffusivity (DO) was determined for cassava within the temperature interval studied. Six drying models, namely, Lewis, Page, Henderson and Pabis, Two-term, Logarithmic and Wang & Singh models were validated using Non-linear regression analysis in NLREG v. 6.3.Software. The results obtained showed that Logarithmic model had the best fit having an R^2 value of 0.99, SEE values of 0.0001, 0.0001, 0.0001 across its constant values of k, a and c with probt value of $4.59E^{-15}$ at thickness layer of 0.5cm and temperature of 50°C. Among other models that also performed well are Two-Term model and Page model. The values of D_o and E_a were estimated to be 4.87 x $10^{-8}m^2/s$ and 2.1425kJ/mol, for cassava chips of 1.0cm, 4.87 x 10-8m^2/s and 1.5348kJ/mol for 0.7cm and 4.87 x 10-8m^2/s and 1.2829kJ/mol for 0.5cm thicknesses.
Keywords: *Modelling, Thin Layer Drying, Cassava Chips, Hybrid Solar Dryer, Characteristics*

1. INTRODUCTION

Cassava *(Manihot esculenta Crantz)* is a perennial, vegetatively propagated shrub grown throughout the lowland tropics for its starchy, thickened roots. Global production of cassava amounted to about 278 million metric tons in 2018 out of which Africa's share was put at about 61% (FAOSTAT, 2020). The world's cassava production has been on the increase from about 240 million metric tons from the year 2010. In the same period, Nigeria alone produced about 42.5 million metric tons which is estimated to be about 18% of total global production. Nigeria's share of world production had risen to 21.5% of world production by 2018. FAO projects that by the year 2025, about 62% of global cassava production will be from sub-Saharan Africa (Ogunyinka and Oguntuase, 2020, FAOSTAT, 2020).

Cassava (*Manihot esculenta Crantz)* is the 4th most important staple in the world after rice, wheat and maize (IFAD/FAO, 2000). It is one of the most popular tropical root crops grown in West Africa especially Nigeria. Cassava is a starchy root crop, which can be used as a food security and famine reserve (Cock, 1982).

In Africa about 90% of the cassava produced is used for human consumption while 50% of cassava produced is consumed in Asia and 40% consumed in Latin America and the Caribbean respectively (IFAD/FAO, 2000). Cassava root and its products are excellent sources of dietary energy but they are poor sources of protein minerals and vitamins. Cassava roots contain about 32% starch, 65% moisture and 0.8–1% protein on a wet weight basis (Tunde-Akintunde and Afon 2010; Cock, 1985). Its starchy roots are a major source of calories for more than 200 million people worldwide, and it is also one of the most efficient calories producers of all food crops, supplying up to 250 kilo calories/ha (Cock, 1985). Most of the tuber and root crops do not store well in the fresh form and storage potentials of tubers and root crops

also vary. Thus the processing into staple non-perishable and easily transportable products such as flour, chips etc, reduces their perishability.

Cassava can be processed into cassava flour, garri and peels can be used as a source of feed to some class of animals. It is also used to produce ethanol and glucose. Cassava meal from dried root chips has been exported for animal feed purpose (Azogu et al., 2004). The cultivation of cassava requires minimal input, but the processing of cassava roots is laborious and time consuming (Lancester et al., 1982).

Production of cassava chips involves peeling, washing, soaking or boiling, chipping, drying and packaging. Undesirable biochemical changes and subsequent contamination and spoilage of the chips can only be prevented if the drying process is fast enough and the final product is dry enough (Maskan, 2000). Heat application to food during drying helps to achieve this.

Though sun drying is the common method of drying of cassava in the tropics, it has a main disadvantage of slowness of the drying process due to ambient temperature that is used for dying. There is need for alternative drying methods that will dry the product faster in a hygienic environment. Hot-air drying which has an extra advantage of providing uniformity of drying (Minguez-Mosquera et al., 1994; Ayensu 1997; Tiris et al, 1994) has been investigated. Product pretreatment has also been considered as a way to accelerate drying (Del Valle et al., 1998; Kudra, 2004).

The trauma of the global COVID-19 pandemic in the distressed economies across Africa deserves some proposals for aggressive interventions in order to prevent it from worsening the food security challenges in the continent. Thus, the new economic imperatives demand much more from the agricultural sub-sector. Nigeria, the most populous country in Africa, is majorly a mono-economy with her crude oil as the major source of revenue to finance her budget. However, in the last one decade, the country has been impacted by the serial shocks in the global oil sector. There are concerns that further shocks in the future may worsen the whole economy architecture including agriculture if appropriate measures are not promptly taken. One of the lowest hanging fruits is to reposition the agricultural sector by putting in place insightful reforms that can enhance ease of doing agribusiness. The objective of drying agricultural products is to reduce the moisture content to a level that controls microbial activities growth and to reduce deteriorative chemical reaction in order to extend the shelf life of food.

During the past few decades, considerable efforts have been made to understand some of the chemical and biochemical changes that occur during dehydration and to develop methods for preventing undesirable quality losses. The widest among drying methods is convective drying, i.e. drying by blowing heated air circulating either over the upper side, bottom side or both, or across the products. Hot air heats up the product and conveys released moisture to atmosphere.

1.2. Mathematical Modelling

Mathematical modeling of drying processes and equipment is an important aspect of drying technology; its purpose is to allow design engineers to choose the most suitable operating conditions, size of the drying equipment and drying chamber accordingly to meet desired operating conditions.

2.0 MATERIALS AND METHODS

The materials used are cassava, knife, an electronic weighing balance, Vernier caliper, moisture analyzer, Dhe 22 hybrid Solar/Electric dryer equipped with an Arduino based data logger (fig. 1)

Fig. 1: Hybrid Solar/Electric Dryer

Freshly harvested cassava was peeled, washed thoroughly and sliced into different thickness layers of 1.0cm, 0.7cm, and 0.5cm. The Cassava chips were then blanched at 100°C for 5 minutes (pre-treated). A known mass of the pre-treated cassava chips was measured and loaded into the drying trays as shown in fig. 2

As drying proceeds, the mass of the material was measured at intervals and recorded. Drying characteristics was calculated using the generated data.

Fig. 2: Sliced cassava chips

Six drying models were validated, namely *Lewis, Page, Henderson and Pabis, Two-Term, Logarithmic and Wang and Singh.*

2. RESULTS AND DISCUSSIONS

The moisture content wet basis (MC_{wb}) was calculated using eqn. (1) as follows:

$$Mc = \frac{Mi - Mf}{Mi} \times 100 \quad (1)$$

where;

M_C = moisture expelled (%),
M_i= Initial mass of sample (g),
M_f = Final mass of sample (g).

3.1. Moisture Ratio

$$MR = \frac{(Mt - Me)}{(Mi - Me)} \quad (2)$$

This was simplified by some investigators (Yaldiz et al., 2001; Togrul and Pehlivan, 2002; Midilli and Kucuk, 2003) because of the continuous fluctuations occurring during drying processes to:

$$MR = \frac{Mt}{Me} \quad (3)$$

where:

MR = moisture ratio, dimensionless; Mt = moisture content at time t (kg water/kg dry mater);
Me = equilibrium moisture content, (kg water/kg dry mater.

Figure 1-6 show the moisture content dry basis against time

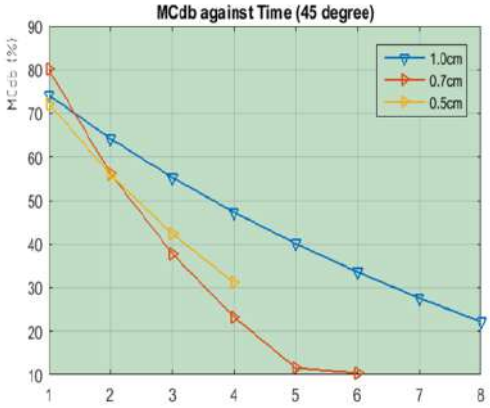

Figure 1: MCwb (%) against Time (hrs)

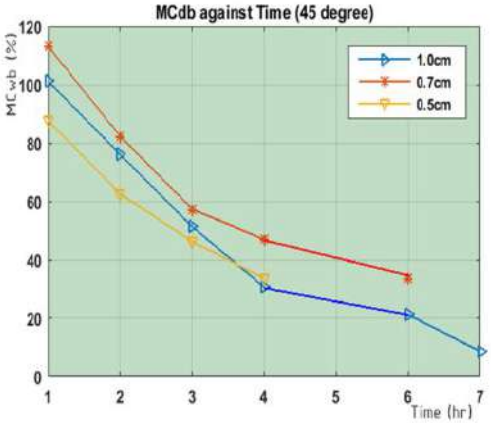

Figure 2: MCwb (%) against Time (hrs)

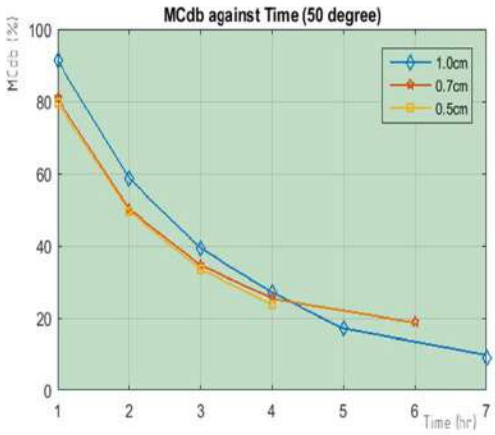

Figure 3: MCwb (%) against Time (hrs)

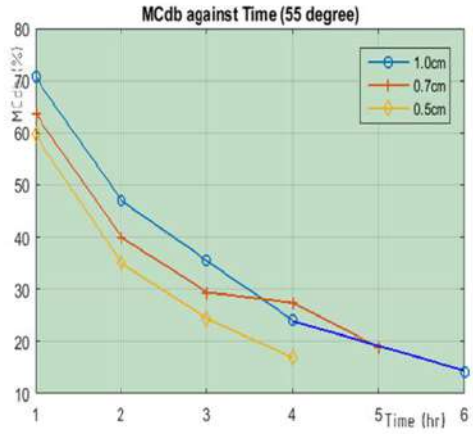

Figure 4: MCwb (%) against Time (hrs)

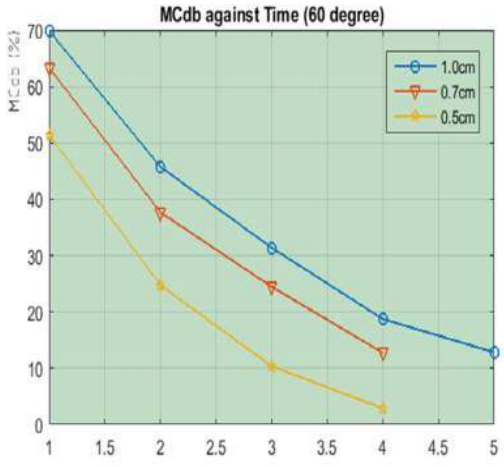

Figure 5: MCwb (%) against Time (hrs)

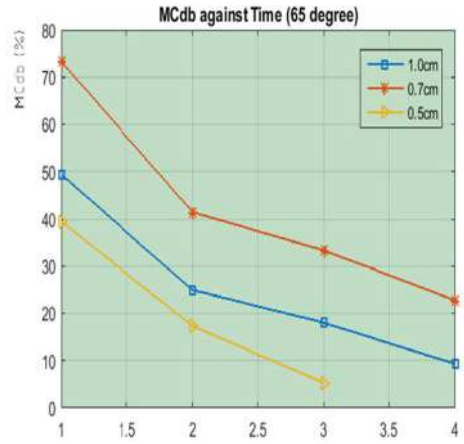

Figure 6: MCwb (%) against Time (hrs)

3.2 Mathematical Modelling via Drying Curve Fitting

The drying data obtained (moisture ratio against drying time) for the samples were fitted into Handerson and Pabis, Newton, Logarithmic, Page, Lewis, Wang and Singh models using NLREG v. 6.3 Software. The models were evaluated based on coefficient of determination (R^2), the reduced *probt* and standard error of estimate. Selection of the best model to describe the drying behavior of cassava chips was based on the highest R^2 and *probt* and SEE values. The drying constants (k) and (b) and coefficients (a) and (n) values for the thin-layer drying models are shown in table 1.

3.2. Thin Layer Models re-validation

Table 1 summarises the vadilation of the thin film drying models.

Table 1: Thin Layers Models re-validation

Models	R^2	SEE	Probt	Parameters
LEWIS(1.0cm)	0.0000	0.1797		k=0.4158
(0.7cm)	0.9721	0.0362	0.00379	k=0.5577
(0.5cm)	0.9441	0.0395		k=0.8285
			0.00001	
			0.00091	
PAGE	0.3598	0.1445		k=0.8007
	0.9806	0.0349	0.02121	n=0.4089
	0.9747	0.0345		
			0.12669	k=0.5548
				n=0.9800
			0.00192	k=0.9065
				n=0.8153
			0.00251	
			0.00702	
			0.02067	
HENDERSON&	0.3426	0.1465		k=0.1642
PABIS	0.9722	0.0404	0.14294	a=0.4982
	0.9831	0.0149		
			0.02728	k=0.5523
				a=0.9889
			0.00137	k=0.6370
				a=0.7519
			0.00109	
			0.02000	
			0.01777	
TWO-TERM	0.3568	0.1774		k_1=0.0986
	0.9945	0.0252	0.00001	k_0=0.2949
	0.9990	--		a=0.5852
			0.00001	b= -0.1417
			0.00001	k_1=0.0212
				k_0=0.3961
			0.00001	a=0.8494
				b=0.7731
			0.00001	k_1=0.0139

Model:	R^2	SEE	Probt	Parameters:
LOGARITHMIC	0.3608	0.1582		k=0.4465
	0.9952	0.0194	0.59462	a=0.4699
	0.9992	0.0082		c=0.1548
			0.26852	
				k=0.3364
			0.40296	a=0.9859
				c=-0.1497
			0.01182	k=0.0428
				a=0.7359
			0.00016	c=-0.0880
			0.09582	
			0.07355	
			0.01811	
			0.19046	
WANG& SINGH	0.0000	0.2049		a=-0.3162
	0.9349	0.0618	0.00157	b=0.0279
	0.9992	0.1264		
			0.00223	a=-0.3823
				b=0.03667
			0.00013	a=-0.5234
				b=0.0658
			0.00223	
			0.01802	
			0.05781	
		45°c		
LEWIS	0.9668	0.0500	0.00003	k=0.3763
	0.9283	0.0816	0.00109	k=0.4264
	0.9668	0.0415	0.00077	k=0.6832
PAGE	0.9872	0.0347	0.00109	k=0.0347,
	0.9972	0.0165	0.00029	n=1.105
	0.9778	0.0410		k=0.2626
			0.00060	n=1.533
			0.00018	k=0.6232
				n=1.148

3.3. Effective Moisture Diffusivity

Effective moisture diffusivity was calculated using eqn. 4 as follows:

$$\text{LnMR} = \text{Ln}\frac{6}{\pi^2} - \left\{\frac{\pi^2 Deff}{r^2 t}\right\} \quad (4)$$

where

D_{eff} = effective moisture diffusivity (m^2)

t = drying time and;

r = radius of the spherical object (m).

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DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF AN ACHA DEHULLING MACHINE

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Abstract
Dehulling is the most time-consuming post-harvest operation for Acha. The removal of the hulls of the paddy acha is traditionally done by women who pound the grains with a pestle in a mortar to crack the hulls, and then winnow successively to separate the grain from the hulls. The grinding/winnowing process is repeated 4 to 5 times to obtain dehulled grain or pre-whitened acha grain. The last grinding/winnowing operation removes the bran to obtain the "whitened" or polished acha. The traditional way of dehulling acha has a very low output, with each woman hulling between 1 and 2 Kg/hr, it is very tedious and time consuming which is a major bottleneck in its processing and utilization. Acha dehuller with dehulling, cleaning and separating mechanisms was designed and fabricated for dehulling Acha seeds. The Dehuller was tested on paddy Acha and the Through put capacity was 125kg/hr for 1hp of electric motor with an observed Dehulling efficiency of 70% and other efficiency like Cleaning efficiency of 68%, Seed recovery efficiency of 85% and Losses efficiency of 5% were all determined. The machine performed satisfactorily. However, there are needs for improvement in the cleaning and separating unit of the Acha dehuller.

Keywords*: Acha, Dehulling Machine, Cleaning Efficiency, Seed Recovery Efficiency, performance.*

1.0 Introduction

Acha has the potential of providing enough food for the increasing population of the poor people in Nigeria. Acha (*Digitaria exilis*) also known as fonio, is a cereal crop of West African where it is the staple food crop for several millions of tribal people and it is considered to be the tastiest of all cereals Kaankuka, Itodo & Awulu (2015). Acha is a very hardy crop and grows well on poor soils, it can even produce seed on soils with Aluminum levels that are toxic to other crops and can be relied on in dry savannah lands, where rains are brief and unreliable Chinwe, Ojukwu & Jackson (2015). Acha grains are very tiny with length and width dimensions of 1.604 mm and 0.864 mm respectively, and a weight of 0.529g for one thousand grains, thus making it difficult to remove the brittle outer shell referred to as the hulls Kaankuka (2015).

Acha is sometimes regarded as the “grain of life” as it provides food early in the farming season, when other crops are yet to mature for harvest Ibrahim (2001). After being sown, depending on the variety, Acha takes just 6 or 8 weeks to produce grains and
75 to 150 days to be matured for harvest. This crop fits into the low–input farming systems as it has unique ability to tolerate poor and marginal soils and can withstand the effect of drought Idris, Yawas & Abdulrahman (2018). According to Idris *et al.,* (2018), acha is the most nutritious of all grains, although it contains 7% crude protein which is similar or slightly lower than that of other grains, Acha contains some essential amino acids like leucine (19.8%), methionine and cystine of about 7% and valine 5.8% which are vital to human health and are deficient in most major grains Cruz, 2004; Idris *et al.,* (2018). Acha digests easily and for it nutritional values, it is traditionally recommended for children, aged, women after delivery, people suffering from diabetes, stomach diseases and also as diet for weight lose Cruz, 2004; Idris *et al.,* (2018).

Acha is grown in various parts of Nigeria, Sierra-Leon, Ghana, Guinea Bissau, Senegal, Togo, Mali, Benin Republic and Cote devoir (Gyang & Wuyep 2005). Acha is known by different names in various communities in Africa such as Acha in Nigeria, Findi in Senegal, Findo in Gambia, Fonio in Sierra Leon, Founde in Mali, Foni in Burkina Faso Kpendo in Guinea Podgi in Benin Republic, Pom/Polin in Cote’d Ivoire and Hungry rice in English. (Gyang & Wuyep 2005). In Nigeria, acha is grown in commercial quantities in some states such as Bauchi, Kaduna Kebbi, Plateau, Nassarawa, Niger, Gombe and FCT with Plateau state being the highest producer with an estimated production of 20,000 tons per annum (Gyang & Wuyep 2005).

1.1 Dehulling is the process of removing the hulls (or chaff) from acha and other seeds. This is sometimes done using a machine known as a huller. Hulls are removed by dehulling to get whole white grains, and the hull constituted about 23% of the Acha weight Cruz, *et al.* (2011). Traditionally, dehulling paddy acha is accomplished by pounding using a pestle and mortar.
The productivity of this work is very low, accompanied with dirt, sand and other foreign materials that have to be removed. It takes nearly one hour to pound just **one or two kilograms** of acha paddy. Thus, mechanizing the processing and cleaning of acha is essential both to reduce the painstaking work for women and to improve the productivity, quality and availability of the product in the market.
In Nigeria these machines are few, scarce, costly and not simple enough to be within the technical capability of our local artisans Bashiri *et al*., (2012). For example, Tokan *et al.* (2012) designed, fabricated and evaluated the performance of Acha-dehulling machine but the limitation of the machine is that it has high percent of broken grains and lower capacity (20Kg/hr) in addition to it complex drive system. To this end, this study was undertaken to remedy some of the deficiencies of the existing Acha-dehulling machine in term of efficiency, capacity, reduce cost and simplicity of construction in order to be within the technical capability of our artisans.

2.0 Materials and Method

2.1 Materials Requires: Biomaterial (Acha grain paddy seeds) and Materials for Machine Construction.

2.2 Description of the machine.

2.2.1 Machine Frame: The machine support is a skeletal frame made from angle iron to withstand the weight and lift the feeding and processing unit to a convenient height to avoid fatigue during operation.

2.2.2 The hopper: is the housing where acha paddy to be dehulled are stored and fed into the machine at a determined rate. The hopper has a shape which facilitates loading, maximum volume utilization, a reliable and complete discharge of material by gravity.

2.2.3 Metering device: This is cylindrical in shape and bears groves at predetermined section of its longitudinal cross-section.

2.2.4 Pulley and Belt: Dehulling shaft have pulley with belt attached to it for rotations in dehulling paddy acha.

2.2.5 Delivery spout: it is rectangular in shape with upper parallel sides and grains outlet with thick galvanize iron sheet.

2.3 Description of acha grain seeds.

Plate I: Acha Paddy.

e 

Plate II: Greatly enlarged of acha grains.

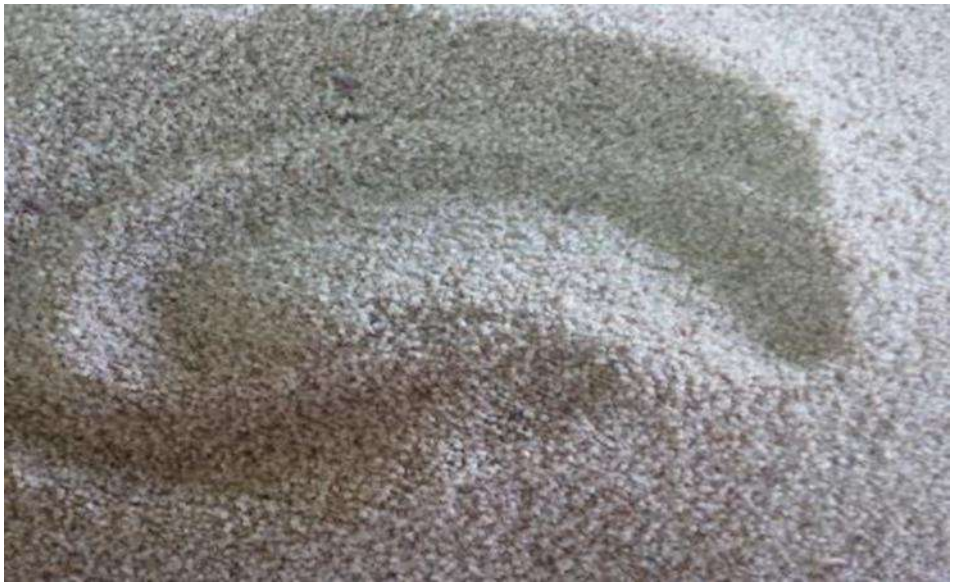


Plate III: Dehulling acha grains.

2.4 Design assumptions

Based on the preliminary studies and literature review, the following assumptions were made and used in the design of the Acha dehuller:

Table 1. Design assumptions for acha dehuller.

Values	Figures	Units
Theoretical capacity of the acha dehuller	125	kg/h
Density of the acha grains	1322.4	kg/m^3
Density of the rubber material	1522	Kg/m^3
Density of the drum material	7750	Kg/m^3
Volume of the Acha in hopper	0.00756	m^3
Acceleration due to gravity	9.8	m/m^2
Operational time in a day	8	hrs.
Total force acting on the roller shaft	7.466	N
Power required to drive the shafts	1759.16	Watts
The angular velocity	157.08	rad/s
Torque	11.20	N/m
Acha grain length	1.84	Mm
Acha grain thickness	0.75	Mm

2.5 Design analysis and Fabrication of the machine

The design procedure would involve an in-depth knowledge of concepts with assumed parameters, hand calculations, material selections, and operational systems of the Dehuller. Design analysis carried out which include the following units: designed of the dehulling mechanisms unit, designed of the blower and conveying system, designed of the power requirements, designed of the transmission system, designed of the rollers, designed of Chassis and selection of Bearings, Belts and pulley designs. The in-depth study of the different types of the dehulling mechanisms were carried out to enable selection and subsequent modification of the mechanism.

2.5.1Centrifugal force

According to the authors higher separating force can be generated by the combination of two different forces. The combination of gravity and centrifugal force for instance, in this case the centrifugal forces are used in the beating process due to its higher effects while the gravity is insignificant as such is not put into consideration. The force of rotation on a constituent material is as

$$F_c = Mr\omega^2 \quad (1)$$

where F_c = Centrifugal force the constituent material is subjected to

r = the path radius

M = Mass of the constituent material

ω = Angular velocity of the constituent material

$\omega = \frac{v}{r}$ v = Tangential velocity of the constituent material

$$F_c = (mv^2)\,r \quad (2)$$

Speed of rotation are commonly computed in revolution per minute, therefore equation 1 becomes

$$F_c = mr\left(2\pi {}^{N}/_{60}\right)^2 = 0.011mrN^2$$

where, N is the speed of rotational in revolution per minute.

2.5.2 Arithmetic mean diameter. The arithmetic mean diameter (Da) of the seed was calculated using Equation 3 given by Baryeh (2002).

$$Da = \frac{L+W+T}{3} \quad (3)$$

Where,

L = length of the acha grain (1.84mm)

W= width of the acha grain (0.85mm)
T= thickness of acha grain (0.75mm)

Da = 1.15mm

2.5.3 Geometric mean diameter. The geometric mean diameter (D_g) was given by Baryeh (2002).

$$Dg = \frac{(LWT)}{3} \quad 4.$$

$Dg = 0.39_{mm^3}$

2.5.4 Roundness. The roundness (R) was determined by Baryeh (2002).

$$R = \frac{\frac{W}{L}+\frac{T}{L}+\frac{T}{W}}{3} \quad 5.$$

R = 0.58mm

2.5.5 Sphericity. The sphericity (ϕ) was determined from Equation 5. given by Baryeh (2002).

$$\phi = \frac{Dg}{L} \quad 6.$$

ϕ = 0.21mm^2

2.5.6 Aspect ratio of seeds. The aspect ratio (R_a) was calculated from Equation 7. given by Omobuwajo *et al*. (1999).

$$Ra = \frac{W}{L} \quad 7.$$

$Ra = 0.46$

2.5.7 Surface area of seeds. The surface area (S_a) was obtained from Equation 8. given by Baryeh (2002).

$S_a=\pi D^2 g$ 8.

S_a = 0.48mm^2

2.5.8 Projected area. The projected area (AP) was determined using Equation 9. given by Mirzabe *et al.* (2013).

$$AP = \frac{\pi WL}{4} \quad 9.$$

$AP = 1.22_{mm^2}$

2.5.9 Volume of seeds. The volume (V) of seeds was determined using Equation 10 given by Mohsenin (1986).

$$V = \frac{\pi LWT}{6} \quad 10.$$

V = 0.61mm^3

2.5.10 Dehulling mechanism unit;

The Power requirement of the machine will be computed using the relationship by Mohammed (2005) and Khurmi and Gupta (2009), $p_{t=\frac{2\pi NT}{60}}$ 11.

Table 2: Some parameters considered for the design of the Acha dehuller.

VALUES	ABREVIATION	FIGURE	UNITS
Centrifugal force	$F_c = Mr\omega^2$	0.011	mrN^2
Arithmetic mean diameter	$Da = \frac{L+W+T}{3}$	1.15	Mm
Geometric mean diameter	$Dg = \frac{(LWT)}{3}$	0.39	mm^3
Roundness	$R = \frac{\frac{W}{L}+\frac{T}{L}+\frac{T}{W}}{3}$	0.58	Mm

Sphericity	$\phi = \frac{Dg}{L}$	0.21	Mm
Aspect ratio of seeds	$Ra = \frac{W}{L}$	0.46	------
Surface area of seeds	$S_a = \pi D^2 g$	0.48	mm^2
Projected area	$AP = \frac{\pi WL}{4}$	1.22	mm^2
Volume of seeds	$V = \frac{\pi LWT}{6}$	0.61	mm^3

2.5.11 Design of cleaning Unit;

The cleaning unit is made up of fan blades, pulley, central shaft and the housing. Gana *et al.*, (2013) used the relationships to compute the total torque on the blower shaft as $T_T = T_S + T_C$ and the tangential velocity of centrifugal fan, which has a large air volume outcome against high resistances with relatively low noise levels, will be determined according to Gbabo *et al*., (2013) using the relationship $\cup = \omega r_f$.

Where $\omega = \frac{2\pi N}{60}$ 12.

2.5.12 Aerodynamic properties of the seeds;

The air –seed interaction will be represented by using the dimensionless drag coefficient C_d. this will be calculated by using the relation reported by Abdullahi (2017) as $C_d = \frac{2F_d}{\delta^2 V_a}$.

Terminal velocity of seeds will be determined according to Mohammed (2005) using this relationship

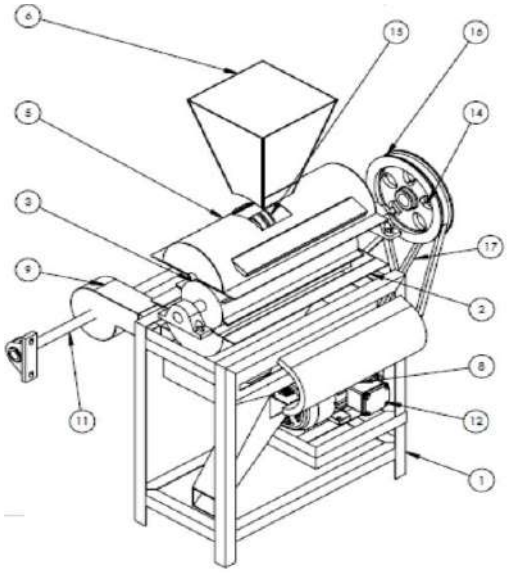
$$\left(Vt = 1.74 \sqrt{\left[\frac{g.dp(\rho_p - \rho_f)}{\rho_f} \right]} \right) \quad 13.$$

2.5.13 The construction of the machine was carried out in stages as outline below;

Frame, Dehulling cylinder, Concave, Hopper, Metering device, Pulley and Belt, Delivery spout, Blower, Winnower, Drives, Final assembly, Calibration of the dehuller.

2.5.14 The Dehulling machines was evaluated based on the following parameters;

Dehulling efficiency, %
Cleaning efficiency, %
Seed recovery, %
Through put capacity, Kg//hr.
Losses, %



ITEM NO.	PART NUMBER	QTY.
1	Frame	1
2	Lower Seperation Chamber	1
3	Dehulling Unit	1
4	Pillow Bearing	4
5	Upper Seperation Chamber	1
6	Hopper	1
7	Acher Passage Unit	1
8	Curved Acher Passage	1
9	Blower	1
10	Blower Fan	1
11	Blower Shaft	1
12	Electric Motor	1
13	Motor Pulley	1
14	Pulley	2
15	Thresher Pulley	1
16	Belt2-2^Assem1	1
17	Belt3-3^Assem1	1

Figure 1: EXPLODED VEIW

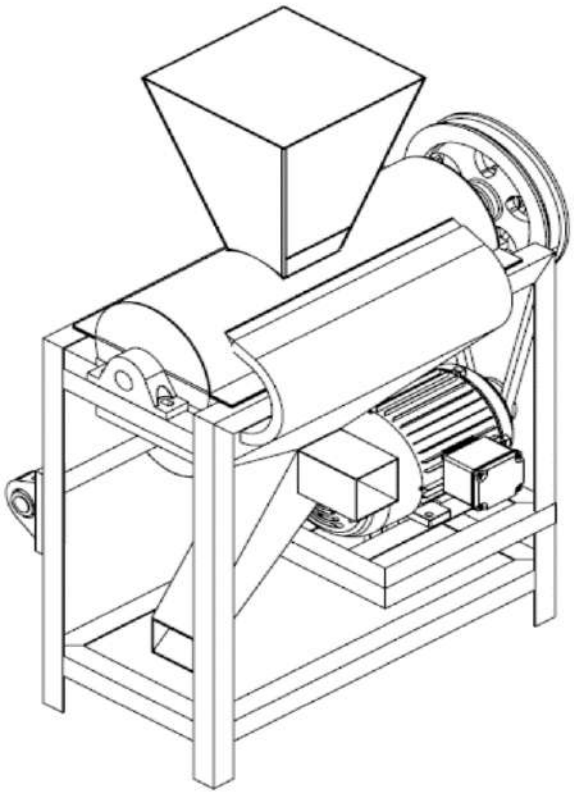


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Figure 2: ORTHOGRAPHIC VIEW

3. Results and Discussion

Some basic parameters used for the design of the acha dehuller based on design considerations, preliminary work and analysis of information are presented in Table 2.

The machine was successfully constructed and evaluated accordingly. The Through put capacity of the machine revealed that the machine performance was averagely satisfactory except for Cleaning efficiency and non-uniformity of Seed recovery. The Dehuller has a dehulling efficiency of 70% with through put capacity of 125kg/hr, on acha seed grains with 1hp electric motor.

Plate IV: Designed and Fabricated Acha Dehuller.

4. Conclusion

The constructed machine has through put capacity of 125kg/hr, dehulling efficiency of 70% while using 1hp electric motor. The machine can be subjected to further modifications in the areas of seeds cleaning and seed recovery. This machine can greatly assist the acha growers in saving their time, energy and money.

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DEVELOPMENT OF FRESH MANGO FRUIT HARVESTER

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Abstract
This work involved the design, construction and performance evaluation of mango fruit harvester. The adopted design was a simple machine mechanism, where the mango is the load, fulcrum is the pole and the effort is the electric motor. The design adopted for harvesting chute was still on simple machine mechanism, the mango stalk is the load, the relapsed spring is the fulcrum and electric motor is the effort. The component of the mango fruit harvester were: 3m galvanized steel pole, 3.5m belt for pulley having 0.03m pulley diameter, 0.175m cutting blade, and 0.007m spring diameter and 0.025m number of revolution respectively. 32W and 42W electric motor were deployed for pulley drive as well as harvesting chute. Given the anthropometric measurements and other design considerations around the mango tree sample space, the mango fruit harvester was able to establish successfully the harvest of mango fruit within the height of 3m for an average mango tree of 5.5m with an average weight of 193g per pluck per second with major diameter of 1.29m. The machine was durable and user-friendly and as such can be used in other similar fruits with close characteristics. This machine has advanced in no small measure harvesting of mango with less drudgery, devoid of mechanical/physical damage and bruises.
Keywords: *Design, Construction, Performance Evaluation, Fresh Mango Fruit, Harvester.*

1. INTRODUCTION

Mango (*Mangifera indica* inn.) is one of the fruit grown in many tropical and sub-tropical regions of the world. Mango is a preferred fruit due to its delicious taste, attractive colour and its nutritive value. it contains high amount of nutrients and vitamins such as vitamin A, dietary fibre, vitamin C, vitamin B-6 etc. It also contains soluble sugar and minerals such as potassium, folate, choline etc. Harvesting as important unit of operation in fruit production, handling and preservation cycle is paramount (Jhala et al. 2018). It is reported that 25-45 percent postharvest loss occurs at different postharvest stages of mango (Hassan, 2010). The existing practices in selecting the fruit for harvest are only based on the visual indicators such as color, shoulder growth, browning of the stem, and age from fruit setting, etc (Parameswarakumarand Gupta, 1991). Normally, mango fruits are harvested manually, which entails the harvester (a human being), climbing the tree and forcefully pulling the fruits off the tree by hand and then throwing it down to a supposed skillful catcher with attendant risks and hazards even with ladder that aid the course. Some harvesting hand tools like sickles and go to hell (which were used to pull down the fruits) were also used during the fruit harvesting. Although, technology had advanced in the area of fruit harvesting and this has led to the development of mini to gigantic machines involved in fruit harvesting processes within a limited time with less or no mechanical damage. Some of these mechanical harvesting devices make use of shaking mechanism to detach the fruits from their stalk while exploring the vibration mechanism that might lead to the destruction or breakage of the tree trunk or branches as well as damage these fruits through bruises and breakage.During harvesting, some of these mango fruits tend to fall to the ground and this causes internal injury to the fruits and subsequently, spoilage. The damages caused at this point are not seen until later during ripening. Bruised and injured mango fruits will tend to develop brown to black spots and this makes the fruit deteriorate and unattractive. Mango fruits harvested without their pedicels secrete sap from the pedicel end and this reduces the shine of the mango fruits and also makes it vulnerable to diseases like stem end rot. Moreover, injuries to the peel or to the stalk end serve as avenues for invasion of microorganisms and lead to rotting of the fruit (Garcia et al. 2002). High fruit yields will be worthwhile only if the fruit reach the consumer in good condition. The quality of the fruit cannot be increased after harvest – it can only be maintained (Waskar et al. 1997). Therefore, proper harvesting method can control the postharvest quality and storage life of mango fruits. The harvesting method can

extend their shelf life and also reduce huge postharvest losses. All these were considered during the design of this fresh mango fruit harvester in order to achieve an effective and more productive harvest. Therefore, the objective of the study was to develop a mango fruit harvester and the specific objectives were to study the physical and mechanical properties of fresh mango fruits, then design, construct and carry out performance test evaluation of the fresh mango fruit harvester in Nsukka municipal mango farms. The Nsukka municipal mango farms (trees) were nearly hundred to two hundred mango trees on average approximately 3 to 10m in height. Within the area presently, the harvesting technique of mango fruits are not really taken into consideration rather stochastic crude harvesting take place and due to this, the safe conditions of the fruits especially after harvesting cannot be guaranteed because of the damages caused to the fruits as a result of mechanical stress undergone resulting from plucking and gravitational fruit fall. One of the major problems faced during harvesting was that all the fruits on the mango tree do not mature/ripe at the same time. Which means the fruits will mature/ripe at different times thus varied harvesting. Therefore, the need to develop harvester that is user friendly, less drudgery, fruit safety-oriented and time-gain appropriate technology must be actualized. The real time harvest of mango fruit devoid of bruises and insect infestation will promote high quality mango fruits and by extension maintain the inherent quality of the mango fruits. Developing a mango fruit harvester will help to reduce the harm caused to the tree, fruits and humans during harvesting by reducing the risk of accident on human, mechanical damage on fruits and improving timeliness in the harvesting operation.

2. MATERIALS AND METHODS

2.1 Materials

The material used for the construction of this project is divided into mechanical and electrical materials. The mechanical materials are Poles, Pulleys, String, Metallic Cutter, Collection basket, Electric motors (stepper motor and DC motor), Spring. The electrical components are: Connecting wires, Veroboard, Resistors (10k, 0.47R 2W, 100R, 6.8k, 1k), L298N dual h-bridge motor driver, Arduino UNO, Switches, 10k Trim-pot, Capacitor (3300uf 25v, 10uf 35v), Diode (1N5408, 1N4007), Fuse, 4.3V 1W Zener Diode, BD139 Transistor, Transformer, 12v DC Relay, 12v DC Battery,

2.2 Methods

The method used in this design was Simple machine(effort, load and fulcrum)mechanism. The load is the mango, the effort is the motor and the fulcrum is the pole.The design of the extension of the pole is by belt and pulley still using effort, load and fulcrum mechanism. The concept used in the cutting of the mango is by shearing under the same mechanism. Therefore, to estimate the pulling force required the extend the pole to the designated height of the mango (plucking height), equation (1) expressed the power of the electric motor used and written as:

$$power\ of\ the\ motor\ (P) = \frac{2\pi NT}{60} \qquad (1)$$

where T= torque,, N= number of coil, π =3.142

Then the operating torque for the motor is given as:

$$(T) = \frac{P60}{2\pi N} \qquad (2)$$

Where power (P) of the stepper motor is given as voltage x current $=V.I$

The voltage capacity of the motor = 12 V, and current capacity of the motor = 2.7 A, therefore, P = 2.7 x 12 = 32W, the stepper motor used was NEMA 23 which had 400 rpm. The torque as given in equation (2) is expressed as: Torque $T = \frac{(32W)(60)}{2\pi(400\ RPM)}$

T = 0.764 N.m

2.3 Cutting Mechanism

The cutting blade has an angular rotation of 30^o as well as the angle of rotation of the DC motor to cause the cutting, (or which gives rise to the shearing) of the stalk of the mango fruit. The displacement of the spring (and first cutting blade) causes the cutting (harvesting of the mango fruit. The spring which has

an adjustable length of 8cm pulls the first cutting blade back to its original position to get ready for the next cutting action.

2.4 Different parts of the harvester includes: poles: the device consists of three poles; the base pole, the second pole and the top most pole. The base has a length of 1 metre while the second and top most pole have a length of 1.08 meters, which reveals only 1 metre each when the device is adjusted to the full length as seen in table 1.

Table 1: Dimensions of the Pole

	Diameter of Poles (m)	Length of Poles (m)	Extra Extension (m)
Pole 1 (base)	0.0572	1	0
Pole 2	0.0254	1	0.0762
Pole 3	0.0191	1	0.0762

a) **Pulleys:** Three pulleys were welded on the device. The first pulley is placed at the top tip of the base pole, the second pulley is welded at the bottom tip of the second pole and the third pulley at the top tip of the second pole.

b) **String:** An inextensible string was used. It was connected to the base of the top most pole and then drawn across the three pulleys and finally connected to the stepper motor. The string is used to attain adjustments of the poles.

c) **Metallic Cutter:** The metal cutter used was shaped in form of a scissors. It is able to carry out its purpose with the help of a dc motor, which controlled its cutting movement and a spring that kept the blades apart when not cutting.

d) **Collection Basket:** It should be able to carry at least five mangoes assuming the diameter of the mango to be 7cm and the height to be 9cm.

e) **Electric Motors:** Two different types of motor were used on this project.

i. Stepper Motor: It was used for the easy adjustment of the pole length. When the motor rotates clockwise, the string which it is attached to it begins to go round the motor's shaft, thereby causing tension to be on the string. This makes the second and the top pole begin to come out and the pole gets elongated. When the motor rotates anti-clockwise, the string attached to it begins to loosen from its coiled-up state round the shaft, which makes the second and the top pole to reduce their height.

ii. DC Motor: It is used at the top of the pole to aid the cutter in the cutting of the fruit at the stalk. It moves in one direction. During its motion, it pulls a string that has one end connected to the shaft of the motor and the other end to the movable part of the cutter as seen in table 2 and figure 1 and 2 show the two electric motors used.

Table 2: Specifications of the Motors used

No	Name	Manufacturer	Type	Current (A)	Voltage (V)	Turns	Connections
1	Stepper Motor	Sanyo Denki	103H6701-1141	1.2 A	12	200 steps/turn	4
2	DC Motor	Mabuchic	C9045-60001		3-12	6500rpm	2

Figure 2: Mabuchic DC motor

Figure 3: Sanyo Denki stepper motor

f) **Spring:** This is put between the cutter blade. This helps to keep the blades separated when not used for cutting and this causes an opening that makes the stalk easily go between the blades. The blade used is 0.45m long.

g) **Veroboard:** It is a pre-formed circuit board. The soldering of the electrical parts is done on it.

h) **Connecting wires:** These were used in the connection of the electrical components. Different type of wire was used on this project; 1mm wire, jumper wires. The jumper wires are electrical wires that have a connector or pin on each end. They were majorly used for the interconnection of the driver and the microcontroller without soldering.

i) **Resistors:** This is an electronic component that limits and regulates the flow of electric current in the circuit boards that were used. Every component used has its maximum current capacity that is needed to be provided for it to function. Once the current capacity is exceeded, these components tend to burn and thereby, rendered useless. The resistor simply prevents this by reducing the amount of current going through it into the board. Various resistors with different capacities were used as seen in Table 3, as well as described in figure 3 and 4and .

Table 3: Characteristics of the Resistor

No	Resistors	Bands	Colour
1	10k	5	Brown-black-black-red-brown
2	0.47R 2W	4	Yellow-purple-silver-gold
3	100R	4	Brown-black-brown-gold
4	6.8k	4	Blue-grey-red-gold
5	1k	4	Brown-black-red-gold

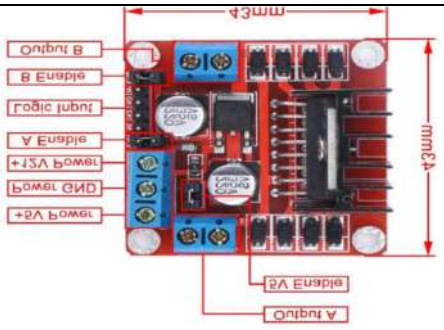

Figure 4:Board Dimension and Pins function

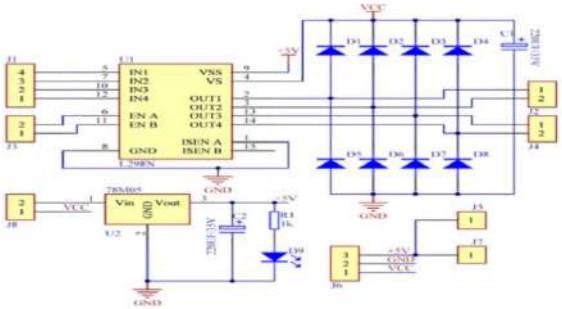

Figure 5:Schematic Diagram of the L298N driver

k) L298N Dual H-bridge Motor Driver: This dual bidirectional motor driver, is an integrated circuit, based on the L298 Dual H-Bridge Motor Driver. It is used to control the stepper motor, enabling it to easily move in both directions. The specification is shown in Table 4 below.

Table 4:Specifications of the l298n Driver

No	L298N Driver	Specification
1	Input Voltage	3.2 - 40 V dc
2	Power Supply	5 - 35 V
3	Peak Current	2 Amp
4	Operating Current Range	0 - 36 mA
5	On-board Regulated Output Supply (supplied to Arduino board)	5V
6	Size	3.4cm x 4.3cm x 2.7cm

j) Arduino UNO Board: This is a microcontroller board. The code that helps in the control of the stepper motor is encoded in it as shown in Fig.5.

No	**Arduino UNO**	**Specification**
1	Operating Voltage	5V
2	Supply Voltage (recommended)	7 - 12 V
3	DC Current per Input/Output	40mA
4	Size	0.6cm x 0.4cm

Figure 6: Ardino UNO specification

k) Switches: It is used to control the flow of current into the device.

l) 10k Trim-pot: This is a high variable resistor with three terminal pins. It was used in the building of the charger. The voltage between the terminals vary as the trim-pot rotates. It varies the voltage as per needed in the charger circuit. The outer two pins are connected to Vcc and 0v, and center pin outputs a variable voltage between 0v and Vcc as the rotary cermets is rotated see Table 5.

Table 5: Specifications of the Trimpot

No	10k Trimpot	Specification
1	Track Resistance	10k ohm
2	Resistance Tolerance	±5%
3	Potentiometer Mounting	Through hole
4	Adjustment Type	Top

m) Capacitors: This is a device that stores electrical energy in an electric field. It has two terminals. Two different capacitors were used in the building of the charger as shown in Table 6.

Table 6: Specifications of the capacitor

No	Capacitors	Tolerance	Rated Voltage	Capacitance
1	3300μF 25V	±20%	25V	3300μF
2	10μF 35V	±10%	35V	10μF

n) Diode: This is a semiconductor device that essentially acts as a one-way switch for current. It allows current to flow easily in one direction, but severely restricts current from flowing in the opposite direction. Two different diodes were used in the building of the charger as seen Table 7.

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Table 7: Specifications of the Diode

No	Diodes	Forward Current	Forward Voltage
1	1N5408	3A	1.2V
2	1N4007	1A	1.1V

o) **Fuse:** This will be used to break the circuit of the charger if a fault in the circuit causes too much current to flow. This is meant to protect the wiring if something goes wrong. The fuse contains a piece of wire that melts easily. A 2-amp fuse was used.

p) **Zener Diode:** A 4.3V 1W Zener diode was used in the building of the charger. It was used for voltage regulation.

q) **BD139 Transistor:** It is used to control bigger loads that consume less than 1.5A in the charger. It has a plastic package as seen in Table 8 as well as figure 6.

Table 8:Parts of the Transistor

Pin Number	Pin Name	Description
1	Emitter	Current drains out through emitter normally connected to ground
2	Collector	Current flows in through collector normally connected to load
3	Base	Controls the biasing of transistor used to turn off or on the transistor

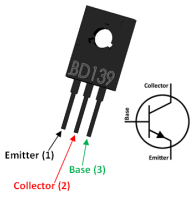

Figure 7: BD139 Transistor

r) **Transformer:** This component was used in the building of the charger. It helps to step down the current entering the circuit to the amount that is needed by the circuit.

s) **12V DC Relay:** They allow a low current flow circuit to control a high current flow circuit and it protects the switch from high voltage spike that can be produced by the relay coil.

t) **12V DC Battery:** The battery used is a lead acid battery with the capacity of 12V and 7000mAh. This serves as the power source for the device

Below is the Isometric view of the mango tree harvester developed as shown in Figure 7

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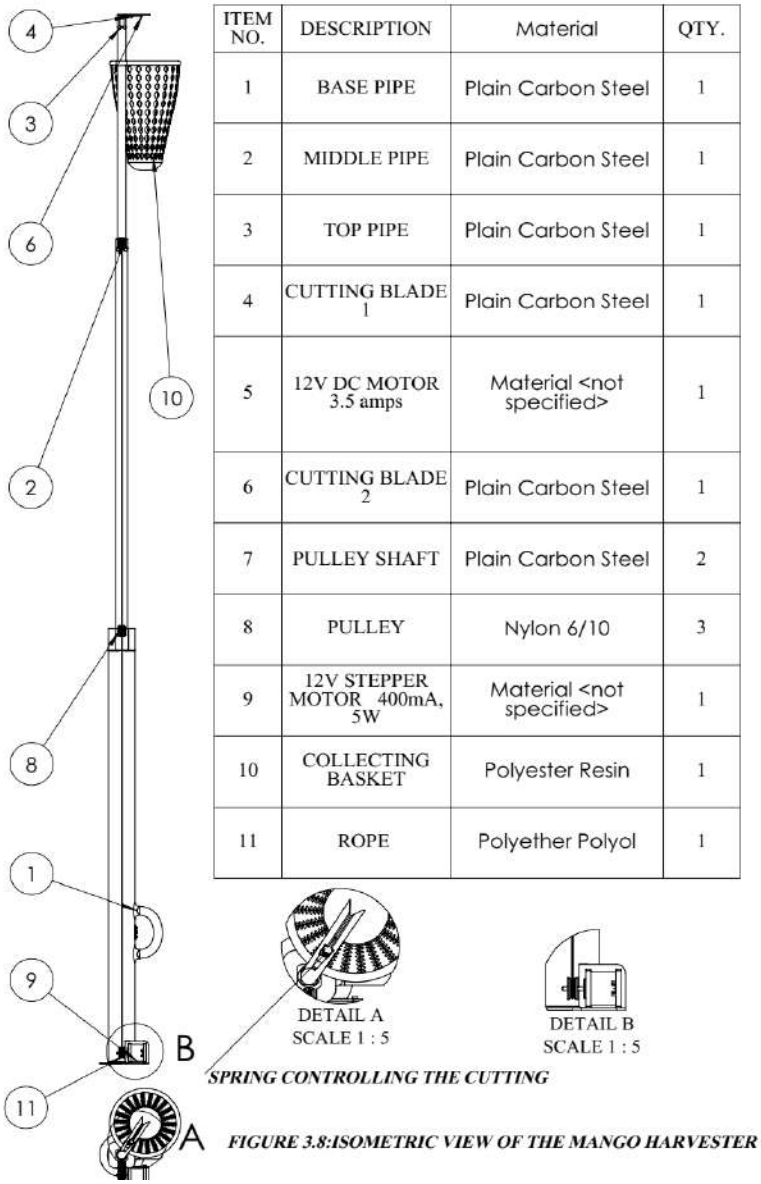

ITEM NO.	DESCRIPTION	Material	QTY.
1	BASE PIPE	Plain Carbon Steel	1
2	MIDDLE PIPE	Plain Carbon Steel	1
3	TOP PIPE	Plain Carbon Steel	1
4	CUTTING BLADE 1	Plain Carbon Steel	1
5	12V DC MOTOR 3.5 amps	Material <not specified>	1
6	CUTTING BLADE 2	Plain Carbon Steel	1
7	PULLEY SHAFT	Plain Carbon Steel	2
8	PULLEY	Nylon 6/10	3
9	12V STEPPER MOTOR 400mA, 5W	Material <not specified>	1
10	COLLECTING BASKET	Polyester Resin	1
11	ROPE	Polyether Polyol	1

FIGURE 3.8:ISOMETRIC VIEW OF THE MANGO HARVESTER

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Figure 8: Mango Fruit harvester

The harvester flow chart is shown in Figure 8 below. The process starts from putting on the switch that lets current flow into the electric component on the device. Then push-button switch, steadily, it is pressed for the stepper motor to begin to rotate clockwise, thereby putting tension on the string which then makes the poles begin to extend. When the needed height (which is $\leq$ 3m) is reached, release the push button and automatically the stepper motor switches to brake mode which is a state where the motor is and cannot move clockwise or anticlockwise while current is still flowing through it. After the needed height is attained, the stalk of the fruit to be harvested is put in between the blades, then push button switch C is pressed thereby making the Dc motor that controls the blade to cut the stalk. Push button B is pushed when the height of the harvester is to be reduced or when the device is done with. Then the switch that lets the in-flow of current is put off.

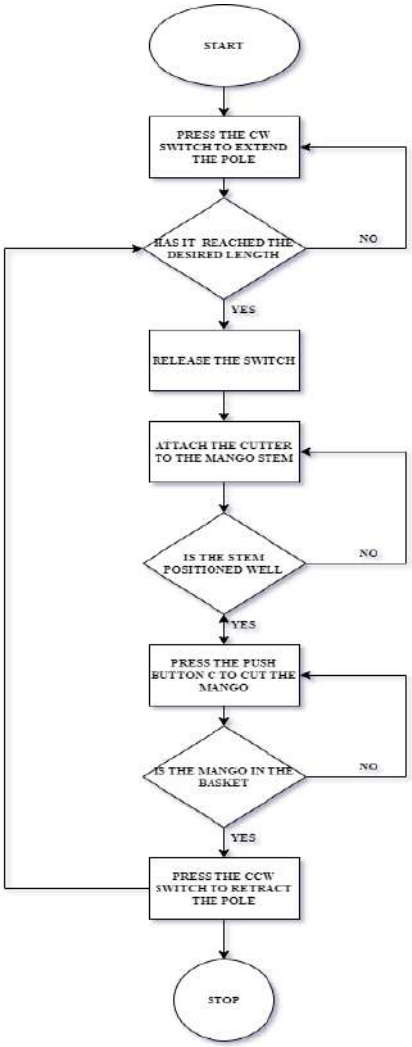

Figure 8: Flow/operational Chart of The mango fruit harvester.

3.0 RESULTS AND DISCUSSION

The anthropometric data of operators that operated the harvester is given in Table 9 below.

Table 9: Anthropometric Data of Operators

No	Age	Sex	Height (m)	Weight (kg)	Palm Length (cm)	Palm Width(cm)
1	26	M	1.82	76	20.00	8.00
2	23	M	1.88	80	21.00	11.00
3	36	F	1.72	64	19.00	7.00
4	18	F	1.80	70	21.00	9.00
5	21	M	1.88	76	21.50	10.00
6	30	M	1.76	66	20.00	8.00
7	40	F	1.78	63	20.00	8.00
8	22	M	1.60	57	19.50	9.00
9	16	M	1.74	66	20.00	9.00
10	18	M	1.52	54	18.00	8.00
Average			1.78	69	20.00	8.70

The table above was obtained through randomly selected individuals/operators that could be found within Nsukka. Therefore, the average height of the operators were 1.78m with body weight of 69kg and palm

length of 20cm as well as palm width of 8.70cm. Similarly,mango trees within the study area had average height of 5.5m and canopy radius of 5.6m as seen in Table 10.

Table 10: Physical Properties of Mango Trees in Nsukka

No	Height (m)	Canopy Radius (m)
1	7.0	6.8
2	5.0	4.7
3	4.4	5.9
4	5.8	6.3
5	4.2	4.8
6	6.1	4.2
7	5.4	5.6
8	4.4	5.6
9	6.2	6.1
10	6.2	5.8
Average	5.5	5.6

The physical properties of the mango fruits to be harvested were also randomly evaluated in terms of the major diameter and weights which are parameters needed in the harvesting process and is shown in Table 11.

Table 11:Physical Properties of harvested Mango Fruits

No	Major Diameter of the Fruit (cm)	Weight of Fruit (g)
1	14.3	200
2	12.4	197
3	14.7	210
4	13.9	210
5	12.7	170
6	13.2	196
7	10.8	205
8	13.6	200
9	11.4	170
10	12.0	168
Average	12.9	193

Therefore, the average major diameter of the mango fruits was 12.9cm with average weight of 193g. There was no physical damage resulting from the use of the mango fruit harvester.

4.0 CONCLUSION AND RECOMMENDATION

The following conclusions were drawn from this study, it includes that the mango fruit harvester was designed, constructed and evaluated successful devoid of injury to the fruits. Moreover, the fruits were harvested with their stalks which eradicated the release of sap on the fruit after harvesting. Loss of fruit during harvesting due to breakage was greatly minimized. Therefore, high quality of fruits was maintained during harvesting operation. Further improvement should be carried out on the design to make it smart with high precision.

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DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF FONIO DESTONING MACHINE

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Abstract
Due to intensified efforts and research to remediate sub-Saharan Africa from the effect of ravaging poverty and food insecurity, fonio grains (an under-utilized grain) has been tip to bring hope and contribute immensely towards the fight to end food scarcity. Fonio has been adjudge to possess very high and vital nutritional components and unique medicinal properties. While it requires less or no attention during its cultivation even under adverse weather condition not suitable for the growth of other crops. Invariably, the demand for fonio continually upsurge even outside the boundaries of Africa until recently when present of sand has been detected to be a major issue associated with local fonio production. This research work is focus at attempt to produce the first machine that completely eliminate sands from fonio grain before or after de-hulling. The design and development of this machine uses a two-deck vibrating sieve specially configured to withstand and operate both vertical and horizontal load and vibrations. The key behind the functionality of the design are majorly considered using engineering properties extracted from credible literature and laboratory experiment which is utilized in accurate and efficient computation, design and fabrication of fonio destoning machine. The fonio destoning machine developed has a through-put of 14kg/hr, de-stoning efficiency of 91% and a cleaning efficiency of 72%. Conclusively, the machine performance was acceptable as is the first recorded machine develop to help mechanize the process of degritting/destoning fonion production. In same vein, it will help boost fonio production, reduces drudgery on farmers and pave the path for sustainable agriculture and improve food security.
Keywords: *Fonio, Destoning Machine, Design, Fabrication, Performance*

1.0 INTRODUCTION

Agricultural diversification towards neglected and under-utilized species is one viable way to substantially increase the food production and improve food security. Efforts are continuously intensified towards exploring underutilized crops for food application and sustainability in sub-Saharan Africa. Fonio referred as a lost and under-utilized crop in Africa has continued to receive increasing attention due to its nutritional and medicinal attribute (Idris et al, 2015) Fonio unique short life cycle, growing conditions and nutritional values has made it a focus of evaluation in improving food security thus commonly referred to as food for the future. (Baye, et al., 2018). Zhu, (2020) also revealed that fonio is a highly underutilized grains with potential for food application and food security compare to other cereal crops like rice, wheat, maize, sorghum.

Fonio is a major staple food in many west African countries and supplies food to more than 3.5 million of the population (Adoukonou-Sagbadja et al, 2008; Cruz et al, 2016). Fonio is a persistent crop that does not require careful cultivation and its variety thrives under a range of difficult agricultural conditions including sterile lands, unproductive soils, difficult terrains, water stress zones including drought and flood conditions. It grows in shallow sandy soil in open grass, forest and savannah. (Hilu et al. 1997; Adriana; Zhu, 2020; Adoukonou-Sagbadja et. al 2008). Fonio is regarded the smallest cereal grain which consist of two species: white fonio (Digitaria Exilis) popularly called Acha, hungry rice, findi, fundi and Asian millet and black fonio (Digitaria Iburua) also known as Iburu. The black and white fonio are similar in shape, size, nutritional composition but differs in morphological features of the kernel. Fonio is mostly consume as a whole grain which is even more nutritious that refined grain (Jideani, 2012;). It is now dubbed as the most delicious cereal grain especially by food lovers who have tasted other cereal grains including rice and maize (Idris, Maiwada, Dauda, Jamilu, & Madungurum, 2015). Fonio grains provide energy of about: 19400kkg/kj more than other cereal crops like rice;18091kj/kg and sorghum;16245kj/kg. (Ballogou, Soumanou, Toukourou, & Hounhouigan, 2013). Cysteine and methionine present in fonio grains but deficient in all other cereals has made it very beneficial to human health (Idris et al, 2015). Fonio is now actively and commercially promoted in the international region including the united states

of America (USA) and European countries for its health benefits. Furthermore, European Union has approbate fonio as a novel food (European commission, 2018.) while it is a still a traditional staple diet of mostly rural areas in Africa whose consumption is highly dependent on the availability of other conventional cereals such as rice, maize, millet, sorghum, wheat(consumption is low when conventional cereals are available). Fonio production and diversity has been majorly constrained due to certain factors such as: lack of adequate harvesting, threshing and processing technology. In addition, the perceive low yield and high labour consumption of fonio crop has dissuaded farmers from cultivating it despite its ability to withstand drought, flood and flourish in poor soil conditions (Adoukonou-Sagbadja et al, 2008). Harvesting and post harvesting method introduce contaminants such as sands, stones, chaff and dust into grains which needs to be cleaned (Usman et al, 2018). Fonio grains are very difficult to process because of its tiny structure, low technical and traditional method employed. Traditionally fonio sheaves are threshed by beating or trampling. the de-husking of fonio is done in sand holes or mortar and the separation of the chaff from the grain is done by washing with water or winnowing. This traditional method of processing is not efficient and it takes 1hour to process and clean 1-2kg of paddy fonio using about 400liters of water (Adriana; Tokan et al. 2012).

This study aims to develop fonio grains de-stoning machine with optimum efficiency using locally source material which will cut down purchase cost for farmers.

2.0 METHODOLOGY

Considering that fonio grains are similar to rice in structure, pneumatic method and reciprocating sieves will be employed in the fonio de-stoner. This process involves lifting light chaffy and dusty material out of the paddy, other material which are the same weight with paddy are separated using a reciprocating screen. (Ojediran et al., 2019). Figure 2.1 below shows the structural dimension of fonio grains and common cereal grains such as rice, maize, millet sorghum and wheat.

Figure 2.1: a.) structural dimension of common cereal crops b.) raw and process fonio

2.1 Machine Description

The machine comprises of the following components; machine frame, feeding unit, de-stoning unit, driving and driven assembly and discharge unit.

2.1.1 Machine Frame

The machine frame of the fonio de-stoner is made of metal iron which holds the main machine components such as hopper, destoning unit, prime movers in position and stabilizes the machine during operation. The machine frame is dimensioned as follows height 800mm, length 630mm and width 560mm. the machine frame was constructed using angular bar.

2.1.2 Feeding/Hopper unit

It is the channel that allows passage of the contaminated grains to the processing/destoning chamber. It is a trapezoidal frame hopper with a manually controlled feed gate to control the fonio grain fed into the de-

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stoning unit. The top section of the is dimension accordingly; 420mm wide, 230mm long and extends with 300m to the base. The base of the hopper is 50mm long and 230mm wide.

2.1.3 De-stoning Unit

This unit consist of two perforated screens for cleaning the fonio grains situated at the top of the eccentric shaft (600mm long) and a non-perforated flat screen (500mm by 550mm) situated at the bottom to collect the screen impurities. At the extreme, slightly beneath the reciprocating screen is located the eccentric mechanism causing vibration of the reciprocating screen in a pendulum motion. The screen aperture is designed based on the size of the fonio grains. The first screen designed with 1.8mm aperture size allows fonio grain size material to pass through and the second screen designed with 0.8mm aperture sizes designed to allow fine sand and stone pass while trapping the clean fonio on the screen.

2.1.4 Driving and driven assembly

A one phase electric motor rated 2hp with an adjoined pulley is connected to the eccentric shaft through a v-belt. Thus, the power from the motor is transferred to the eccentric shaft which is finally translated as vibratory motion to the sieve system which rest on specially designed load springs connected via a rod.

2.1.5 Discharge unit

The machine consists of two discharge outlets, one centrally located which expels the clean destoned fonio grains and another that discharge the impurities, stones and sand matters.

2.2 Principle of Operation:

Fonio de-stoning machine comprises of the hopper unit, de-stoning mechanism unit and the output unit. The hopper system is a trapezoidal chute fixed on the upper frame to receive deposit of the unclean fonio. The unclean fonio passes through the feed gate (manually controlled) of the hopper unit to the de-stoning mechanism unit. The de-stoning mechanism unit consist of two perforated screens with different aperture sizes and a non-perforated screen. The first reciprocating screen is inclined at 7" receives the uncleaned fonio grains from the hopper unit. It allows the screening of fonio grains and material smaller than fonio grains into the second perforated screen inclined at angle of repose of the fonio. The residual matters on the screen flows to a discharge channel. The second perforated screen allows particle smaller than the fonio grain pass through while it holds the fonio grains. The residual fonio grains are pass to a discharge outlet. The screened particle including sands and stones on the third screen are collect and conveyed to the matter discharge point. The process stated above is facilitated as prime mover drives the shaft carrying the exciter causing the vibrations of reciprocating screens. The clean fonio is collected at the central out-let and the impurities are collected in a side located out-let. Plate 2.1 and 2.2 display the fonio destoner.

Plate 1: side view-a of the fonio destoner

Plate 2: side view-b of the fonio destoner

2.3 Design calculation, Analysis and theories of the Machine

2.3.1 Design for Hopper Determination of the Hopper Capacity

The hopper design will take a shape of trapezoidal prism with a manually controlled discharge feed gate to ensure efficient de-stoning of the mass passing through the de-stoning unit. (Olusegun et al., 2018); (Ibrahim et al., 2016) established equation 15 for determination of hopper capacity.

$$volume\ of\ a\ trapeziodal\ prism = \frac{Hh(a+b)}{3} \quad 1$$

Where,
h is height of trapezoid (m), H is height between trapezoid (m),
a is base of trapezoid (m),
b is bottom base of trapezoid (m)
allowable volume of fonio in the hopper is given by:
volume of fonio V = $volume\ of\ fonio(v) = \frac{3}{4}(volume\ of\ the\ hopper)$

$v = 0.00103125m^3$

2.3.2 Determination of Screen Capacity

The screen capacity is important in determining the machine capacity and efficiency. It is determine using equation 16 (Olusegun et al., 2018):

$$V = LBH \quad 2$$

Where,
V is the screen capacity(m^3)
, Lis the Length of the screen(m),
B is breadth of the screen(m),
H is the depth of the screen (m).

2.3.3 Determination of Screen Aperture

It is useful in determining the efficiency of de-stoning and cleaning process of the machine. It is obtained by the geometric mean diameter and sphericity of the grains calculated to be 1 and 2 respectively.

$$d = \sqrt{\frac{D^2(3\pi - 2c_o)}{c_o}} \quad 3$$

Where, d is the diameter of aperture size on screen (mm),
D is the maximum diameter of fonio grain(mm)
C_o is the coefficient of opening on screen 1.5

2.3.4 Determination of seive parameter

The processing unit comprise of a seive that is vibrated in an upward and downward motion via the shaft. According to the expression given by Tokan *et al.* (2012), the total forces acting on the sieve shaft can be calculated using equation (4);

$$F = w_a + w_{s1} + w_{s2} \quad 4$$

where:
F = Total force acting on the seive shaft (N),
W_a = Weight of Fonio grains on the seive (N),
W_{s1} = Weight of the first sieve (N)
W_{s2} = Weight of the second sieve (N).

2.3.5 Power Requirement to vibrate the screen

In selecting power of electric motor needed to drive the fonio de-stoner, the total power required to drive all the reciprocating unit must be determined (Olusegun et al., 2018). Equation 5. is used in determining the power requirement Khurmi and Gupta (2005); (Dauda et al., 2017):

$$p = Tw \quad 5$$

$$w = \frac{2\pi N}{60} \quad 6$$

Where:
P = Power required to drive the shafts (watts),
T = torque (N/m), and
w = angular velocity rad/s

2.3.6 Determination of Speed and Pulley Size

The speed and size of the pulley were deduced from equation 18. (Hannah & Hillier, 1978)

$$N_m D_m = N_v D_V \quad (7)$$

Where,

N_m is the speed of the motor (rev/min),

D_m is the diameter of the pulley motor (m),

N_m is the speed of the eccentric shaft (rev/min),

D_m is the diameter of the pulley attached to the eccentric shaft (m).

2.3.7 Determination of Eccentric Shaft Size

It is important to ascertain the eccentric shaft size that would withstand the load and twisting. It was determine using Khurmi & Gupta, (2007) relationship expressed in equation 8:

$$D^3 = 16\sqrt{(k_m M)^2 + (k_t T)^2}\,\pi b_d \quad (8)$$

Where,

D is the diameter of the eccentric shaft (m),

k_m is the combined shock and fatigue factor for bending,

M is maximum bending Moment (Nm),

b_d is maximum bending stress (N/m^2),

k_t is combined shock and fatigue factor of torsion,

T is maximum torsion (Nm).

2.3.8 Determination of Amplitude and Frequency of Vibration

For a system of forces vibration with a single degree of freedom, the Amplitude is given by equation 9 (Ayodeji & Yisa, 2014):

$$Y = \frac{\frac{F}{K}}{\left[\left\{1-\left(\frac{w}{w_n}\right)^2\right\}^2 + \left\{2\varepsilon\left(\frac{w}{w_n}\right)\right\}^2\right]^{0.5}} \quad (9)$$

$$w = \frac{2\pi N}{60} \quad (10)$$

$$w_n = \sqrt{\frac{k}{m}} \quad (11)$$

$$f = \frac{w}{2\pi} \quad (12)$$

Where,

F is the magnitude of excitation force(N),

ε is the coefficient of damping (Ns/m),

k is stiffness of the spring (N/m),

w is the frequency of excitation force, (hertz),

Y is the amplitude state of the vibration (hertz),

m is mass of the system (kg),

w_n is the natural frequency of vibration of the system(hertz),

f is the vibration frequency of the system(hertz).

2.4 MACHINE TESTING AND PERFORMANCE EVALUATION

Sample of fonio grains that was used for machine testing was collected from National Cereals Research Institute (NCRI), Badeggi Acha field. One variety was considered in the sampling, D-Exilis *Nkpwos* variety. A number of 8 sampled weighing 500grams were prepared. The machine fabricated was evaluated based on the following performance underlisted below;

2.4.1 Determination of Fonio De-Stoner Throughput Capacity;

Fadele & Aremu, (2016) **stated equation 13 can be used to determine the capacity of the machine.**

$$C = \frac{Q}{T} \quad (13)$$

where,

C is the capacity of machine(kg/s),

Q is the quantity of milled fonio introduced through the hopper (kg);
T is the time required for operation(s)

2.4.2 Determination of the De-Stoning Efficiency (D.E):

The efficiency of the de-stoner will calculated using equation 14 formulated by Gbabo et al., (2015).

$$D.E = \left(1 - \frac{M_{scf}}{M_{sm}}\right) \quad 14$$

where,

***D.E* is the de-stoning efficiency (%),**

***Mscf* is the mass of the stone in the clean fonio after separation(g),**

***Msm* is the initial mass of the stone in the mixture (g).**

2.4.3 Determination of Fonio Separation Efficiency (RSE):

This is the percentage ratio of the mass of clean fonio grains to the fonio grains in the mixture before separation. The separation efficiency of the machine will be determined using equation 15 (Gbabo et al., 2015);(Dauda et al., 2012)

$$R.S.E = \frac{M_{cf}}{M_{fm}} \times 100 \quad 15$$

where,

***Mcf* is the mass of the clean fonio grains, g;**

***Mfm* is the mass of fonio grains in the mixture before separation.**

2.4.4 Impurity Level After Separation (IML): This is the percentage ratio of mass of stone in the clean fonio to the sum of the mass of clean fonio and the mass of stone in the fonio (Gbabo et al., 2015). It can be determined using equation 16

$$IM_L = \frac{M_{scf}}{M_{cf} + M_{scf}} \quad 16$$

where,

IML is the impurity level after separation (%)

2.4.5 Tray Loss (TL)

This is the quantity of fonio which was not recovered in the process can be determined using the equation 17 below(Gbabo et al., 2015)

$$T.L = \left(1 - \frac{M_{cf}}{M_{fm}}\right) \quad 17$$

3.0 RESULTS AND DISCUSSION

The results obtained from the testing and performance evaluation of the fonio de-stoner at federal polytechnic Bida, Niger state are shown in table 3.1.

Table 3.1: Data recorded and computed from testing and performance evaluation of the fonio de-stoner.

Sample	Duration	Sample weight (kg)	Out-put weight (kg)	Residual (kg)	Destoning efficiency (%)	Separation efficiency (%)	Tray loss	Through-put capacity (kg/hr)
1	141.6	0.5	0.38	0.12	0.917	76	0.24	12.712
2	180	0.5	0.28	0.22	0.955	56	0.44	10.000
3	153	0.5	0.3	0.2	0.950	60	0.4	11.765
4	133.8	0.5	0.35	0.15	0.933	70	0.3	13.453
5	96	0.5	0.37	0.13	0.923	74	0.26	18.750
6	93.6	0.5	0.39	0.11	0.909	78	0.22	19.231
7	156	0.5	0.44	0.06	0.833	88	0.12	11.538
8	114	0.5	0.37	0.13	0.923	74	0.26	15.789
Total	1068	4	2.88	1.12	7.343	576	2.24	113.238
Average	133.5	0.5	0.36	0.14	0.918	72	0.28	14.155

From the table 3.1, the computed results from the recorded data during testing and performance evaluation of the machine shows that the machine is capable of delivering de-stoning efficiency of 91.8%,

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separation efficiency of 72% and an overall average through-put of 14.155kg/hr. comparative performance with other machine of its kind prove abortive as there is no recorded of existing machine developed for destoning/degriting fonio.

4.0 CONCLUSION

The fonio de-stoner result shows that the machine is capable of destoning fonio at an average of 72% separating capacity and 91.8% destoning efficiency while it has an approximately 14kg/hr. These out-put from this machine is far more advantageous and effective than the local method which uses over 200- 300 liters of water to de-grit 1-2kg of fonio grain for an hour. Regardless of the success recorded in fabricating this machine, there is need for significant improvement of the machine performance to attain at least 99% separating efficiency and increased through-put capacity.

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DETERMINATION OF SOME ENGINEERING PROPERTIES OF FRESH AND BOILED OIL PALM FRUITS.

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Abstract
Palm fruit is a product of oil palm and consists of the nut, the kernel, the fibre, oil and water. These components are separated by way of processing to get the desired products. For rational design of the handling systems, the engineering properties of the products are very important. A research was carried out to determine some engineering properties of fresh and boiled palm fruits. The properties determined are moisture content, sphericity solid and bulk densities, porosity, angles of repose and coefficients of friction. One thousand samples of the products were selected, conditioned and used for the experiments. The geometric and arithmetic mean diameters, volume, size and spherisity were calculated from the axial dimensions. The moisture contents were determined using gravimetric method. The angles of repose and coefficients of friction were determined on wood, glass and metal surfaces. The solid and bulk densities, porosity and compressive strength were determined using standard procedure. Results gave average moisture content of the fresh fruits to be 24.63 % and that of the boiled as 15.25 %. For the arithmetic and geometric mean diameters, the results were 1.9 cm and 580.6 cm respectively (fresh); 2.05 cm and 965.77 cm respectively (boiled), The average sphericities were calculated to be 70.7 % (fresh), and 73.28 % (boiled),. The average solid and bulk densities were 1.66 g/cm^3 and 0.00054 g/cm^3 respectively for fresh fruits, 1.32 g/cm^3 and 0.00054 g/cm^3 for the boiled product. The porosities of the samples were 60.21 % (fresh), and 75.73 % (boiled), The average values for the angles of repose on wood were 20.8 ^{0} (fresh), 22.81 ^{0}(boiled), On glass, the angles of repose were 18.09 ^{0} (fresh), 21.99 ^{0} (boiled), On the metal surface, the angles of repose were 19.45 ^{0} (fresh), 21.7 ^{0} (boiled), The coefficients of static friction on wood were 0.38 (fresh), and 0.42 (boiled), On glass surface, the coefficient of static friction were 0.33 (fresh), 0.44 (boiled) while that of metals surface gave the coefficient of static friction were 0.35 (fresh), 0.4 (boiled),

Keywords: *Palm Fruits, Fresh, Boiled, Engineering Properties*

1. INTRODUCTION

Oil palm fruit is a product of oil palm (Elaeis guineensis) and consists of the nut, the kernel, the fibre, oil, water, etc. The constituents are separated by way of processing to get the desired products. The fruit grow in massive clusters and in bunches which weighs between 5 kg to 10kg (Leafy Place, 2022). The fruits range in sizes from less than I inch to 2 inches and are red and black when ripe (Specialty Produce, 2022)
In the sixties, palm produce was the major source of income for the government of the old Eastern region whose economy was then adjudged to be the fastest growing in the whole world. Palm produce is seen as a mortgage lifter and a big income earner. The economy of Malaysia today depends on palm produce.
Some of the processes involved in processing operation for palm produce include; boiling, cooling, digestion, pressing/squeezing, separation, etc. In palm fruit processing, two basic methods are involved. These are traditional and mechanized. Traditional method is full of drudgery, time consuming, slow rate and increase in losses. For increased palm oil yield, reduced drudgery, high efficiency, mechanization of palm fruits processing is imperative. Mechanization in agricultural production and processing is the

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introduction of some forms of mechanical assistance to human power in carring out operations in agriculture.

Over the years, there have been calls for indigenous designs and manufacture of agricultural machines to handle local products since imported machines from the temperate regions are not suitable in the environment (Odighoh, 1983; Kasali, 2017). The machines from the temperate regions are seen to be too costly beyond the financial reach of the poor farmer. The machines are also known to be technically too complex and do not suit the tropical environment.

Rational design and manufacture of local machines requires engineering properties of the products to be handled. Knowledge of engineering properties of agricultural products to process will reduce waste of materials of construction, cost of manufacture of the machinery, mechanical injury on the materials being handed by ensuring precision in the process.

Researchers have been carryng out studies on engineering properties of oil palm fruits. For instance, Owolarafe, *etal*, 2007, investigated the physical and mechanical properties of two varieties of oil palm fruit. The varieties investigated were dura and tenera. And the properties studied are size, sphericity index, aspect ratio, true density, bulk density, porosity, cracking force, pressure, dynamic angle of repose and coefficient of friction. Renel, 2013, determined some physical and mechanical properties of oil palm fruit. The properties investigated were sphericity, 0.78, density 1. 016, specific gravity, 1.011, bulk density 707.55(fresh) and 708.66(conditioned), porosity (30.23%), bio yield force 38. 93N The objective of this paper is to present an experiment conducted to determine selected engineering properties of local variety of fresh and boiled oil palm fruits. Davies (2012) investigated physical and mechanical properties of palm fruit, kernel and nut. The parameters investigated were linear dimensions, mean diameters, sphericity, surface area, volume, true and bulk densities, porosity, angle of repose and static coefficient of friction. Ezeoha *etal*, 2012 proposed average values of some engineering properties of palm kernels. Afolabi *etal, 2019* determined some engineering properties of palm nuts, kernel shell, fibre and woods for effective mill equipment design.

Most the works as reviewed were done on improved varieties of palm fruits. Again, some of the works did not state whether the fruits worked were fresh or boiled. The ones that gave the state of the product s indicated that the works were for fresh fruits. In as much as we encourage adoption improved varieties of palm fruits, local varieties are still being processed in many towns and villages in Nigeria. Also, many unit operations on palm fruits processing are done on boiled ones. These call for the need for continued studies on engineering properties of fruits.

The objective of this study is to determine some engineering properties of local variety of palm fruits in Ubakala areas of Umuahia South Abia state Nigeria.

2. MATERIALS AND METHODS

2.1. Sourcing and Conditioning of the Palm Fruits

The local variety of palm fruits used for this study was sourced from a local market at Ubakala in Umuahia South Local Government Area of Abia state. One thousand (1000) samples of the fresh fruits were selected, and cleaned manually. This was done to remove all foreign matters such as dusts, pebbles, broken and rotten fruits. One hundred samples of the fresh fruits were selected at random from the one thousand fruits and weighed.

2.2. Determination of the Moisture Content of the Palm Fruits

Ten fresh fruits were further selected at random from the conditioned and weighed samples. Another set of 10 samples were selected at random, boiled and allowed to cool for 30 minutes and the weight determined. The sets were oven dried for 20 hours at 105^0C. The moisture contents of the two sets of samples were determined using the relationships as described by *Ndirika and Oyeleke (2006)* as below:

$$M_c\ (W_b)\ \% = \frac{Ww - Wd}{Ww} \times 100 \quad (1)$$

Where: M_c = Moisture content, %, w_w= Weight of wet samples (g) ;w_d= Weight of dried samples (g) and W_b =Wet basis

2.3. Determination of the Arithmetic and Geometric Mean Diameters

For each fruit, the linear axial dimensions; major (L), intermediate (W) and minor (T) diameters were measured using a vernier caliper (Kanon Instrument, Japan) with reading accuracy of 0.01mm. Hence the measurement of the 100 samples of all size indices was replicated for both fresh and boiled fruits. The arithmetic and geometric mean diameter samples were calculated from the following relationships as described by *(Mohsenin, 1986).*

$$D_a = \frac{L+W+T}{3} \quad (2)$$

$$D_g = (L \times W \times T)^{1/3} \quad (3)$$

where: D_a= arithmetic mean diameter (cm), D_g= geometric mean diameter (cm), L= major diameter (cm), W= intermediate diameter (cm) and T= minor diameter (cm)

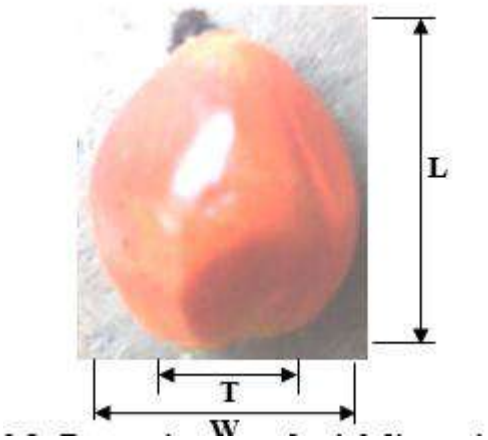

Fig. 1: Determination of axial dimensions of palm fruit

2.3. Determination of the Sphericity and Volume

The average sphericity and volume of the sample were calculated from the values obtained from the axial dimensions.

For the sphericity (S_C), the dimensions obtained for the 100 samples were used to compute the index as described by *(Maduako and Faborode, 1990).*

$$Sc = \frac{(L \times W \times T)^{1/3}}{L} \times 100 \quad (4)$$

Where symbols still remain the same as described above.

For the volume, the mass of individual sample for both fresh and boiled palm fruit was first determined by using electronic weighing balance (Scout Pro SPU 40L, China) to an accuracy of 0.1g and the volume of the individual sample for both fresh, boiled fruits was determined by taking the dimensions of the three linear axes and it was estimated using the following relationship given by *(Mohsenin, 1978):*

$$V = \frac{\pi LWT}{6} \quad (5)$$

where: V= Volume of sample (cm^3), L =Major diameter of sample (cm), W= Intermediate diameter of sample (cm) and T= Minor diameter of sample (cm)

2.5. Determination of the Solid, Bulk Densities, Porosity Angles of Repose and Coefficient of Frictions

Solid density was determined for the products using:

$$\rho_s = \frac{M}{V}, \text{ g/cm}^3 \quad (6)$$

The bulk fruit was put into containers whose weight and volume were known and was weighed. Both the fresh and boiled of the sample were replicated three times and their average values recorded.

Porosity (P) was determined using the relation of densities (bulk and solid) parameter as described by *(Mohsenin, 1978)* as:

$$P=1-\left(\frac{\rho_b}{\rho_s}\right)\times 100 \quad (7)$$

where: M= mass (g), V= volume(cm^3), $\rho_s = solid\ density$ and $\rho_b = bulk\ density$

For the angle of repose, each sample was placed on plywood for the angle of repose which rests on a table in a conical form. The plywood was then tilted until the sample began to slide freely. The height (opposite side) of the plywood was measures with the tape as at the time of free flow and horizontal distance (adjacent) taken. The experiment was replicated for both the glass and metal.

Angle of repose was then calculated using the relationship:

$$\theta = tan^{-1}{}^{h_1}/_{h_2} \quad (8)$$

Where: θ= angle of repose (^{0}), h_1= vertical height (cm) and h_2= horizontal length (cm)

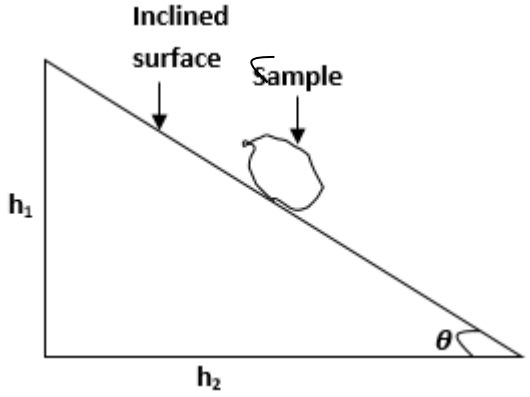

Fig. 2: Determination of angle of repose of the samples

The coefficients of friction of the samples were determined by using the angle of repose found against the three structural materials (plywood, glass and metal). It was estimated using the following relationship as described by Pliestic *et al.* (2006):

$$\mu = Tan\theta \quad (9)$$

Where: μ= coefficient of friction and θ= angle of repose

Compressive strength test was determined at Federal Institute of Industrial Research, Oshodi, Lagos State, Nigeria (FIIRO). Ten (10) samples of the products for both lateral and longitudinal positions were determined using an Instron Universal Testing Machine, Testometric make and model M500-25KN. Each sample was placed between the compression plates of the testing equipment. The sample was compressed at a constant deformation rate of 0.33 cm/min. The force and stress at peak deformation, energy at yield point, young modulus etc. were recorded by the data logger attached to the machine. The average mean and standard deviation were recorded as obtained data.

Fig. 3: Experimental set up using
Instron Universal testing machine

3. RESULTS AND DISCUSSION

The engineering properties (measured and calculated) of the fresh and boiled palm fruits were grouped into two, physical and mechanical. These properties were presented in two tables (Tales 1 and 2)

3.1. The Physical Properties of Fresh and Boiled Fruits

The physical properties of the fresh and boiled palm fruits determined in this study are shown in Table .1. The properties presented in the Table are, mass, length, width, thickness, volume, arithmetic and geometric mean diameter, spherecity, solid and bulk densities, porosity and moisture content. However, only the major physical properties are discussed and these are; the,

mass, the arithmetic and geometric mean diameters, the spherecity, bulk density, porosity and moisture content.

3.1.1. The masses. The masses of the samples were 4.74 g for fresh and, 4.88 g for the boiled. From the results, the boiled fruits gave higher mass than the fresh fruits. This could probably be as a result of water absorbed during the boiling process. The increase was 1.14g.

3.1.2. Sphericity. The sphericity indices of the samples gave the average sphericity indices 70.7 % for the fresh fruits and 73.28 % for the boiled fruits. This shows that the sample is neither round nor spherical, but will always tend to roll when they are on a particular orientation. This agrees with results obtained by Owolarafe *et al*, (2007) for dura variety.

3. 1. 3. Arithmetic mean diameters. The arithmetic mean diameters of the products were 1.9 cm for the fresh fruits and 2.5 cm for the boiled registering an increase of 0.6 cm. 3.1.4. Geometric mean diameters. The geometric mean diameters samples were 580.6 cm for the fresh fruits and 965.77 cm for the boiled fruits. The geometric mean diameter of the boiled fruits was significantly higher than that of the fresh. The result was 385.17 cm (66.34%)

3.1.4. Bulk density. For the bulk density, results show that the bulk densities of the fruits are 0.00054 g/cm^3 (fresh) and 0.00053 g/cm^3 (boiled).

3.1.5. Porosity. The porosities of the samples as calculated were 60.21 % (fresh) and 75.72 % (boiled).

3.1.7. Moisture content. The mean moisture contents of the samples were 24.63 % for the fresh fruit and 15.25 % for the boiled.

Bulk Density (g/cm^3)	0.00054	0.00053
Solid Density (g/cm^3)		

Table 1: Physical Properties of Fresh and Boiled Dura Palm Fruits

Properties	Fresh	Boiled
Mass(g)		
Mean	4.74	4.88
Std. Dev	(±1.09)	(±1.09)
Co. Variance (%)	23.00	22.24
Spherecity (%		
Mean	70.7	73.28
Std. Dev.	(±7.55)	(±8.82)
Co. Variance (%)	10.68	12.04
Length(cm)		
Mean	2.59	2.74
Std. Dev.	(±0.33)	(±0.33)
Co. Variance(%)	12.74	14.54
Width(cm)		
Mean	1.72	1.79
Std. Dev.	(±0.33)	(±0.33)
Co. Variance(%)	19.19	18.44
Thickness(cm)		
Mean	1.47	1.6
Std. Dev.	(±0.33)	(±0.32)
Co. Variance(%)	22.49	20.00
AMD		
Mean	1.9	2.05
Std. Dev.	(±0.30)	(±0.28)
Co. Variance(%)	15.79	13.66
GMD		
Mean	580.6	965.77
Std. Dev.	(±940.96)	(±1482)
Co. Variance(%)	162.07	153.45
Volume(cm^3)		
Mean	3.49	4.35
Std. Dev.	(±1.84)	(±1.94)
Co. Variance(%)	52.72	44.60
Mean	1.66	1.32
Std. Dev.	(±0.77)	(±0.59)
Co. Variance (%)	4.64	4.4.7
Porosity (%)	60.21	75.72
Moisture Content (W_b)		
Mean	24.63	15.25
Std Dev.	(±7.99)	(±2.79)
Co. Variance (%)	31.63	18.30

3.2.1 Angles of repose

The angles of repose of the fresh and boiled samples on the three surfaces are presented in Table 3. 2. From the Table, the angles of repose of the fresh sample was 20.8 ^{0} on wood surface, 18.09 ^{0} on glass surface and 19.45 ^{0} on metal surface. For the boiled samples, the results were 22.81 ^{0} on wood surface, 21.90 ^{0} glass surface and 21.70 ^{0} on metal surface. These results are in line with the results of the studies by Owolarafe *et al*. (2007) who stated that the dynamic angle of repose on plywood, aluminum, mild steel and galvanized steel were found to be 22.01 ^{0}, 21.01 ^{0}, 19.91 ^{0} and 22.23 ^{0}, respectively. These variations in the angle of repose values obtained on the three surfaces may indicate that samples have neither very smooth nor rough surface.

3.2.2. Coefficients of static friction

The coefficients of static friction of the samples were also given in Table 2. From the Table, the coefficients of static friction of the fresh palm fruit were 0.38 on wood, 0.33 on glass and 0.35 on metal steel. For the boiled fruit, the results were 0.42 on wood, 0.44 on glass and 0.40 on metal sheet. From the results, there was a small difference in the coefficient of friction obtained on wood, glass and metal sheet for each of the sample. Tabatabaeefar (2007) observed similar trend in the static coefficient of friction of wheat. He recorded lowest static coefficient of friction on glass surface, followed by galvanized iron and lastly plywood. The reason for higher coefficient of friction on the boiled samples might have been due to the increase in moisture content.

3.2.3. Compressive strength

The compressive strengths of the samples at lateral and longitudinal positions were also given in Table 2. From the Table, the average forces at break for both the fresh and boiled fruits at lateral was 973.9 N and at longitudinal positions the strengths for the fresh and boiled samples was 1208.6 N. The significance of this result is that boiling has no effect on the compressive strengths of the palm fruits when measured at lateral and longitudinal positions. However, it is observed that average force at break at longitudinal position was higher than the average force at lateral position. This could probably be due to the fact that the force at break for a material on lateral position is always lower than the force at break on longitudinal positions.

Table: 2: Mechanical Properties of Fresh and Boiled Oil Palm Fruits on Three Surfaces (Dura Variety)

Dynamic Angles of Repose		
Wood	Fresh	Boiled
Mean	20.8	22.81
Std. Dev.	(±3.40)	(±4.68)
Co. Variance (%)	16.35	20.52
Glass		
Mean	18.09	21.99
Std. Dev.	(±3.18)	(±8.33)
Co. Variance (%)	17.58	37.88
Metal		
Mean	19.45	21.7
Std. Dev.	(±3.11)	(±3.87)
Co. Variance (%)	15.99	17.83
Coefficient of Static Friction		
Wood		
Mean	0.38	0.42
Std. Dev.	(±0.07)	(±0.1)
Co. Variance (%)	18.42	23.81
Glass		
Mean	0.33	0.44
Std. Dev.	(±0.06)	(±0.41)
Co. Variance (%)	18.18	93.18
Metal		

Mean	0.35	0.4
Std. Dev.	(±0.06)	(±0.08)
Co. Variance (%)	17.14	20.00
Compressive Strength		
At Lateral Position	Force at Break (N)	Stress at break(N/cm^2)
Mean	973.9	973. 9
Std. Dev.	(±212.6)	(±212.6)
Co. Variance (%)	21.83	21. 83
At Longitudinal Position		
Mean	1208.6	1208.6
Std. Dev.	(±802.8)	(±802.8)
Co. Variance (%)	66.43	66.43

4. CONCLUSIONS

The following conclusions can be drawn from the results of this study:

The essential engineering properties of a local variety of fresh and boiled oil palm fruits have been determined.

The results are in agreement with some studies of earlier researchers;

There are no significant differences between the properties of varieties tested for fresh and boiled fruits

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.Paper No 2: Meteorological Drought Intensity Over Selected States in the North-Western Region of Nigeria Using Spai Model

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Paper No 31: Development of a Greenhouse System for Manure Drying Operations.
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METEOROLOGICAL DROUGHT INTENSITY OVER SELECTED STATES IN THE NORTH-WESTERN REGION OF NIGERIA USING SPAI MODEL

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Abstract
This study assesses 'the drought intensity over selected states in Northwest zone of Nigeria'. The zone is prone to drought occurrence, characterized by various intensities. 15 Years (2006-2015) of daily rainfall as obtained from NIMET by the Drought Early Warning System (DEWS) Team of Futminna Sponsored by TETFUND. Before the datasets were used for the analysis, they were subjected to quality control test. Standardized Precipitation and Anomaly Index was used to estimate droughts while the drought intensities and categorisation were done on three (3) timescales (3, 6 and 12) using EXCEL SOFTWARE. It was revealed that the study area has experienced mild, moderate and severe droughts. Similarly, drought years were identified within the study period using SPAI, the monthly drought frequencies identified include: 8 times of moderate droughts (in Gusau Kano and Sokoto under the timescales considered), 4 times of extreme conditions in all the stations considered under the timescales (3,6 and 12) and no severe conditions recorded in all the stations under the timescales between 2006 and 2020.

Keywords: *Meteorology, Drought, Intensity, SPAI Model, Nigeria*

1. Introduction

Drought is a very common disaster in most countries of the world, particularly in the arid and semi-arid regions (Achugbu, and Anugwo, 2016). It is defined as a "period of insufficient rainfall either in time or in space" caused by low rainfall, often associated with high rates of evaporation. This causes crop failure, enough to cause a severe shortage of food in a rural population (Abdullahi, *et al*, 2006). The socio-economic and environmental impacts of drought affect many sectors of African economy (Olatunde and Aremu, 2013). Different types of drought can be distinguished, i.e meteorological, Agricultural (soil moisture drought), hydrological and socio-economic drought.

Drought is a complex phenomenon which varies spatially and temporally in its extent, duration, frequency and severity. It becomes important to study the drought distribution characteristics on the time and space of a region and cause of the drought for the design and management of water resource systems (Rhee *et al*., 2007; Bao*et al*., 2011).Spatial and temporal analysis can also help to assess the exposure of water resources, vegetation patterns and the entire environment to drought. Researches on drought all over the World have shown that drought analysis gives important information on water deficit and its impact on agriculture and the hydrology of an area, which is a pre-requisite for mitigating drought and the planning of new water project. Therefore, a shift in focus to the provision of information in this direction is vital (Vicentra-Serrano *et al*., 2012; Masih*et al.,* 2014).

There is no uniform method to characterize drought conditions and many different drought indices have been used to monitor meteorological drought since it triggers the onset of other droughts (Heim, 2002; Quiring, 2009). Several indices have been developed to evaluate the water supply deficit in relation to the time duration of precipitation shortage (Keyantash and Dracup 2002; Heim2002). Drought indices are indicators used to characterize drought to assist decision makers for taking measures for mitigating its effects (Mendiccino *et al*., 2000).

Some of the most popular indices used in drought estimation includes the Palmer Drought Severity Index (PDSI) (Dai, 2011), the self-calibrating Palmer Drought Severity Index (*sc*-PDSI), the Rainfall Anomaly Index (RAI), the Soil Moisture Drought Index (SMDI). A drought index which is widely used by the US Department of Agriculture for emergency drought assistance, is Palmer Drought Severity Index (PDSI) which is typically a single number developed by Palmer in 1965 (Palmer, 1965). It was found to perform better when working with large areas of uniform topography. Some of the other metrological drought indices commonly in use are percent of departure, percent of normal and deciles. These indices have diff erent significances depending on their characteristics based on robustness, transparency, sophistication, extendibility and dimensionality (Keyantash and Dracup 2002). Diff erent researchers have

suggested different drought indices best suited for a particular area based on their respective merits. Hayes *et al*. (1999) showed from his studies that Standardized Precipitation Index (SPI) is more feasible than PDSI because of its versatile nature and flexibility for different timescales. Hayes *et al*. (2000) from their studies say that SPI has greater importance than PDSI because it provides a clear quantitative appraisal of three drought dimensions such as intensity, duration and spatial extent. Guttman (1998) recommended SPI than PDSI because of its simplicity, spatially consistency and its probabilistic nature in risk decision analysis. The use of standardized drought indices, such as the SPI, as an operational basis of drought monitoring systems has been increasing in many parts of the world. Recommendations for the use of the SPI, and those indices that share its properties, do not take into account the limitations that this type of indices can exhibit under the influence of multi-decadal climate variability (Núñez*et al*., 2014). Limitations in the use of the SPI index are as follows:

1. In arid climates or dry seasons, where the frequency of zero values (no precipitation cases) is high, the SPI values are lower bounded and fail to adequately indicate a drought occurrence (Wu *et al*., 2007).
2. A small deficit in precipitation may be reflected as a large negative SPI value for the locations with small variation in precipitation (Mallya *et al*., 2013).

Since there are teleconnections between climate indices and drought in many regions in the world, the aim of this study is to present a Standardized Precipitation and Anomaly Index (SPAI) with climate indices as covariates. The anomaly index may be able to correct the limitations mentioned above (1 and 2).

Despite the increase in interest by many researchers, institutions and government of countries or regions in the area of drought management, there is a limited research capacity in Nigeria particularly in North-Western region of the country to inform a dependable early warning system that can enhance the preparedness of the country to drought incidents (Adeogun, 2014). To this end, this study is drought intensity over selected states in the north-western region of Nigeria using the Standardized Precipitation and Anomaly Index (SPAI).

2.0 MATERIALS AND METHODS

2.1 Study Area

Northwest zone of Nigeria is located between Latitudes 9° 021N and 13° 581N and Longitudes 3° 081E and 10° 151E (Fig 1). The area so defined covers a land area approximately 91, 633.75square miles. Northwest zone of Nigeria shares borders with Niger Republic in the northern part, Benin and Niger Republic in the Western part, Niger State and FCT to the south, and Yobe, Bauchi and Plateau States to the East. The climate of Northwest zone of Nigeria is the tropical wet-and-dry type (Koppen's Aw climate).

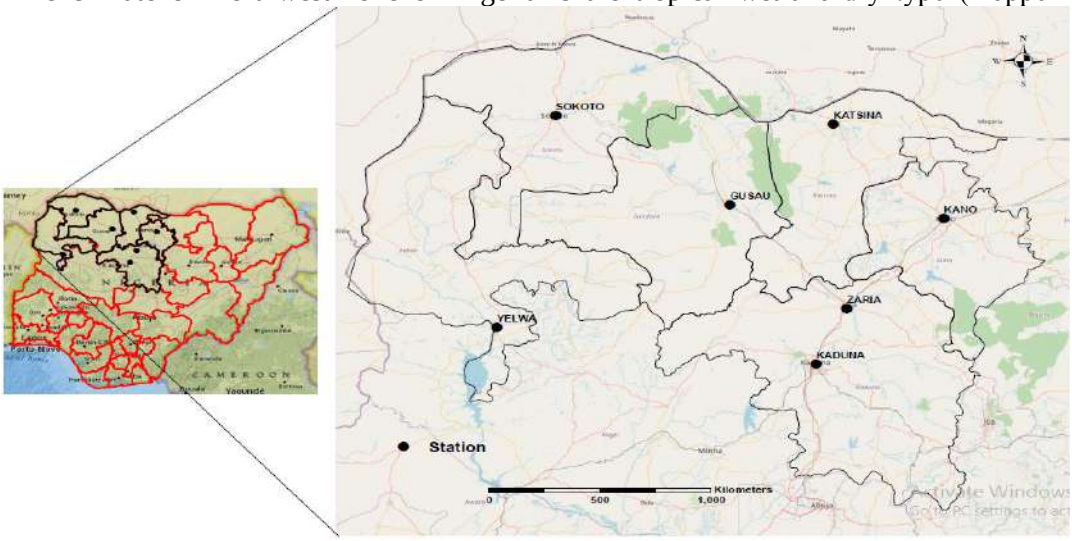

Figure1. Map of North-Western region of Nigeria showing the study meteorological stations
Source: Ejepu, 2021

2.2 DATA SOURCE

15 Years (2006-2015) of daily rainfall as obtained from NIMET by the Drought Early Warning System (DEWS) Team of Futminna Sponsored by TETFUND. Before the datasets were used for the analysis, they were subjected to quality control test. Some of which are days with missing values and possible outliers, which might have occurred due to human or measuring equipment errors.

2.3 PRELIMINARY DATA ANALYSIS

Mann-Kendall Test for Annual Series

In the implementation of this approach, to remove the impact of serial correlation, the annual data series was pre-whitened as noted by Wang *et al*. (2005) and reported in Otache (2008). Thus, the annual series was pre- whitened by employing equation (1)

$$M_i = x_i - \Phi x_{i-1} \quad (1)$$

where,

$M_i$is the pre-whitened series value, x_i is the original series value, and Φ, the estimated lag-one (1) serial correlation value.

To fully implement the Mann-Kendall approach, the mean daily series (temperature and precipitation, respectively) were aggregated to annual mean values. The null hypothesis (H_o) for this test was that the series: x_1…., x_N come from a population where the random variables are independent and identically distributed (iid). The test statistic S was expressed according as

$$S = \sum_{i=1}^{N-1} \sum_{k=i+1}^{N} \operatorname{sgn}(x_k - x_i) \quad (2)$$

where

$$\operatorname{sgn}(x) = \begin{cases} +1 & x > 0 \\ 0 & x = 0 \\ -1 & x < 0 \end{cases}$$

Mann-Kendall test statistic tau, τ is computed as

$$\tau = \frac{2S}{N(N-1)} \quad (3)$$

and

$$\sigma_s^2 = \frac{1}{18}\left[N(N-1)(2N+5) - \sum_{i=1}^{m} p_i (p_i - 1)(2p_i + 5) \right] \quad (4)$$

Here, m is the number of tied groups in the data set andp_i, the number of data points in the i^{th} tied group. Similarly too, under the null hypothesis, the quantity z was taken to be standard normally distributed. Based on this,

$$z' = \begin{cases} (S' - 1)/\sigma_{s'} & S' > 0 \\ 0 & S' = 0 \\ (S' + 1)/\sigma_{s'} & S' < 0 \end{cases} \quad (5)$$

b. Standardized Precipitation Anomaly Index (SPAI)

In the computation of SPAI, the precipitation anomalies were used instead of raw precipitation values. The anomalies of the precipitation are given by

$$y_{i,j} = x_{i,j} - x'_i \quad (6)$$

Where $y_{i,j}$ is precipitation anomalies for the iththear and jth year time step of the year: $x_{i,j}$is the

precipitation value for the ith year and jth time step of the year. x'_i is the long term mean precipitation for the jth time step of the year. Noteworthy is that the unit of the rainfall anomaly series is the same as that of the rainfall series. This needs to be standardized to convert to the scale of Z score. It is explained as follows.

8.0. After obtaining the anomalies, a single probability distribution is fitted to the entire anomaly series (y). Gussian, t-location-scale, three parameter gamma or empirical distributions are various options to model the anomaly series.

9.0. It is noted that because anomalies are not lower bounded by zero, the gamma distribution (commonly used in SPI computation) is not applicable here. Though Gussian distribution might be most preferable among the alternatives, considering the higher order moments of rainfall anomaly series, it may not pass the statistical test(s) of distribution fitting. If a sufficiently long dataset (> 30-35 years) is available, am empirical distribution would be a good choice. Whereas goodness-of-fit tests are mandatory for parametric distributions, such as t-location-scale distribution and three parameter gamma distribution, the empirical distribution estimates the true underlying CDF of the points in the sample. To obtain the empirical CDF of the rainfall anomaly series (y), the Weibull's plotting position formula is found to be the best (Makkonen, 2006) and is expressed by

$$p = \frac{m}{N+1} \quad (7)$$

Where p is the cumulative probability, m is the rank of dataset arranged in descending order, and N is the sample size as explained before, i.e., the total number of the time steps in the dataset.

iii. After fitting the empirical distribution, the quantile values corresponding to each anomaly values are obtained. These quantile values, ranging from 0 to1. Maybe designated as the reduced variates of the rainfall anomalies. These reduced variates are transformed to standard normal variates (Z), i.e., the numbers on the real line which would correspond to the values of reduced variates in a standard normal distribution are determined. The obtained standard normal variates are (Z) are the required SPAI. Similar to the SPI, SPAI values also range between -∞ and +∞ where negative (positive) values reflect drier (wetter) conditions.

3. RESULT AND DISCUSSION

3.1Trend Analysis Results

3.1.1Mann-Kendall Test for Annual and Monthly Rainfall

From the results of Mann-Kendall test for both annual and monthly rainfall presented in the Table 1 below, it shows that at 95% level of significance, the null hypothesis of no trend is rejected if |Z|>1.96. The Z-values for all the months in all the stations lie between the set Z-statistic value ($Z = \pm 1.96$), so therefore there were insignificant trend in the rainfall data for all the stations considered.

Table 1: Mann-Kendall test for mean annual rainfall for all stations

S/N	Stations	Z-values	τ
1	Gusau	0.00	0.18
2	Kano	0.00	0.15
3	Sokoto	0.00	0.17

3.2 STANDARDIZED PRECIPITATION ANOMALY INDEX (SPAI)

3.2.1 Mean Annual Standardized Precipitation Anomaly Index

The figures (2a,b and c) below show the mean annual SPAI values for selected stations in North-Western region of Nigeria for Gusau, Kano and Sokoto respectively. The SPAI values were computed on the basis of three accumulations (3-month, 6-month and 12-month timescales). Standardised Precipitation Anomaly Index (SPAI) was used for the analysis of the drought effect of annual rainfall in the various stations. The

index shows the fluctuation in amount of rainfall recorded over a long period of time where the negative values indicate years with rainfall distribution ranging from near normal to extremely dry condition. As shown below, dry spells outweigh the wet spells in all stations (seven months of dry spells and five months of wet spells) considered which occur between 2011to2017 and ranging from near normal to extremely dry conditions.

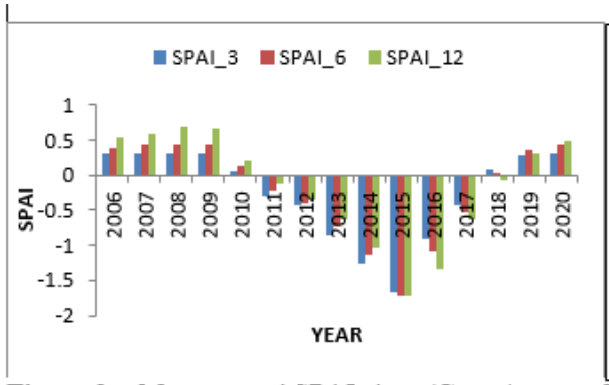

Figure 2a: Mean annual SPAI chart (Gusau)

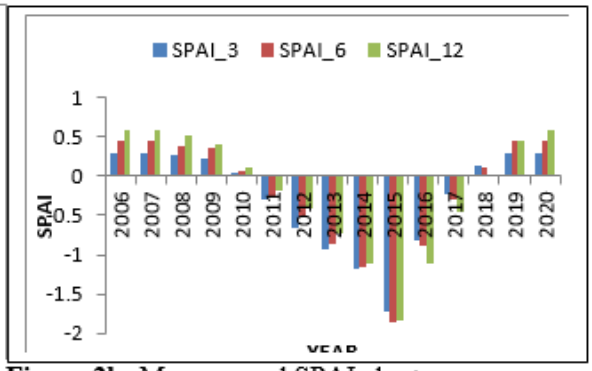

Figure 2b: Mean annual SPAI chart (Kano)

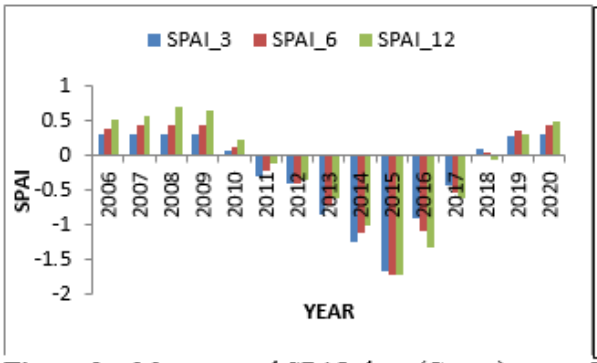

Figure 2a: Mean annual SPAI chart (Gusau)

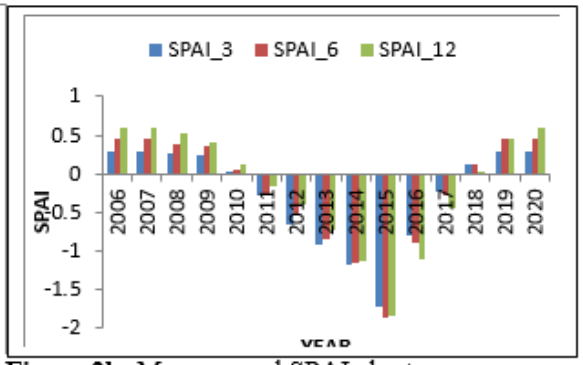

Figure 2b: Mean annual SPAI chart (Kano)

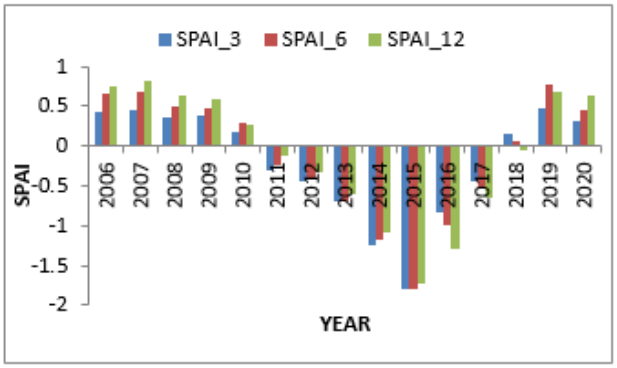

Figure 2c: Mean annual SPAI chart (Sokoto)

3.3 CATEGORISATION OF DROUGHTS USING STANDARDISED PRECIPITATION ANOMALY INDEX (SPAI)

The tables below show the drought intensity summary for three selected stations (Gusau, Kano and Sokoto) at 3, 6 and 12 months using Standardized Precipitation Anomaly Index (SPAI). The categorisation was done on the basis of extremely wet, very wet, moderately wet, near normal, moderately dry, severely dry, extremely dry.

Table 2a: Kano Drought Intensity Summary Table

Drought Intensity	Index Threshold	SPAI_3		SPAI_6		SPAI_12	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Extremely Wet	>2	0	0	0	0	0	0
Very wet	1.5 to 1.99	0	0	0	0	0	0
Moderately Wet	1.0 to 1.49	0	0	0	0	0	0
Near Normal	-0.99 to 0.99	166	93.25842697	163	93.14285714	157	92.89940828
Moderately dry	-1 to -1.49	8	4.494382022	8	4.571428571	8	4.733727811
Severely dry	-1.5 to -1.99	0	0	0	0	0	0
Extremely dry	<-2	4	2.247191011	4	2.285714286	4	2.366863905
Total		178	100	175	100	169	100

Table 2b: Gusau Drought Intensity Summary Table

Drought Intensity	Index Threshold	SPAI_3		SPAI_6		SPAI_12	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Extremely Wet	>2	0	0	0	0	0	0
Very wet	1.5 to 1.99	0	0	0	0	0	0
Moderately Wet	1.0 to 1.49	0	0	0	0	0	0
Near Normal	-0.99 to 0.99	166	93.25842697	163	93.14285714	157	92.89940828
Moderately dry	-1 to -1.49	8	4.494382022	8	4.571428571	8	4.733727811
Severely dry	-1.5 to -1.99	0	0	0	0	0	0
Extremely dry	<-2	4	2.247191011	4	2.285714286	4	2.366863905
Total		178	100	175	100	169	100

Table 2c: Sokoto Drought Intensity Summary Table

Drought Intensity	Index Threshold	SPAI_3		SPAI_6		SPAI_12	
		Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Extremely Wet	>2	0	0	0	0	0	0
Very wet	1.5 to 1.99	0	0	0	0	0	0
Moderately Wet	1.0 to 1.49	0	0	0	0	17	10.0591716
Near Normal	-0.99 to 0.99	166	93.25842697	163	93.14285714	140	82.84023669
Moderately dry	-1 to -1.49	8	4.494382022	8	4.571428571	8	4.733727811

Severely dry	-1.5 to -1.99	0	0	0	0	0	0
Extremely dry	<-2	4	2.247191011	4	2.285714286	4	2.366863905
Total		178	100	175	100	169	100

CONCLUSION

Drought constitutes of the environment and occurs in every part of the globe. It adversely affects the lives of a large number of people, causing considerable damage to environment, economies and property. It affects countries and zones differently, having a greater impact on countries or zones with poor economic conditions. One of the negative features of North Western zone of Nigeria is the periodic occurrence of meteorological drought. The most frequent source of this phenomenon has been attributed to the occurrence of long-term rainless seasons. Since droughts are more frequent in this zone, there is need for a close monitoring over this zone in order to identify the onset, intensity, cessation, duration and spatial extent as well as its frequency in a timely manner for its proper management.

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CORROSION SUSCEPTIBILITY OF ANAEROBIC BIO-DIGESTERS IN BIOGAS AND FERMENTATION SLUDGE MEDIA.

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Abstract

Corrosion – the deterioration of a material because of an electrochemical-typed reaction with its environment, is a common challenge association with the use of metallic materials. In this work, the susceptibility of an anaerobic biodigester fabricated using mild steel sheet to corrosion caused by the produced biogas and digestate water was investigated using gravimetric and electrochemical test methods. It was observed that the corrosion behavior is more dependent on the media – gaseous versus liquid media. Coated steel samples exhibited better corrosion resistance in the presence of fermenting sludge than in the biogas. Uncoated steel coupons were less corrosive in the presence of the unscrubbed gas. Hence, coating the fermentation chamber of biodigesters fabricated using mild steel is necessary, but the gas collection and storage chamber can be left uncoated. This study lends to potential ways of elongating the service life of anaerobic biodigesters while reducing the overall manufacturing cost.

Keywords: *Corrosion, Anerobic Biodigester, Biogas, Sludge, Fermentation*

1. Introduction

The current push towards achieving carbon neutrality has increased the global demand for environmentally friendly and sustainable sources of energy(Obileke et al., 2020). It is widely acknowledged that conventional fossil-based fuels are not sustainable beside being major drivers of climate change(Mulu, M'Arimi, Ramkat, & Kiprop, 2021). Renewable sources such as solar and wind, although sustainable, are expensive and beyond the reach of people living in developing and low-income countries. Hence, developing renewable energy from raw materials prevalent in developing countries is one way to meet the growing energy demand without impeding shift towards carbon neutrality(Awasthi et al., 2022).

Lignocellulosic-based materials (biomass) and wastewater from processing of agricultural products are among the commonest sources of waste in developing countries(Bond & Templeton, 2011). The environmental impact of improper disposal of these waste – a common practice in these countries is well reported in the literature(Bond & Templeton, 2011; Nong, Whangchai, Unpaprom, Thararux, & Ramaraj, 2020). However, modern waste management procedures lean towards a circular economy-based concept rather than the traditional linear economy principles(Awasthi et al., 2022). Therein, wastes are recycled, reused, or repurposed rather than disposed as proposed by conventional linear economy concept. Several studies have shown potentially viable ways of achieving circularity in the management of wastewater and biomass. Daniel-Mkpume et al. (2022) have published several studies showing the potential application of biomass in producing low cost and eco-friendly composite materials(Daniel-Mkpume et al., 2022). Salam et al. (2019) showed that agro-industrial wastewaters can be utilized as bio-stimulants for growing of micro-organisms for environmental remediation(Salam & Ishaq, 2019). Anaerobic bio-digestion to produce biogas – a sustainable fuel presents another circularity-based management approach for these wastes(Awasthi et al., 2022; Obaideen et al., 2022; Zhang, Wang, & Liu, 2020).

During anaerobic bio-digestion, microbes convert the organic components of biomass and agro-industrial wastes into fuels such as biomethane and biohydrogen, as well as other products like manure(Sawyerr, Trois, & Workneh, 2019). Numerous studies have shown that this process take between 3 – 7 days, with the generated fuels often meeting the requirement to be directly utilized for household heat and cooking purposes. Bio-digestion are carried out in biodigesters which can be domestic (household) or commercial(Cheng, Li, Mang, & Huba, 2013). Common domestic biodigesters designs include the Puxin digesters, Indian floating drum, Chinese dome, among others(Mir, Hussain, Verma, & Dubey, 2016).

These devices can be fabricated using steel sheets, hence are inexpensive and fit for rural inhabitants. However, due to the composition of the gases and other compounds produced during the bio-digestion period, metallic biodigesters are prone to corrosion.

This work reports the corrosion susceptibility of an upward flow anaerobic digester fabricated using steel sheets. The corrosion susceptibility was investigated in detail, namely: susceptibility to scrubbed biogas, unscrubbed biogas, and digestate water, as well as the influence of spray painting as a corrosion mitigator. Hence this work serves as basis for choosing the corrosion inhibition approach for the fabrication of different parts of a metallic biodigesters.

2. Materials and Methods

2.1 Materials

Steel coupons cut from the steel sheets used for the fabrication of the biodigester.

2.2 Sample preparation

Nineteen squared shaped coupons (3cm x 3cm) cut from steel sheet used for the fabrication of the biodigester were filed, ground, and polished with emery paper of grit size (P60D and P220D). The coupons were washed with distilled water to remove debris and air dried. Seven coupons were coated with aluminum spray paint (Vimax industries) for the estimation of the influence of painting as a cheap corrosion inhibitor. Figure 1. Shows the steel coupons.

Figure 1. Steel coupons for corrosion test.

2.3. Corrosion media

Scrubbed gas, unscrubbed gas and digestate from the co-digestion of pawpaw leaves and waste starch water were used as media for the corrosion study. For the detail of the biogas design, biogas composition and substrate mix, see (Ayadiuno, 2021).

2.4 Gravimetric test

Nine uncoated and four coated samples were weighted with a digital weighing scale, fastened to strings, and immersed inside the fermentation chamber of the bio-digester. After every 10 days, a sample is taken out, washed, dried and reweighed. Total duration of the corrosion study was 90 days, however, the test for uncoated samples were discontinued after 20 days.

Corrosion rate (CR) was calculated using the formula

$$\mathbf{CR} = \frac{\mathbf{KW}}{\mathbf{DAT}} \qquad (1)$$

Where $\mathbf{K}$ = 8.76 x 10^4mmyr^{-1}. $\mathbf{T}$, is the time of immersion (days). $\mathbf{A}$, is the area of coupon (cm^2), $\mathbf{W}$, is the weight loss (g) $\mathbf{D}$ is the density of mild steel in gcm^{-3} given as 7.85gcm^{-3}

2.5 Electrochemical test

Tafel analysis of the coupons were carried out using an electrochemical workstation at a scanning rate of 0.01v/s. Figure 2 shows the setup for the electrochemical test.

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Figure 2. Setup for corrosion test using the electrochemical workstation.

2.6 Microstructural analysis

Microstructural evaluation of the non-corroded and corroded mild steel was done using EDS attached scanning electron microscope (VEGA 3 TESCAN).

3. Result and Discussion

3.1 Gravimetric method

Gravimetric method (weight loss method) is a simple method of examining corrosion rate. Figure 3 shows the weight loss and corrosion rate of uncoated steel coupons. The weight loss of the uncoated samples immersed in the mixture of waste pap water and shredded fallen pawpaw leaves increased with time. However, the corrosion rate decreased with time, which is contrary to the observed weight loss. The inverse relation observed in this work defies known behavior of mild steel in potentially corrosive environment, hence will require further studies. However, similar trend have been reported by (Oparaodu & Okpokwasili, 2014) in steel under different soil conditions. Nonetheless, the anoxic nature of the environment, presence of microbes and compounds might have induced some form of passivity on the steel coupons. The observed weight loss and corrosion rate were quite significant between the first 20 days.

Based on the observed weight loss, corrosion behavior of the uncoated steel coupons, the corrosion behavior of samples coated with aluminum spray paint was studied from 5 to 20 days. As shown in Figure 4, the weight loss for the coated coupon also changes with time but were smaller when compared to those of the uncoated coupons, thus showing that the aluminium spray paint used as a coating material inhibited the corrosion of the mild steel coupon.

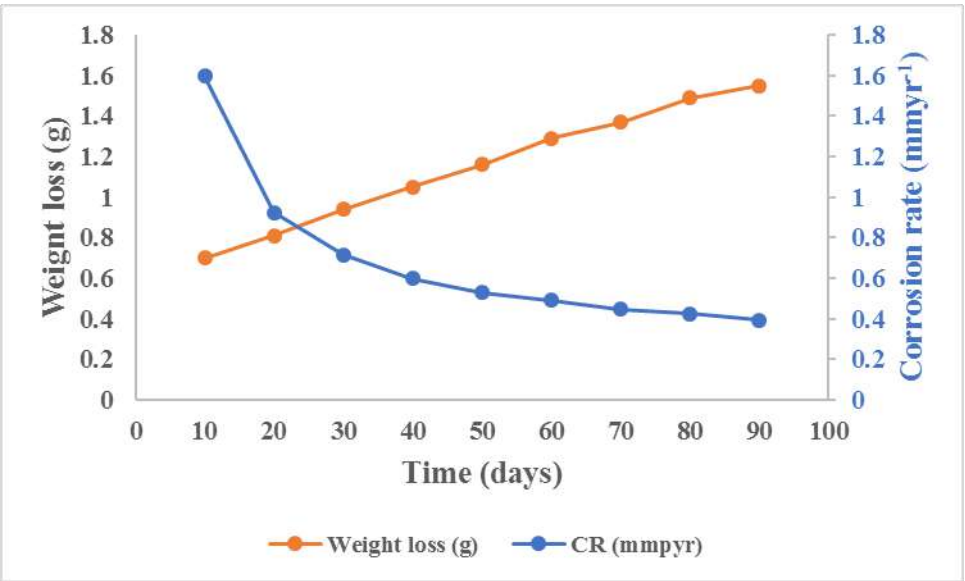


Figure 3 A graph of weight loss and corrosion rate for uncoated coupons.

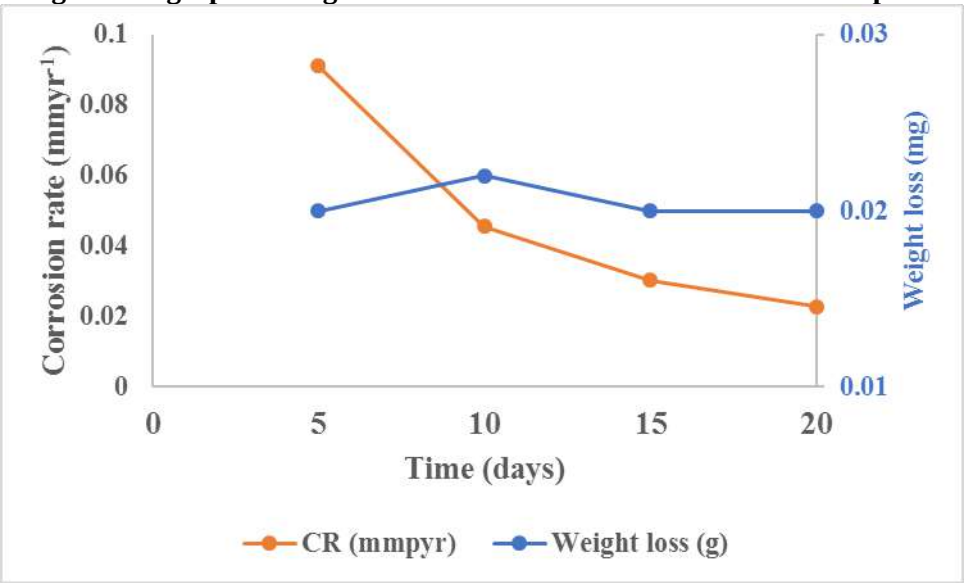
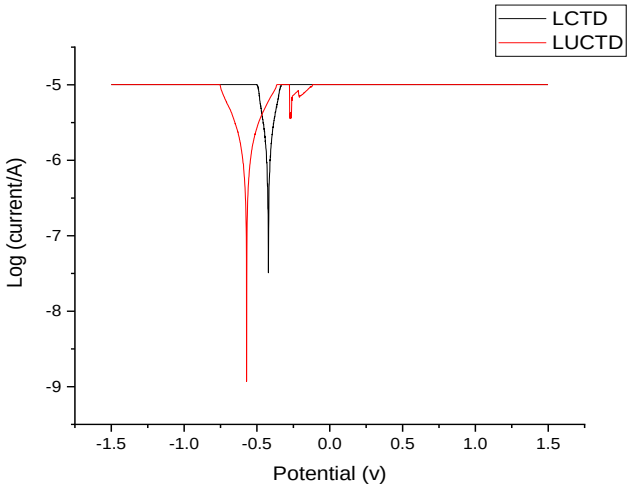


Figure 4 Graph of weight loss and corrosion rate against time for uncoated mild steel

3.2 Electrochemical test

3.2.1 Coated and Uncoated mild steel coupon in liquid medium

Figure 5 shows that the coated mild steel coupon has a lower potential (< -0.5V) compared to the uncoated mild steel coupon in fig 4.5 with a greater potential (>-0.5V), the uncoated mild steel coupon is said to be more susceptible to corrosion than the coated coupon when exposed in the liquid environment used in this research work. The fermentation chamber of the bio-digester (see figure 5) will be prone to corrosion if not coated since its houses the mixture containing the liquid for as long as it takes for the retention time. The presence of liquid and changing composition during the fermentation period might have influenced the observed corrosion behavior.



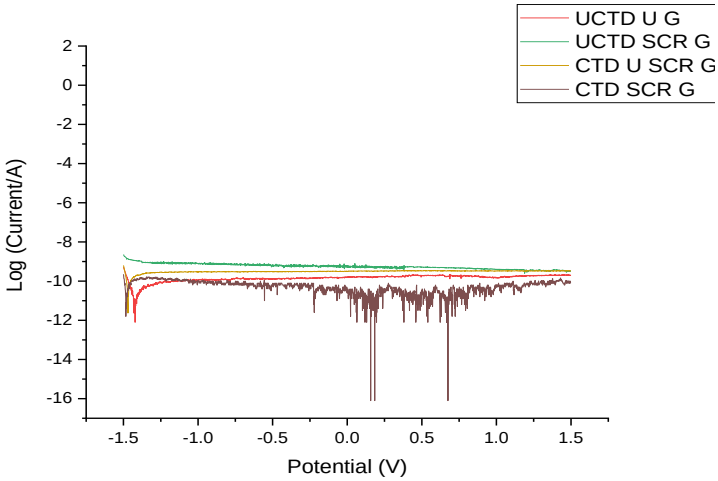
*LCTD = coated mild steel coupon; LUCTD = uncoated mild steel coupon

Figure 5 Tafel plot in a liquid medium for coated and uncoated mild steel coupon

3.2.2 Coated and Uncoated mild steel coupon in gas medium

On exposure of the coupon in an un-scrubbed gaseous medium, the uncoated coupon was observed to exhibit a better resistance to corrosion compared to the coated coupon (see Figure 6). This is due to the corrosion current density of the uncoated coupon been lesser than that of the coated coupon as shown in Table 1. Additionally, the corrosion current density and the corrosion rate of the uncoated mild steel coupon is lower than the coated mild steel coupon. The observed behaviour can be attributed to gaseous composition, which might have passivated the uncoated coupons but developed an electrochemical cell in the coated coupons. Hence, using uncoated mild steel sheet in fabricating the gas storage and collection chamber of a bio-digester will yield better returns in service life.

Unlike the behaviour of the coated and uncoated coupon in an un-scrubbed biogas environment, the coated mild steel gives a better corrosion resistance when exposed in a scrubbed biogas environment compared to the uncoated. From Table 1, the value of the corrosion rate and the corrosion density for the coated mild steel coupon are collectively lower than that of the uncoated mild steel coupon. The coated mild steel coupon will perform exceedingly well in a scrubbed gas environment than the uncoated mild steel coupon in the same medium with respect to the environment considered in this project work. The result in Table 1 shows that the coated mild steel coupon corrodes at a rate of 1.8660E-06mil/yr whereas the uncoated mild steel coupon corrodes at 4.8780E-05mil/yr.



*UCTD U G = uncoated mild steel coupon in unscrubbed gas; UCTD SCR G = uncoated mild steel coupon in scrubbed gas; CTD U SCR G = coated mild steel coupon in unscrubbed gas; CTD SCR G = coated mild steel coupon in scrubbed gas.

Figure 6 Tafel plots in biogas media

Table 1. Summary of values from Tafel plots

Sample	medium	cathodic slope	Anodic slope	cathodic intercept	anodic intercept	lin pol R(ohms)	icorr	CR(mil/yr)
UCTD	Un-scrubbed gas		2.302		-10.450	8338373824	2.3370E-11	2.6520E-07
CTD	Un-scrubbed gas		2.043		-9.839	129053856	1.2500E-10	1.4210E-06
CTD	scrubbed gas	2.755	2.758	-10.477	-10.700	479585984	1.6440E-10	1.8660E-06
UCTD	scrubbed gas	0.333		-10.01		2747902976	4.2980E-09	4.8780E-05
UCTD	liquid	5.473	5.131	-5.943	-5.931	25340	1.6180E-06	1.8370E-02
CTD	liquid	2.177	4.436	-5.22	-5.460	12456	5.2780E-02	5.9920E-02

*UCTD = Uncoated mild steel coupon; CTD = Coated mild steel coupon.

3.3 Microstructural analysis

The micrographs of the corroded and uncorroded mild steel samples are shown in figure 7a & b. The micrograph of the uncorroded mild steel show abraded morphology due to the surface preparation process while the corroded sample shows a surface coated with corrosion products.

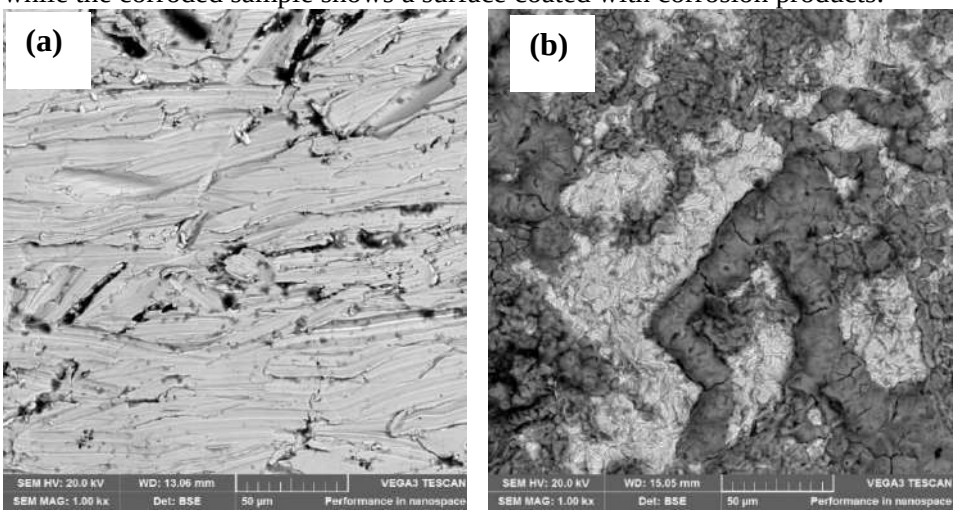


Figure 7. Micrograph of mild steel sheet (a) uncorroded and (b) corroded.

4. Conclusion

This work reveals that the corrosion behaviour of mild steel in environment prevalent in anaerobic biodigesters is dependent on media – gaseous or liquid. Corrosion rate is minimal in the gaseous media than in the liquid mediums. Coated mild steel was found to be more resistant to corrosion in the fermentation chamber but more susceptible in the gaseous environment. Scrubbed biogas was found to be corrosive to uncoated mild steel coupons compared to the coated samples. Hence spray coating mild steel sheets used in fabricating domestic biodigesters can be a good corrosion mitigation approach for the fermentation chamber but less beneficial to the gas collection and storage chamber.

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EVALUATION OF RURAL WATER SUPPLY CHALLENGES: AN INSTRUMENTAL COMPONENT IN DEVELOPING AND COMBATING COVID-19 IN RURAL COMMUNITIES OF AKWA IBOM.

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Abstract

Adequate potable water supply and sanitation has been a problem in rural communities of Akwa Ibom state, despite the actions taken by the governments at all level and stakeholders to improve rural water and sanitation. However, the outbreak of the covid-19 pandemic has caused stress on the water usage pattern. This work is focused on evaluating the main causes that impedes the proper development of water supply and sanitation in rural communities of Akwa Ibom. The method used in carrying out this research is the investigative approach through the distribution of questionnaires, personal interview and field observation. The causes of inadequate rural water supply and sanitation identifies were borehole failure (total failure), failure of power supply, pump breakdown, damaged borehole facilities, theft, inappropriate distribution of water ,theft, inadequate community participation, alternative to other source of water supply (ex. stream, rainfall, etc.), government policies. Recommendations were made to ensure that the water supply system is improved and they include geophysical survey, adequate piping and distribution of water works, rural dwellers should be educated on the need for good source of water supply. Communities participation should be encourage among the rural communities. .

Keywords: *potable water supply, sanitation, rural community, COVID-19.*

1. Introduction

One of the foremost methods in the fight against covid-19 is washing of hands regularly with soap and water, social distancing, wearing of nose mask amongst other precautionary measures as recommended by the world health organization (WHO, 2019). Nigeria, the giant of Africa with an estimated population of 170million (NPC, 2006) is being ravaged by covid-19 as shown on Figure 1 and Table 1.

Table 1: COVID-19 CASES IN NIGERIA

Confirmed cases	Active cases	Discharged cases	death
17148	11070	5623	455

Source: NCDC (17/06/2020)

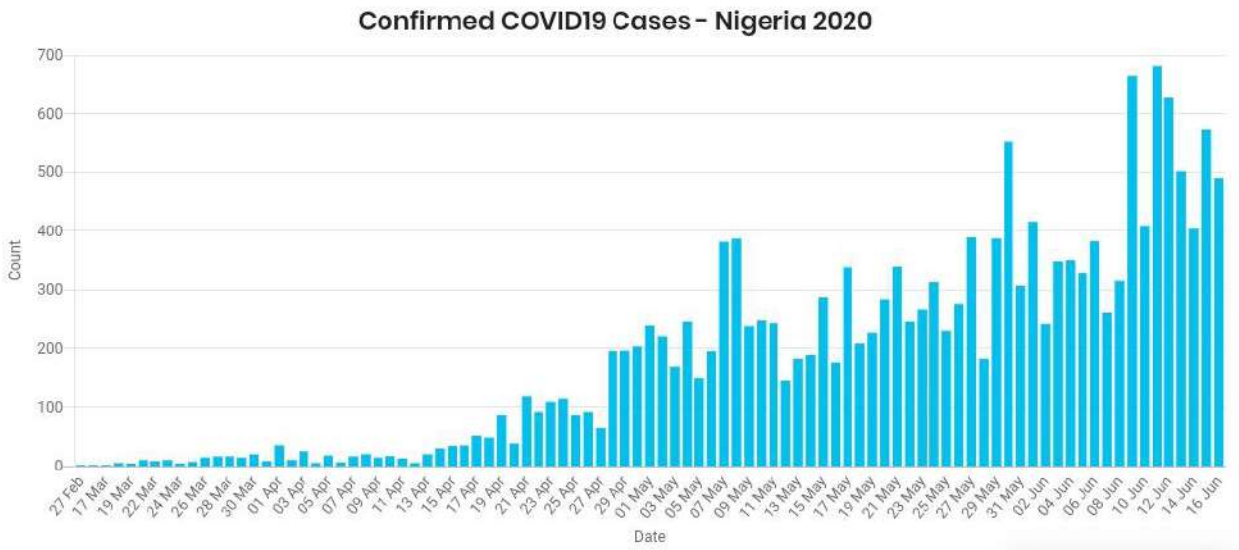

Figure 1: graphical representation of covid-19 cases in Nigeria

Source: NCDC (17/06/2020)

It is estimated that 63.6 million Nigerians still lack access to safe and wholesome water and are basically rural dwellers (WASH, 2014). Clean water is absolutely fundamental to life as we know it. The outcome of this covid-19 pandemic has contributed to water use pattern and resulting to water stress. The issue of potable and adequate water supply has been a problem even before the covid-19 pandemic (Adah and Abok, 2013; Akpabio, 2014).

Hence, the issue of washing hands regularly as a means of fighting the spread of covid-19 in the rural areas will be facing a major setback. However, the earth is flooded with water, with a total volume of some 1.4 billion cubic kilometers (325 million mi^3) of water, which covers 75% of the earth surface (Tebbutt, 1998). Millennium Development Goals (MDGs), a comprehensive set of goals aimed at addressing the most important needs of people in the developing countries to improve their well-being by the year 2015, was adopted by the United Nations at the UN Millennium Summit in 2000 by world leaders (UN, 2015). Another world leaders' meeting was held, this also led to the formulation of Sustainable Development Goals (SDGs) to be achieve by the year 2030 (UN, 2015). Yet, the issue of rural water supply and sanitation still persist.

The issue of covid-19 was first discovered as pneumonia of unknown cause in Wuhan, China (WHO, 2019). It was reported to the WHO country office in China on the 31st December 2019. The outbreak has declared a public health emergence of international concern on 30th January, 2020. On 11th February 2020, WHO announced a name for the new corona disease as COVID-19. 54 countries have been affected and other countries across the continents of the world. On 27th February 2020, Nigeria confirmed its first case in Lagos, as an Italian citizen who works in Nigeria returns (NCDC, 2020).

The virus has affected the country and has posed a serious threat to the rural dwellers. Most of the rural communities lack basic amenities such as health facilities, adequate water supply and proper access to information. This will also affect agricultural productions and its value chains as most activities are carried out in the rural communities. This will lead to shortage in food supply, thus, affecting the country's GDP (gross domestic product). World Health Organization has also estimated that 361,900 people die yearly in Nigeria due to poor water and sanitation condition while the United Nations Children Emergency Fund (UNICEF) also estimated that 194,000 children under the age of five die from diarrhea caused by poor water and sanitation yearly in Nigeria (WHO/UNICEF, 2010). A 2008 survey of household without access to improved drinking water conducted by the Federal Ministry of Water Resources showed that between 20% and 80% of the residents in all the country's 36 states lacked access to improved drinking water (NSDWQ, 2007). The situation has resulted in high mortality from water borne diseases across the country and this could probably send a wrong signal in the fight against covid-

19. Potable water is the water that has not been previously used and is conducive to life whether treated or untreated (Parsons and Jeffersons, 2006). Akpan and Aster (2010), studied the accessibility level of portable water supply in rural communities of Akwa Ibom state. However, Ibok and Daniel (2014), analyzed the impact of rural water supply to sustainable development in Akwa Ibom state.

Ekpo and Olaniyi (1995) defined rural development as a process through which rural poverty is alleviated by sustained increase in the productivity and income of poor rural dwellers and households. This definition is defective as it dwelt mainly on the economic growth, which is just an aspect of development. Taking into cognizance the economic growth and social upliftment as aspects of development, Ijere (1990) regarded rural development as the process of increasing the per capita income and the quality of life of the rural dweller to enable him become prime mover of his own destiny.

Combining all the essential elements of development, rural development can be described as the integrated approach to food production as well as physical, social and qualitative changes which result in improved living standards of the rural populations. It therefore infers that the supply of potable water and provision of a clean environment are components of rural development as more than two-third of Nigerian citizens is rural dwellers.

Water is fundamental to life on earth and thus one of our most valuable resources. During the last century, global water consumption has grown twice as fast as population, driven by increased irrigation, industrialization, urbanization, tourism development and per capita demand (WELL, 1998). The factors that affect the choice of potable water supply in a given location are usually affected mainly by three factors namely; the quantity of water available, the quality of available water and cost.

The aim of this paper is to investigate the challenges of water supply in rural communities in Akwa Ibom state, in order to suggest better means of promoting and sustaining adequate water supply as a means of combating covid-19 pandemic within the rural communities.

2. Materials and Methods

2.1 Study Area:

The location of the study is Akwa Ibom state. The study area is one of the 36 states in Nigeria with a population of over 5 million people (NPC, 2006). It is located in the coastal South-Southern part of the country, lying between latitudes $4°32^1$ and $5°33^1$ North, and longitudes $7°25^1$ and $8°25^1$ East with a land mass of $7081km^2$.

2.2 Data Collection

Data used in this work is made up of primary and secondary data. Primary data was obtained by using well-structured questionnaires to household in rural areas in addition to field observation, focus group discussion and informal discussions. While secondary data used in this study was obtained from the internet, and survey reports, newspapers as well as other published and unpublished articles documents.

2.3 Methods

This research was carried out using the investigative research approach method, which deals with the distribution of questionnaires, personal interview and field observation.

This research is a review work that aims at improving the livelihood of the rural dwellers through adequate rural water and sanitation. The adequate supply of rural water and sanitation is necessary in order to boost the fight against covid-19 in rural communities of the study area and the country at large. This work was carried out through reviews of related literatures, sites visitation, interviews were conducted at the rural communities and ministries of water resources were visited for proper evaluation and reviews.

3. Results and Discussions

3.1 Results

The results obtained in the distribution of questionnaires, personal interview and field observation are presented in this subheading.

3.1.1 Distribution of questionnaires

Table 2 shows the numbers of questionnaires distributed and the percentage coverage among the local government of the study area covered.

Table 2: Distribution of Questionnaires

Selected LGA	No of Questionnaires	Percentage of Total Questionnaires Shared
Abak	50	12.5
Essien Udim	60	15
Etim Ekpo	50	12.5
Ikot Ekpene	50	12.5
Obot Akara	60	15
Oruk Anam	70	17.5
Ukanafun	60	15
Total	**400**	**100%**

3.1.2 Problems of water supply as identified by the rural dwellers within the rural communities of Akwa Ibom state

Table 3 shows the problems associated with the rural water supply within the rural communities of Akwa Ibom state, as obtained from the distributed questionnaires to the rural dwellers.

Table 3: Problems of Water Supply within the Rural Communities of Akwa Ibom State

s/n	Problems of Water Supply As identified By the rural dwellers within the Rural Communities of Akwa Ibom State	Frequency	Percentage
1.	Nonfunctional boreholes	48	13.79
2.	Defaulted boreholes	105	30.17
3.	Inappropriate distribution of water	50	14.37
4.	Theft	34	9.77
5.	Inadequate community participation	72	20.69
6.	Alternative to other source of water supply (ex. stream, rainfall, etc.)	21	6.03
7.	Government policies	18	5.17
	Total	**348**	**100%**

Table 3 shows that 348 questionnaires out of 400 were filled correctly and returned for analysis, which shows that 87% of the distributed were returned, showing a positive outcome. The analyzed result obtained show that 30.17% of the population agreed that defaulted borehole affected the adequate supply of rural water supply within the study area. These default bores are functional boreholes but have stopped working due to fault developed. 20.69% indicated that inadequate community participation has hindered the rural water supply and development with the study area. 14.37% stated that the inappropriate distribution of water has affected the rural water supply and sanitation, as nearness to water source has discourage its usage. A total of 13.79% indicated that nonfunctional boreholes have prohibited the adequate supply of rural water supply and sanitation. This could be as a resulted of total failure of the borehole or unproductive aquifer. 9.77% attributed the inadequate supply of rural water supply to stealing of the borehole accessories, which made the boreholes not to be beneficial to the rural dweller and have discouraged its usage. 6.03% of the total sampled population attributed poor rural water supply to rural dwellers having an alternative to other source of water supply, such as; stream, rainfall, etc. Only 5.17% attributed poor rural water supply to government policies, some of the population stated that it is the duty of the rural dwellers to protect their water projects. While other stated that the government response has hindered the actualization of good rural water supply within the rural communities.

3.1.3 Causes of borehole failure identified from field observation in rural communities of Akwa Ibom state

During field work, the causes of borehole failures were studied within the rural communities of Akwa Ibom through interaction and observation. The observations made during the field visit are presented as shown on Table 4.

Table 4: Causes of Borehole Failure identified from field observation

s/no	Problem of Boreholes Identified From Field Observation	Numbers of Boreholes	Percentage of Boreholes
1	Borehole Failure (Total Failure)	4	8
2	Failure of power supply	10	20
3	Pump Breakdown	6	12
4	Damaged Borehole Facilities	5	10
5	Pump Theft	14	28
6	Having more than one of the above stated problems	11	22
		50	100%

The results obtained from field observation, show that, borehole theft (pump) has hindered the adequate supply of rural water supply as it takes 28% of the causes of nonfunctional boreholes visited within the rural communities. 22% of the boreholes that were not functioning were found to have more than one of the above stated problems that caused the failure of borehole. 20% of the borehole stopped functioning as a result of power supply failure, which has halted the supply of rural water supply within the rural communities, as solar panels are being destroyed, inverter battery are stolen and generators broken. 10% stopped working as a result of the borehole facilities damage. 12% of the borehole stopped working as a result of the pump failure, while 8% stopped functioning as a result of total failure.

3.2 Discussions

3.2.1 Inadequate National Philosophical Base and Integrated Pilot Demonstration

The Nigerian rural development strategy lacked a philosophical ideology and holistic foundation. It has a body (policy makers and government functionaries) but has no mind to give it life and sense of direction. The usual practice has been to be in office propounding slogans and manifestos for the people they rule. That was instrumental to the failure of some rural projects such as farm settlement scheme; operation feed the nation among others. A philosophical base is typified by an internal motivation and compelling force or commitment to work for improved standard of living. Without philosophical superstructure, rural development remains an echo of good intentions from government and its agencies.

After the creation of Akwa Ibom State, several water and sanitation programmes have been carried out in collaboration with local, state, federal and international organizations. There has been lots of work done but the problem is the proper synchronization of the executed project to the host communities for proper benefit.

3.2.2 Diverse Policies

Despite the numerous benefits of rural water supply and sanitation, the sector has been hampered by adverse policies, legal constraints, short term policies and lack of coordination between the sectors to which it contributes; Agriculture, forestry, rural development, environment and trade (Ibok and Daniel, 2014). The supply of potable water in rural communities has been at bay and mostly done by individuals and policies that restrict the usage of surface water and borehole installation are not effective.

3.2.3 Source of Water Supply

A rural water supply system cannot service its customers unless there is a continuous supply of water to meet domestic consumption needs in the broadest sense and water needs for sanitation. Water sources need to be selected carefully to make sure that this fundamental requirement is met. Two main factors that affect water supply selection are; quality of water and quantity of water (Ekpo *et al*., 2018). In Nigeria, the problem with shortage of water is basically caused by different factors that range from climatic, geological and environmental factors. The demand for water supplied by rural water system has two driving components; Consumer consumption and an adequate and reliable water supply.

3.2.4 Inadequate Community Participation

The top bottom approach to rural development employed by government functionaries' whip up enthusiasm among the people as there is absence of total community participation(Ibok and Daniel, 2014). Due to the approach adopted by people evoke unwilling response as they are regard as being incapable of standing on their feet.

3.2.5 Distribution of Water

The problem of most urban water projects has been distribution; it creates drudgery among host communities and has caused them to opt for water that is close which may not be safe for consumption (Akpan and Aster, 2010). It is essential to understand the basic types of water supply systems and the physical arrangement of system components prior to design or evaluation concepts associated with these components. There are two basic types of water supply systems to create water pressure within the distribution system to supply water to build up areas of a community. However, the build up areas in rural communities are scattered.

3.2.6 Breakdown of Water Supply System

This is the most prevailing problem facing rural water supply in rural communities. Several factors are known to be the cause of breakdown of the water supply system.

3.2.6.1. Power Breakdown

This has led to the total breakdown of water supply in almost all water station available within the country since power supply is not stable, moreover power is expensive.

Selection of source of power supply should be based on cost, availability and reliability. As such in the construction of water supply system, solar based or wind powered system is preferred to diesel powered system since it requires little maintenance and it is inexpensive compare to the use of diesel engine which is highly expensive but in treatment plants it may be supplemented with diesel plant to prevent operations from been stagnated. In rural water supply, the use of cheap source of energy is the most preferred choice such as wind, solar etc., as this will not impose any operational cost on the host communities.

3.2.6.2. Pump breakdown

Pump breakdown has led to the Failure of the pumping system can lead to the total breakdown of the water supply system, most service provider do not adhere to the design and specifications of the job. Several types of pump are used in the abstraction and distribution of potable water supply, though some are distributed by means of gravity. Without the proper functioning of the pump the system cannot function so to prevent this menace, the pump that suits the type of operations should be used. It should be properly design and adhere strictly to during installations. As such care should be given to avoid unnecessary breakdown.

3.2.6.3. Burst/Damage Pipelines

Burst/Damage Pipelines has also been known to be another factor that has mitigated the adequate supply of adequate water supply in the rural region. If the whole system is working except the piping system, the water cannot reach the targeted consumers Burst or damaged pipes can lead to wastage of water and people will opted to get the available source of water which may not be safe for consumption. This fault may lead to the inaccessibility of water to the consumer and the entrance of pollutants through the damaged parts of the pipe.

3.2.7 Maintenance Policy

This is generally a problem with Nigerians; government spends much money in executing a project but care less about the maintenance of the project. Personnel are not available within the host community as to cater for the maintenance of the water supply systems (Ibok and Daniel, 2014).

4.0 Conclusion

In conclusion, most Nigerians dwell in the rural communities and the provision of basic infrastructures brings about development in the area. Therefore, the provision of potable water supply will help in the fight against covid-19. This will also lead to improved standard of living, health and socio-economic activities within the region, thus, bringing about development. Reduction of water borne diseases that has caused high child mortality can be achieve through the supply of safe and wholesome water for consumption and improvement of the quality of sanitation. Based on the study carried out, it is therefore recommended that feasibility studies and geophysical survey be carried out before commencing drilling of boreholes. Piping and distribution of water should done in such a way that each segment of the rural community will have access to potable water supply without much labour and drudgery as this will encourage the use of the new source of water supply. Rural dwellers should be educated on the need for

good source of water supply. In order to fully achieve the provision of rural water supply and sanitation in other to fight against covid-19 and also meet up with the SDGs target on adequate water supply. Communities should be carried along during the execution of water supply projects in terms of training, execution and maintenance. Government and communities should ensure that contractors uses materials that are of high quality to ensure the prolong usefulness of the water supply i.e. design period, so that the rural dwellers will not fall back to the old source of potable water supply.

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COMPARATIVE EVALUATION OF FIVE EVAPOTRANSPIRATION MODELS FOR UYO LOCAL GOVERNMENT AREA, AKWA IBOM STATE

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Abstract
For this research, Penman-Monteith (PM), Priestly Taylor (PT), Blaney-Morin Nigeria (BMN), Jensen-Haise (JH) and Hargreaves-Samani (HS) were used to estimate reference evapotranspiration (RET) for Uyo, AkwaIbom State, Nigeria from 1997 to 2017. Good correlation was found between the RET values estimated by each of the four radiation and temperature based models and the Penman-Monteith (PM) model. The mean annual RET estimated by the Penman-Monteith (PM) model as the standard tool for Uyo station was found to be 1034.1mm, while the mean annual RET estimated by the Priestly Taylor (PT) model was found to be 586.5mm, the mean annual RET estimated by the Blaney-Morin Nigeria (BMN) model was found to be 1496.2mm, the mean annual RET estimated by the Jensen-Haise (JH) model was found to be 520.1mm and the mean annual RET estimated by the Hargreaves-Samani (HS) model was found to be 1547.7mm, respectively. The best model for estimating reference evapotranspiration as compared to Penman-Monteith (PM) method is the one with the intercept value closest to zero, the regression slope (m) value closest to 1.0, the smallest Root Mean Square (RMSE) and t-statistics value and with the highest coefficient of simple determination with greater emphasis on the RMSE and t- values. Based on the criteria listed above, Hargreaves-Samani (HS), Blaney-Morin Nigeria (BMN) and Priestly Taylor (PT) were ranked first, second and third best models, respectively.The Penman-Monteith (PM) estimates was used to develop correction factors for the two models that predicted best in the station for their potential use without sensitive error. This was done in order to achieve accurate and reliable evapotranspiration estimate.

***Keywords*:** *Comparative, Evaluation, Evapotranspiration, Models, Uyo*

1.0 INTRODUCTION

Evapotranspiration (*ET*) is a controlling factor in the water cycle and energy transport among the biosphere, atmosphere and hydrosphere, and therefore plays an important role in hydrology, meteorology and agriculture (Egwuonwu, 2012). Understanding evapotranspiration dynamics will help to predict regional-scale surface runoff and simulate large-scale atmospheric circulation and global climate change and schedule field-scale irrigation and tillage operations over cropland (Itenfisu*et al*., 2000). Therefore, the capability to accurately estimate evapotranspiration in land surface and energy budget modeling at different temporal and spatial scales could be a valuable asset in hydrology, climatology and agriculture.

According to Ahaneku (2011), water is becoming scarce in many parts of the world, Nigeria inclusive. Over the years, it is widely believed that climate change, increasing demand for freshwater by the competing users in different sectors and more importantly the environmentally induced problems such as desertification and overexploitation of the existing water resources will have a significant effect on the availability of water.

A lot of water is required for agricultural practices and also for domestic activities. In view of this, it is imperative to have the knowledge of the rate at which water is being returned to the atmosphere either from water bodies, reservoirs, land surfaces and from plant bodies, this process is termed evapotranspiration (*ET*) (Adeboye *et al*., 2009).

A major challenge in sustainable stormwater management is to comprehend the components ofthe water budget and balance the components. The water budget on land surfaces consist ofprecipitation, infiltration, run off and evapotranspiration (*ET*). Each component itself is difficultto measure but the evapotranspiration (*ET*) process is the most challenging. Figure 1 illustrates the processes of the water budget (Allen *et al*., 1998).

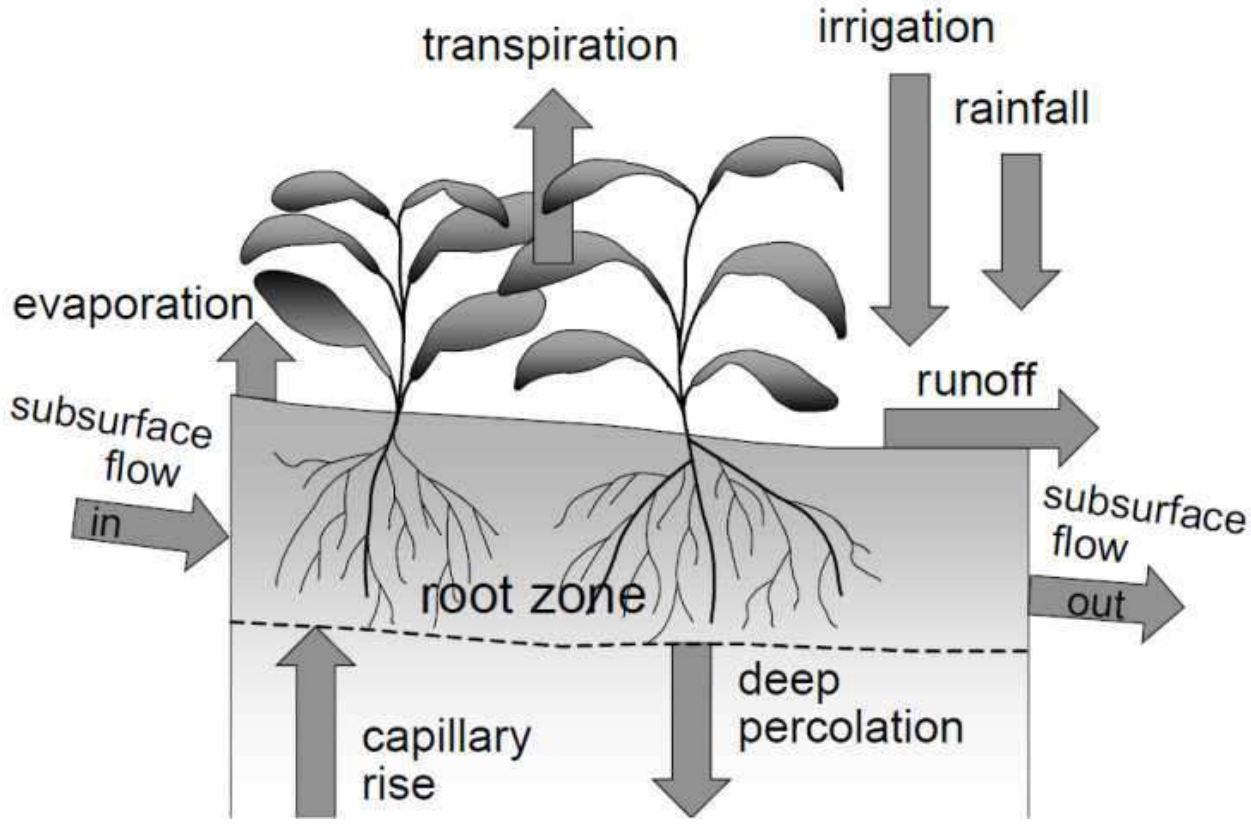

Figure 1: Water Budget on Land Surface (Allen *et al*., 1998).

Flow through the atmosphere, surface and subsurface is shown with arrows. Evaporation and transpiration are shown separately but are often combined as evapotranspiration.

Water is supplied to the crops naturally through precipitation and subsurface moisture, but when these supplies prove to be inadequate for crop use, farmers resort to irrigation. To schedule irrigation properly, a farmer must understand the environmental demand for surface water. For the farmer, this surface water loss occurs primarily through evapotranspiration (*ET*). One of the most important factors in agriculture is water availability. Water availability is a critical variable for virtually every other economic activity, including industry, the energy sector and public use. In recent years, water availability has become an issue even in the relatively wet state of Akwa Ibom, as periods of prolonged drought have stressed both agriculture and non-agriculture sectors in the area (Essien and Cyrus, 2019).

Evapotranspiration is defined as the combination of two separate processes, in which water is lost from the soil surface by evaporation (E) and used in plant uptake for biological processes that is transpiration (T) (Hassanli, 2010). Evaporation and transpiration occur simultaneously and are difficult to distinguish, and even more challenging to measure accurately. The rate of evapotranspiration is influenced by several factors which include temperature, relative humidity, solar radiation, wind speed and the availability of water.

Reference evapotranspiration (*ETo*) is defined as "the rate of evapotranspiration from a hypothetical crop with an assumed crop height (0.12 m) and a fixed canopy resistance (70 s/m) and albedo (0.23) which would closely resemble evapotranspiration from an extensive surface of green grass cover of uniform height, actively growing, completely shading the ground and not short of water" (Tyagi *et al*., 2000).
The knowledge of reference evapotranspiration (*ETo*) is routinely required for the estimation of crop water use in the planning, design and operation of irrigation systems and soil and water conservation systems (Maeda*et al*., 2011).
Evapotranspiration (evaporation and transpiration) may be quantified from soil surface, open water surfaces as well as vegetation surfaces for those applications to be achieved. This quantification can be done through direct measurement or through estimation using meteorological data and established models. The direct measurement of evapotranspiration is complex, expensive and time consuming, thus the estimation of evapotranspiration is usually done indirectly using the reference evapotranspiration (Ejieji *et al*., 2011).

The indirect measurement involves the use of empirical models which were developed to estimate ET. These models range from simple expressions which relate evapotranspiration to temperature or radiation to models having extensive data requirement and is only applicable when the required data are available and reliable (Alexandris *et al*., 2006). The combination method is the third approach and it is based on the original Penman-Monteith (PM) model which consists of the radioactive and the aerodynamic part. This model has been modified over the years because it produces good results when applied over different climatic regions.

According to Allen (2000), crop water requirement can be computed at various locations or in different seasons, using the reference evapotranspiration when water and environmental stress factors are applied, which are the ETc and ETcadj as given in equations 1 and 2.

$$ET_c = ET_o \times K_c \quad (1)$$

$$ET_a = ET_o \times K_c \times K_s \times ET_{cadj} \quad (2)$$

The main purpose of the research reported in this paper is to compare and evaluate the reliability of five evapotranspiration models for Uyo Local Government Area, AkwaIbom State in South-South, Nigeria. The mean monthly and annual RET values estimated by the four methods were compared with estimates by the standard Penman-Monteith (PM) method. The objective for such comparison is to examine the relationships and to determine the method that best predicted reference evapotranspiration as compared to the Penman-Monteith (PM) method. The second objective was to evaluate the reliability of the methods when data from nearby stations are used for estimating reference evapotranspiration. Thirdly, monthly correction factors for adjusting the models that predicted best were developed for their potential use at the study site.

2.0 MATERIALS AND METHODS

The five evapotranspiration models for estimating reference evapotranspiration for Uyo Local Government Area in South-South, Nigeria (one combination: Penman-Monteith (PM), two radiation based: Priestly Taylor (PT) and Jensen-Haise (JH) and two temperature based: Hargreaves-Samani (HS) and Blaney-Morin Nigeria (BMN)) were used to estimate reference evapotranspiration for Uyo. Weather parameters were collected from Nigerian Meteorological Agency (NIMET), headquarter, Lagos, Nigeria, from 1997-2017. The weather parameters collected were mean monthly values of air temperature including maximum and minimum temperatures, sunshine hours, wind speed, vapour pressure, relative humidity and rainfall.

The short- wave radiation(Rn), Stefan- Boltzman constant ($\delta Ta4$), black body radiation(δ TK4), rate of change of temperature with saturation vapour pressure (ea), Extra- terrestrial radiation (Ra), mean daily maximum duration of bright sunshine hours (N) and Psychometric coefficient (γ) were obtained from meteorological monograph. The mean monthly reference evapotranspiration were computed for each month using weather data for the month in the RET equation.

3.0 STATISTICAL ASSESSMENT

The Penman-Monteith (PM) was compared with the other four empirical ET_o estimates using statistical tests which include coefficient of determination (R^2), root mean square error (RMSE) and t-statistics. These statistical tests are as follows:

$$R^2 = \left(\frac{\sum_i^h=1 (Oi-\bar{o})(Pi-\bar{P})}{\sqrt{\sum_i^n=1 (Oi-\bar{O})^2} \; iu \sqrt{\sum_i^n=1 (Pi-\bar{P})^2}} \right)^2 \quad (3)$$

$$RMSE = \sqrt{\frac{\sum_i^n=1 (Oi-\bar{P}i)^2}{n}} \quad (4)$$

Where

O_i =ET FAO P-M_{56}

Pi=$ET_{EMPERICAL}$

$\bar{O}$i=mean of observed ET FAO-PM56 data

n=the total number of observation

$$ET_o = \frac{0.408\Delta(R_n+G)+\gamma\frac{900}{T_a+278}\mu_2 e_s - e_a)}{\Delta\gamma(1+0.34\mu_2)} \quad (5)$$

Where

ET_o = reference evapotranspiration ($mmday^{-1}$)

R_n= net radiation at the crop surface ($MJm^{-2}day^{-1}$)

G = soil heat flux density (MJm-2day-1)

T = is the mean daily air temperature (^OC)

U_2= wind speed at 2m height (ms^{-1})

e_s= saturation vapour pressure (KP_a)

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e_a= actual vapour pressure (KP_a)
e_s- e_a = saturated vapour pressure deficit (KP_a)
Δ = slope vapour curve (KP_a)
γ = psychometric constant ($KP_a\ ^{O}C^{-1}$)

Regression and correlation analyses were performed to examine the relationships of the mean monthly reference evapotranspiration estimates from the four methods and the mean monthly estimates by the standard Penman-Monteith (PM) method.
The Root Mean Square Error (RMSE) parameter was used to indicate the goodness of fit of reference evapotranspiration estimates as compared to the standard of Penman-Monteith (PM) method without any adjustment. The conclusion was further verified by calculating a t-statistics for each of these models as suggested by Jacovides and Kontaytinanis(1995). These authors suggested that the t-statistics should be used in conjunction with the RMSE to better evaluate a model's performance. Data from Meteorological Agency (NIMET) were applied to compute radiation for estimating the reference evapotranspiration in Uyo study area. Solar radiation (Rs) was first computed using the relation.

$$R_S = R_A\ (0.5n/N + 0.25) \quad (6)$$

Where: R_s is solar radiation, R_a is Extra- terrestrial radiation
n is sun shine hours and N is possible sun shine hours.

4.0 RESULTS AND DISCUSSION

Table 1: Long term (1997-2017) Mean monthly weather parameters for Uyo station Akwa Ibom State

Month	J	F	M	A	M	J	JL	A	S	O	N	D
TMAX (ºC)	25.9	29.2	28.5	27.7	26.7	27.5	25.2	26.4	27.3	28.3	29.6	30.6
TMIN (ºC)	15.4	19.6	18.7	19.9	19.0	18.7	19.4	16.7	17.2	18.5	18.9	17.3
AVET (ºC)	20.65	24.4	23.6	23.8	22.9	23.1	22.3	21.6	22.3	23.4	24.3	24.0
RAIN.F (mm)	25.7	36.3	91.5	169.3	247.0	304.3	374.2	319.3	357.8	247.2	56.2	8.5
SUNHRS (W/m^2)	1.6	2.2	1.6	1.7	2.1	1.1	0.7	0.8	0.7	1.2	2.0	1.9
RH (%)	56.6	60.4	67.2	75.7	77.6	78.0	78.9	83.7	85.3	80.4	79.1	63.5
VAP (mb)	22.7	27.3	29.2	29.5	30.6	28.2	27.4	29.5	29.7	30.4	28.1	26.3
WID Speed (mph)	95.6	93.2	120.5	115.4	130.6	112.6	116.5	155.4	126.3	120.3	114.4	111.1
Ra	12.1	13.8	14.6	15.2	14.1	14.3	14.7	15.0	15.4	15.9	14.5	14.1
Rs	4.2	3.7	3.5	3.8	3.8	2.7	2.4	2.2	2.6	2.8	3.5	3.3
Rs/A	0.0877	0.0993	0.0905	0.0936	0.0935	0.0730	0.0698	0.0672	0.0728	0.0789	0.0904	0.0875

Table 2: Mean monthly and annual reference evapotranspiration estimated by different models for Uyo Station

Month	BMN	HS	JH	PM	PT
J	171.4	124.5	42.0	82.9	41.3
F	168.2	135.2	53.5	80.5	53.5
M	154.3	156.2	54.7	100.0	57.0
A	130.5	135.4	49.3	87.9	53.9
M	123.7	128.5	48.2	106.2	58.3
J	104.3	95.3	28.9	93.5	40.3
JL	92.5	128.7	37.1	90.7	45.9
A	82.6	115.2	28.0	80.5	42.3
S	81.7	120.0	35.9	72.1	44.1
O	101.1	136.5	43.0	81.7	48.9
N	134.5	125.4	44.5	74.3	52.3
D	151.4	146.8	55.0	83.8	48.7
ANNUAL	**1496.2**	**1547.7**	**520.1**	**1034.1**	**586.5**

Table 3: Results of the regression analysis of mean monthly RET estimated by four methods against that estimated by Penman-Monteith (PM) methods for Uyo station

Estimation method	Regression equation	R^2	RMSE	T-Value	P
BMN	PM = 81.946 + 0.325 BMN	0.645	0.452	3.72	0.00
HS	PM = 71.264 + 0.603HS	0.629	0.473	3.20	0.00
JH	PM = 78.102 + 0.964 JH	0.631	0.480	3.31	0.00
PT	PM = 54.513 + 0.645 PT	0.705	0.478	3.78	0.00

Table 4: Results of comparative statistics of Penman-Monteith RET Prediction by four models for the period (1997-2017) for Uyo station using actual data

	BMN	HS	JH	PT
Total Annual RET (mm)	1496.2	1547.7	520.1	586.5
Intercept	81.946	71.264	78.102	54.513
Slope	0.325	0.603	0.964	0.645
T-Value	3.72	3.20	3.31	3.78
P-Value	0.00	0.00	0.00	0.00
R	0.807	0.785	0.784	0.735
R-Sq. (%)	64.5	62.9	63.1	70.5
RMSE	0.452	0.479	0.480	0.478
F-Value	6.27	5.89	5.90	7.01

The mean monthly and mean annual reference evapotranspiration obtained by averaging the monthly and annual values across the period of record for the station is summarized in Table 2.The mean annual RET estimated by the Penman monteith (PM) model as the standard tool for Uyo was found to be 1034.1mm. While the mean annual reference evapotranspiration estimated

by other four models were found to be 1496.2 for Blaney-Morin Nigeria, 1547.7 for Hargreaves-Samani, 520.1 for Jensen Haise and 586.5 for Priestly taylor.Blaney Morin Nigeria (BMN) and Hargreaves-Samani (HS) overestimated the Penman-monteith (PM) reference evapotranspiration which was used as a standard by 45% and 50%, respectively while Jensen- Haise(JH) and Priestly Taylor (PT) under-estimated the Penman monteith (PM) RET by 50% and 43%, respectively. This could be as a result of high climatic parameters or flatness of the region.

The results from the findings are in consonance with those of Anyanwu *et al.*, (2016), who reported similar overestimation of Penman-monteith (PM) by the two temperature based models and underestimation of Penman-monteith (PM) by the two radiation based models, although with lower percentage values for Blaney Morin Nigeria (BMN), Hargreaves-Samani (HS) and higher percentage values for Priestly Taylor and Jensen-Haise(TH) models. The highest total annual reference evapotranspiration estimates was predicted by Hargreaves-Samani, which is 1547.7mm and the lowest total annual reference evapotranspiration estimates was predicted by Jensen-Haise, which is 520.1mm. Considering the level of significant of the models used, all of them are significant at 1%.

According to Parmele and McGuiness (1974), the best method for estimating reference evapotranspiration as compared to Penman-Monteith (PM) method is the one with the intercept value closest to zero, the regression slope (m) value closest to 1.0, the smallest Root Mean Square (RMSE) and t-statistics values, the highest coefficient of determination (R^2).

The Root mean square error (RMSE) and t-statistics value were used as the main parameters for assessing the models that predict best in the area (Amatya*et al*., 1995).

Based on these results, using the criteria listed above, the Hargreaves-Samani (HS), Blaney-Morin Nigeria (BMN) and Priestly Taylor (PT) were ranked first, second and third respectively. Jensen Haise (JH) model was ranked fourth predictor even though it has a better regression slope than Hargreaves-Samani. The degree of fitness of the regression improved considering the F-value and the percentage of the total variation. The Hargreaves-Samani (HS) andBlaney-Morin Nigeria models performed better as there were significant improvements in all of the statistical parameters.

A graphical representation was equally considered for the station to best showcase or ascertains the relationship among the models. Also, it was clearly showed that the temperature based models performed better than that of radiation based models.

Table 5: Monthly correction factors for the two models that predicted best in the station

MONTH	PM	BMN	CF	PM	HS	CF
J	82.9	168.2	0.5	82.9	124.5	0.7
F	80.5	171.4	0.5	80.5	135.2	0.6
M	100.0	154.3	0.6	100.0	156.2	0.6
A	87.9	130.5	0.7	87.9	135.4	0.6
M	106.2	123.7	0.9	106.2	128.5	0.8
J	93.5	104.3	0.9	93.5	95.3	0.9
JL	90.7	92.5	0.9	90.7	128.7	0.7

A	80.5	82.6	0.9	80.5	115.2	0.7
S	72.1	81.7	0.9	72.1	120.0	0.6
O	81.7	101.1	0.8	81.7	136.5	0.6
N	74.3	134.5	0.6	74.3	125.4	0.6
D	83.8	151.4	0.6	83.8	146.8	0.6

Monthly correction factors were deduced for the two models that predicted best in the station for their potential use. The reason is to give or achieve a more accurate and reliable estimate without a sensitive error as compared to the standard Penman-Monteith (PM).

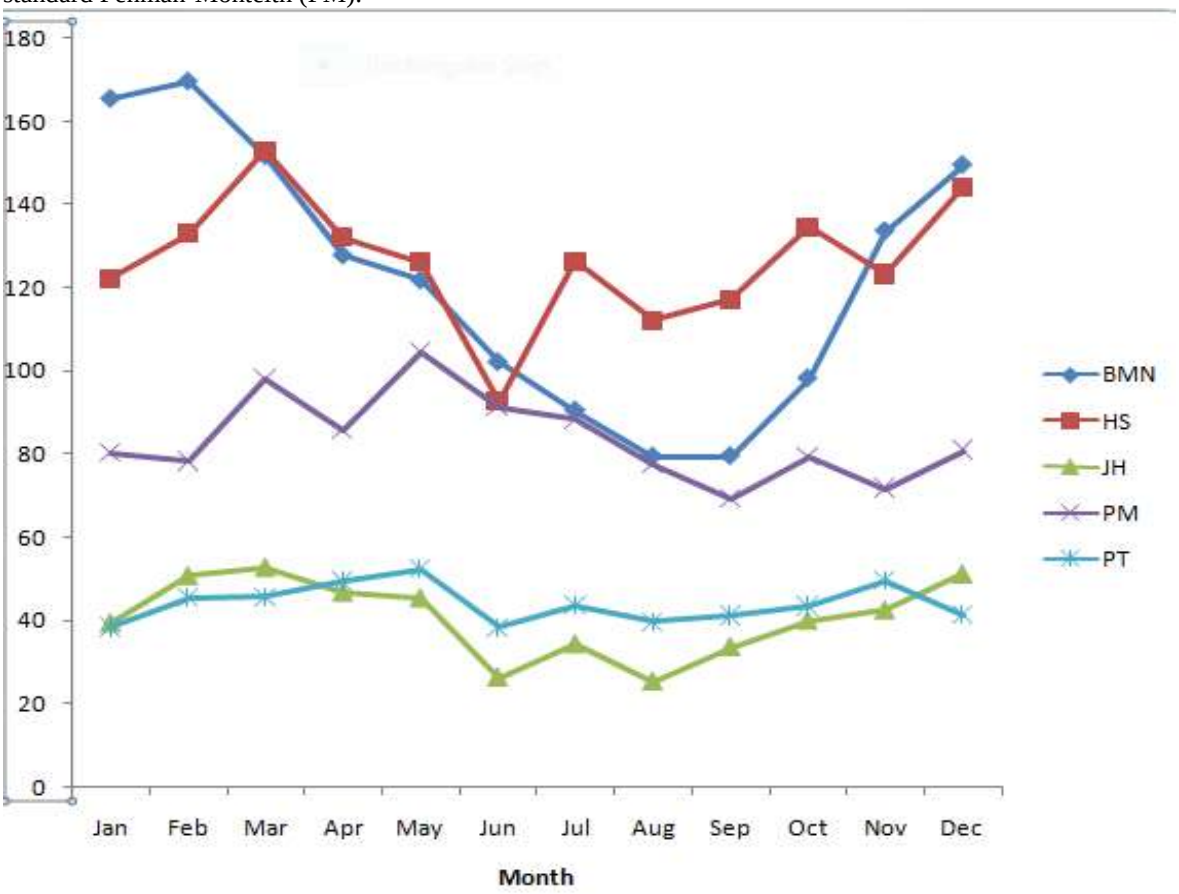

Figure 2: Graph of Mean monthly and annual Reference evapotranspiration estimated by different methods for Uyo station

5.0 CONCLUSION

The mean annual RET estimated by the Penman Monteith (PM) method as the standard for Uyo was found to be 1034.1mm. The mean annual reference evapotranspiration estimated by the other models namely, Blaney-Morin Nigeria (BMN), Hargreaves-Samani (HS), Jensen-Haise (JH) and Priestly-Taylor (PT) were found to be 1496.2mm, 1547.7mm, 520.1mm and 586.5mm for Uyo Local Government Area, respectively.

From the study, the best reference evapotranspiration (ET_o) estimate for Uyo station was given by Hargreaves-Samani. The temperateure based model was highly reliable since it predicted best

and also ranked first in all the analyses for the station. Monthly correction factors were developed for Hargreaves-Samani (HS) and Blaney-Morin Nigeria in table 5, since they ranked first and second in the station. The reason is to get an accurate and reliable reference evapotranspiration (ETo) estimate without sensitive error. The comparison of the methods for estimating RET in different stations is very paramount since accurate estimation of reference evapotranspiration (ETo), hence, crop water requirement is highly essential for efficient planning, operation and management of irrigation systems.

6.0 RECOMMENDATIONS

The research presented in this paper should be viewed as an exploratory view of the performance of reference evapotranspiration (ET_o) models in Uyo. It provides insight into the general performance of ET_o models in the area, which provide a starting point for further research.

The research presented in this paper also provides basic guidance to the agricultural community in Uyo, Akwa Ibom State, as to which models will give a better estimate of reference evapotranspiration (ET_o) in light of data availability, for use in irrigation scheduling.

These research results may help the agricultural industry to maximize the impact of its water resources by reducing stress on the water supply, thereby potentially increasing productivity, profit and environmental impact.

The results of reference evapotranspiration (ET_o) fromHargreaveSamani (HS) model in this study, apart from the generally accepted Penman-Monteith (PM) model are recommended for computing reference evapotranspiration (ET_o) for design, operation and management of irrigation systems and efficient agricultural planning in this location in Nigeria.

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SURVEY OF NOISE POLLUTION FROM SMALL-SCALE AGRO-PROCESSING MACHINES

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Abstract
Noise pollution is a problem all over the world despite its observed low level of recognition, especially in developing countries. Environmental noise pollution, a form of air pollution, is a threat to health and well-being. It is now more severe and widespread than ever before, and it will continue to grow because of sustained growth in highway, rail, air traffic and industries, which remain major sources of environmental noise. In factory and workplace, workers are exposed to high noise due to facilities or machines in routine. This study surveyed noise pollution concerns from 5 different small scale agro-processing machines. The noise level from different small scale agro-processing machines were measured using a noise level meter. **The noise level of the machines was comparable and varied between 97.1 dB to 112.3 dB.** The results from the study suggest that the machine operators/workers are prone to noise-induced hearing loss thus requiring noise protective equipment.

Keywords: *Noise, Pollution, Agriculture, Machines, Operators*

Introduction

Sound, a normal feature of our life, is a means of communication and entertainment among animals, including human beings. A low-level sound is pleasant whereas loud sound is unpleasant and is commonly referred to as 'noise'. Noise can be defined as an unpleasant and unwanted sound. Whether a given sound is as pleasant as music or as unpleasant as noise depends on its loudness, duration, rhythm and the mood of the person. But loudness is definitely the most significant criterion which converts sound into noise (Firdaus et al. 2010). Exposure to loud noise is indeed annoying and harmful too. Noise is a physical form of pollution and is not directly harmful to the life supporting systems namely air, soil and water but its effects are more directly on the receiver, that is, man (Gupta et al., 2018). Noise pollution is the result of modern industrialized urban life and congestion due to over population (Morillas et al., 2018). The importance of noise pollution as environmental problem is being recognized and the ill effects of noise on human health and environment are becoming evident with each passing day.

Noise is usually machine-created sound that disrupts activity or balance of human's way of life. It is a growing environmental problem that is increasingly becoming an omnipresent, yet unnoticed form of pollution not only in developing countries but also in developed countries (Passchier *et al*. 2000). However, developed countries such as Japan, Norway, Sweden, United Kingdom and the United States of America have laws regulating machine-generation of noise and protection of workers in workplaces. There is general agreement that exposure to sound levels less than 70 dB does not produce hearing damage, regardless of the duration of exposure and a general agreement that exposure for more than 8 hours to sound levels in excess of 85 dB is potentially hazardous. To put this in context, 85 dB is roughly equivalent to the noise of heavy-duty trucks on a busy road.

This study presents results of the survey of the level of noise pollution from small-scale agricultural processing machines in Nsukka, Enugu state.

Methods

The noise pollution survey was carried out at the milling section at Ogige Market, in the heart of Nsukka Local Government area of Enugu state. The market is a daily within and is surrounded by both commercial and residential buildings. The study area was selected after

reconnaissance and sweeping "noise proneness" surveys. The reconnaissance surveys were done in order to identify and characterize the study area and its environs. Evidences of prevalence of noise pollution based on presence of potential "noisy" commercial activities guided the initial study area selection. Additional site visits and investigations enabled the establishment of boundaries of the study area and identification of major small scale agro-processing machines within the market.

Measurement caution

When measuring noise, various important practical issues need to be taken into account. To obtain representative data in an agricultural processing facility, care was taken not to disrupt the work of the operators and that of the machines. Safety considerations are also important when measuring noise in an open environment. Therefore, prior to the survey through field observations, it was decided that the most appropriate technique for the measurement of noise in an open space or area was the use of a handheld sound level meter.

Machines selection

The machines were selected to be representative. The aim was to select machines with different functions. In total, 10 different agricultural processing machine owners within the surveyed area were approached to participate in the project. Of these, 5 machine owners agreed to a detailed noise and acoustic surveys of their facilities. The machines consist primarily of a hopper, 1- 2hp prime mover (electric motors or diesel/petrol engines), frame, shaft, bearing, grinding plate, the driving and driven pullets, v- belt, and discharge chute. The produce to be milled are loaded into the hopper and collected through the discharge chute.

Noise level surveys were conducted to assess daily noise exposures of the workers/operators. The following items were obtained for each machine: major food crop milled, duration of each operation, general noise characteristics (continuous, fluctuating or intermittent).

Noise measurement instrument

Noise level measurements were taken using a sound-level meter: integrating sound-level meter type TA8000 (SN 3R40010401). Tripod stands were used for holding and supporting the noise level meters in the right vertical and horizontal position.

Fig. 1. Noise level meter

Data collection and measurements

To measure noise levels, the tripod stand for the noise level meter was set up in the desired location. The noise level meter was then mounted on the tripod stand and the tripod stand adjusted so that the noise level meter was at a height of 1.2 m above the ground and at a distance of 0.2 m from the noise source in accordance with the European Union (EU) Directive 86/188/EEC. The 0.2 m distance is the typical distance from the machine to the worker or operator; in addition, noise level from the machines was also measured 25m from the machines in the North, East, South and West directions. **Data were collected in three blocks at the beginning, middle, and end of each operation.**

Questionnaire

All operators within the surveyed area were covered in the interviews and questionnaire survey. In the study, annoyance due to sound level was assessed with the following question: "The list below summarizes a number of aspects that you may be aware of and/or be annoyed by when you spend time in the area. Please indicate for each aspect whether you are aware of it and whether it annoys you." The response to each aspect was registered on a five-point scale: 1 "do not notice," 2 "notice, but not annoyed," 3 "slightly annoyed," 4 "rather annoyed," and 5 "very annoyed."

Results and Discussion

Machineries assessed for noise pollution

Five different agricultural product milling machines were surveyed in the study and the include cassava, Bambara nut, tomato, melon and soy bean milling machines (Fig. 2a - e)

Fig. 2(a) Cassava milling machine (b) Bambara nut milling machine (c) Tomato grinding machine

(d) Melon seed milling machine (e) Soy bean seed milling machine

Measured noise levels

In order to get the impression of noise pollution resulting from activities undertaken within the surveyed area, noise level surveys were carried out on the five different machines, A, B, C, D, and E. Table 1 presents results of noise level measurement recorded from the milling machines. The Bambara nut milling machine generated the highest mean noise level followed by the cassava and tomato milling machines. The melon seed milling machine had the lowest mean noise level. The recorded peak noise levels of the machines were also comparable. The recorded mean noise level from all machines surveyed is all higher than 90 dB which is the upper safe limit thus suggesting that all operators/workers on the machines are prone to noise-induced hearing loss (NIHL).

Table 1. **Noise Level Measurements from small scale milling machines**

Machine	Milled crop	Sound level (dB) at different stages of operation			Mean	Peak noise level
		Beginning	Middle	End		
A	Dried cassava	112	101.5	113.8	109.1	115
B	Bambara nuts	113.9	109.6	113.3	112.3	114.3
C	Tomatoes	109	104.1	109.6	107.6	110.6

D	**Melon seeds**	**99.6**	**94.3**	**97.5**	**97.1**	**99.6**
E	**Soy beans**	**106.5**	**103.6**	**104.8**	**105**	**105.2**

The seriousness of noise levels prevailing from the machines can be appreciated more in the backdrop of ILO (1977) recommended noise limits. ILO (1977) guidelines which state that a worker/operator should not enter an area or operate a machine in which the noise level is 115 dB or more without ear protection, even for a short time. It is noteworthy that workers/operators of these machines did not use any kind of ear protection and unsurprisingly, most of them reported that they were suffering from NIHL as well as tinnitus and ear itch.

From Table 1, it can be deduced that all the machines have relatively high noise level above 90 dB at the beginning, middle and toward the end of the milling operations. This may have been influenced by the structural state of the biomaterials at the different stages of the operation. **The high noise level from the Bambara nut milling machine could be due to the nature of the nuts which have a relatively high yield strength compared to the other biomaterials. An interesting observation made during the survey is that generally, the mean recorded noise level gradual increases between 12 – 2 pm and decreases slightly between 3 – 5 pm. The increase of noise level between 12 – 2 pm could be attributed to interference of other commercial activities as the area is always highly populated around this time compared to morning or evening periods.** This result shows that irrespective of the type of small-scale milling machine being operated, that the level of noise being perceived by the operator/worker exceeds the recommended noise limit for any commercial or industrial activities without ear protection and thus poses serious threats to the worker/operator.

Environmental noise pollution within and around the neighborhood of the surveyed area is mainly due to the small-scale agro-processing machines, with contribution from road traffic. According to BS 4142 (BSI 1990, 1997), noise levels in the neighborhood of the surveyed area are very likely to cause complaints. This is because the subjective impact of noise introduced into an existing noise environment depends on the level of the new noise relative to the preexisting noise level. In addition, if the new noise level is at 10 dB or more above the background level, complaints are highly likely. On the other hand, if the new noise level is 10 dB or more below the background noise, complaints are unlikely.

Perception of noise effects from the machines

To ascertain the perception of the operators and customers of these facilities to noise pollution from the milling machines, 130 persons including the operators were interviewed. The analysis revealed that most respondents were aware of the noise but ignorant of its effect on human attitude, fatigue, and behavior. About 38% of the respondents noted that the noise caused high irritation/annoyance while 23% reported no irritation from the noise. However, 39% of the respondents reported some level of irritation/annoyance due to the noise from the milling machines. It was noticed that workers/operators experience more of physiological deterioration such hearing impairment or eardrum rupture; this was observed during interaction with most of the workers/operators. These effects are rarely easily noticed and before it becomes evident, the long-term damage may have become permanent and irreversible.

Conclusion

The noise level recorded in this study for the machines were comparable and varied between 97.1 and 112.3 dB which is above the upper safe limit of 90 dB. The high level of

noise produced from the small-scale processing machines cause annoyance, disturbs sleep and noise-induced hearing loss (NIHL). In order to reduce noise, acoustic barriers, overhang baffles and acoustic foam may be installed at the processing facilities. And in order to reduce the noise at the source i.e., at the machine, dampers may be used between the machine and the foundation block to reduce vibration. Acoustic enclose should be installed either partially or fully to reduce noise. Another safety measure that should be taken at source is the use of earplugs by the operator(s).

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EFFECT OF GROUND INSULATION AND FEED STOCK ON PERFORMANCE OF FIXED DOME BIOGAS DIGESTER

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Abstract

The aim of the study is to determine the effect of ground insulation and feedstock on performance of fixed dome biogas digester. To achieve this, six identical fixed dome biogas digesters with volume of 32 liters were designed, constructed and used to carryout anaerobic digestion of three feedstocks namely cow abdominal waste, poultry droppings and 1:1 mixture of cow abdominal waste and poultry droppings. Three digesters buried underground for insulation while the remaining three kept on the surface uninsulated. The ANOVA result showed that there were significant differences in the slurry temperature, volume of biogas produced and slurry pH respectively at 5% significant levels. The highest volume of biogas and slurry temperature were produced by uninsulated fixed dome biogas digester with poultry droppings feedstock. The results generally indicates that the uninsulated fixed dome biogas digester performed better than the ground insulated fixed dome biogas digester. The range of pH, Volume of biogas and slurry temperature (ST) in all the feedstocks (Cow abdominal waste, poultry droppings and 1:1 mixture of Cow abdominal waste and poultry droppings) were 6.987-7.045, 2.342-3.460 liters and 27.975-28.717^{o}C, respectively. The highest volume of biogas and slurry temperature were produced by poultry droppings feedstock. The results showed that digesting only poultry droppings is performed better than digesting only cow abdominal waste and the 1:1 mixture of both feedstocks.

Keywords: Fixed Dome Biogas Digester, Ground Insulation, Feedstock, Cow abdominal Waste, Poultry Dropping

1.0 Introduction

Nigerian energy scenario, like in many other developing countries, is predominantly from fossil fuel which is non-renewable and environmentally unfriendly. This calls for renewable energy production efficiency including biogas production in the country. Biogas technology is specifically viable in the rural areas given the availability of cheap raw materials, its environmental friendliness, its renewable nature and its ability to be used for cooking, heating and lighting (Yong et al.,2019**). Most rural people in Nigeria rear cattle, goats, sheep and chicken, whose manure and kitchen wastes can be used as substrates to produce biogas (**Mukumba et al 2019**). Also, rural schools, hospitals restaurants and others institutions have a lot of the raw materials needed for biogas production** (Sichilalu et al.,2017).

Biogas is a flammable mixture of gases produced by anaerobic digestion of organic matter, such as animal mature, food waste, sewage waste, green waste and energy crops (Noraini et

al., 2017; Ilaboya et al., 2010)**. Anaerobic digestion is basically a microbiological process of decomposing organic material in the absence of oxygen to produce biogas (**Velmurugan et al.,2011)**, a mixture of methane 59%, carbon dioxide 40% and some traces of hydrogen sulphide (0.08%), nitrogen (0.89%) and water vapor (0.003%) (**Ahmad et al 2016)**. Production of biogas in anaerobic digesters is affected by many factors which include among others: carbon/nitrogen ratio, pH value, presence of volatile substances, biological oxygen demand (BOD), chemical oxygen demand (COD), temperature, substrate loading rate and biodegradability of the substrate ((**Mahanta et al., 2005; Niselow, 2019; Cioabla et al.,2012).

Temperature inside the digester is one of main factors influencing biogas production since it influences the rate of reaction and multiplication of the microbes responsible for gas production (Teleszewski et al.2018)**. Biogas yield rate increases by about two times for every 5 ◦C rise in temperature up to 35 ◦C (**Karimov et al., 2012)**. This means that the methanogenic bacteria multiplication increases with temperature in the mesophilic temperature range (30–40 ◦C) (Buan, 2018). Variations in the slurry temperature sacrifice methane production since the methane forming bacteria are very sensitive to rate of temperature variation (**Fu et al.,2015)**. To sustain a constant biogas production from any anaerobic digester the health of the microorganism thriving in the digester environment need to be provided for, that is preferred substrate, favorable temperature and pH. Thus, temperature regulation is an important design criterion when designing anaerobic digesters** (Nelsen et al., 2017).

Unfortunately, in Nigeria and many developing countries, most domestic bio-digesters are built without a heating system or means of maintaining a stable temperature inside the digester. This means biogas production from such digesters will vary during the day following temperature variations, decreasing greatly during the nights and in winter. A means to maintain a stable temperature in a digester is really necessary for a stable supply of biogas and extracting as much gas as possible from substrates. A stable temperature in a bio-digester improves the quantity and quality of the produced biogas. Hence the need to evaluate and analyze different methods of substrate heating and come up with a recommendable method which enhances homogeneous and uniform heat and temperature profile in the digester.

Digester temperature can be controlled in a number of ways such as sufficiently insulating the digester, heating the substrate using heat exchangers or using heating elements, placing digesters in water baths or in greenhouses and blowing steam in the digester. Many studies have been conducted to find out how best a constant substrate temperature can be maintained in anaerobic bio-digesters (Yuan et al., 2011; Karmov et al.,2012; Sichulalu et al.,2017; Houngue et al.2017). In all these cases was noticed an increased productivity of biogas showing that maintaining constant temperature in a digester promotes productivity and stability. The substrate temperature in a digester is greatly affected by environmental temperature to such an extent that no amount of insulation can completely curb temperature fluctuations (Pham et al.,2014; Mukumba et al.,2015). Temperature in the digester also must be restored to the set point immediately if the stability is disturbed by temperature variation (Chapleur et al., 2016; Kim et al., 2016). Heating the substrate controllably remains the most applaudable options to maintain constant digester temperature and ensuring process stability and biogas productivity. Hence the **aim of the study is to determine the effect of ground insulation and feedstock on performance of fixed dome biogas digester. The specific Objectives of this study are to: design and construct a batch biogas digester, determine the effect of ground insulation of the digester on biogas yield, determine the impact of substrate properties on methane production and determine the effect of co-digestion on biogas yield**

2.0 MATERIALS AND METHODS

2.1 Collection and Preparation of Feedstock

The cow abdominal waste was obtained from abattoir in Ikpa Market Nsukka (latitude: 6°51'33.41" and longitude: 7°23'52.51"), **Enugu state Nigeria while the poultry droppings was collected in bags from the National Centre for Energy Research and Development, University of Nigeria Nsukka** (latitude: 6°51'33.41" and longitude: 7°23'52.51"). The feedstocks respectively were mixed with water in the ratio of 1:2 (feedstock:water). The operational mode was the batch method using an operational mesophilic temperature. Biomethanation of these slurries was carried out for energy production in a fixed dome reactor and cumulative biogas production; slurry temperatures were monitored throughout the study. The digester was tightly corked with rubber stopper to create anaerobic condition and connected to a gasometrical chamber.

2.2 Experimental Set up

Six identical fixed dome biogas digesters were designed and constructed for the study. The anaerobic experiment was set up the premises of the National Centre for Energy Research and Development, University of Nigeria Nsukka. Three of the developed fixed dome biogas digesters were recharged with each of the three feedstocks respectively and were buried in the ground to insulate the digester while the remaining three digesters were also fed with the three feedstocks respectively and kept on the surface without insulation (Fig.1). The six digesters each with a volume of 32 liters were allowed to run concurrently under the same ambient temperature for a period of 30 days. To ascertain the performance of the digester's physicochemical properties of the biogas production process were determined using standard procedures. Each experimental digester was fed through the inlet with 14 kg of fresh dairy cow dung thoroughly mixed with tap water to bring the weight of slurry to 20 kg. Mixing of dung and water was provided by manual mixing in a water bath by hand. The loading rate was determined using the procedure described by FARMESA (1996). The inlets were securely sealed and the complete assemblies of digesters carried and placed in trenches, which were dug in an open space in National Center for Energy Research and Development, University of Nigeria Nsukka and natural conditions (NC) to accommodate them. Provision for the agitation of the digester contents during the digestion process was not made because its effect on small-scale digesters is considered minimal (Barnett et al., 1978). Emptying of sludge was done through the inlet opening after elapse of a given hydraulic retention time.

Fig.1. Experimental Set Up of Fixed Dome Biogas Digesters (A)Buried Underground (B) kept on the surface uninsulated

2.3 Laboratory Analysis of Samples

Three digesters were charged and buried under ground for insulation while the remaining three were charged and kept on the surface uninsulated. The experiment lasted for 30 days. The laboratory analysis was based on standard procedures. In a batch digester the waste is put into the plant with a starter, if available, and the gas collected as it is given off. The time in which biogas production was simply negligible or equal for both sites was considered the hydraulic retention time. At this point the experimental digesters were stopped and their contents discharged. The daily gas yields

were measured using jar displacement method and the corresponding temperature using Delta-T logger device. The pH was determined using hand held pH meter.

2.4 Statistical Analysis

One way ANOVA was used to determine the effect of the treatment on the response of the biogas production parameters. Multiple comparison of means was carried out using Duncan Multiple Range Test at 5% Probability. Statistical analysis and Graphical Plots were carried out using statistical Package for Social Sciences (SPSS) Version 21.0.

3.0 RESULT AND DISCUSSIONS

3.1 Variation of Slurry Temperature, pH and Volume of Biogas produced in different feedstocks

The variation of Slurry temperature, pH and volume of biogas produced in different feedstocks during the 30 days anaerobic digestion is presented in Figs.2A, Fig. 2B and Fig. 2C respectively.

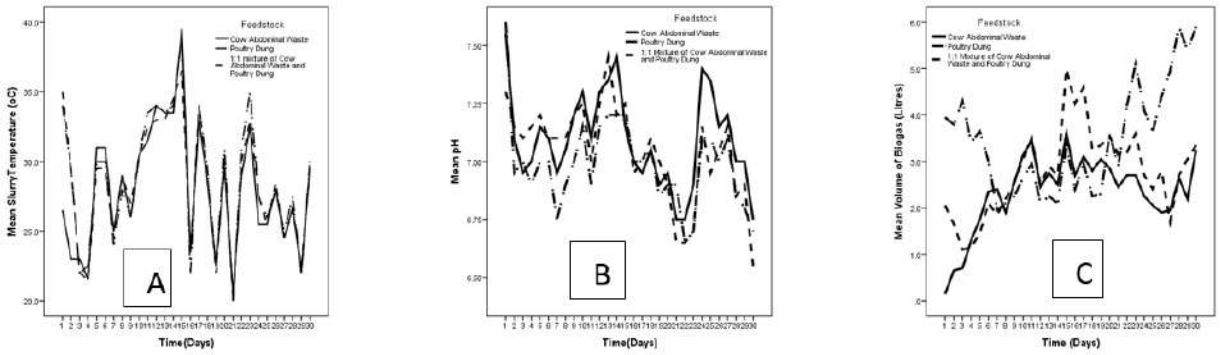

Fig.2. Variation of (A) Slurry Temperature, (B) pH and (C)Volume of Biogas produced in different feedstocks

3.2 Graphical Comparisons of the Effects of Ground Insulation of Digester and Feedstock on Slurry Temperature, pH and Volume of Biogas.

The comparison of the effects of ground insulation of digester and feedstock on slurry temperature, pH and volume of biogas produced are presented in Fig.3A, Fig..3B and Fig.3C respectively.

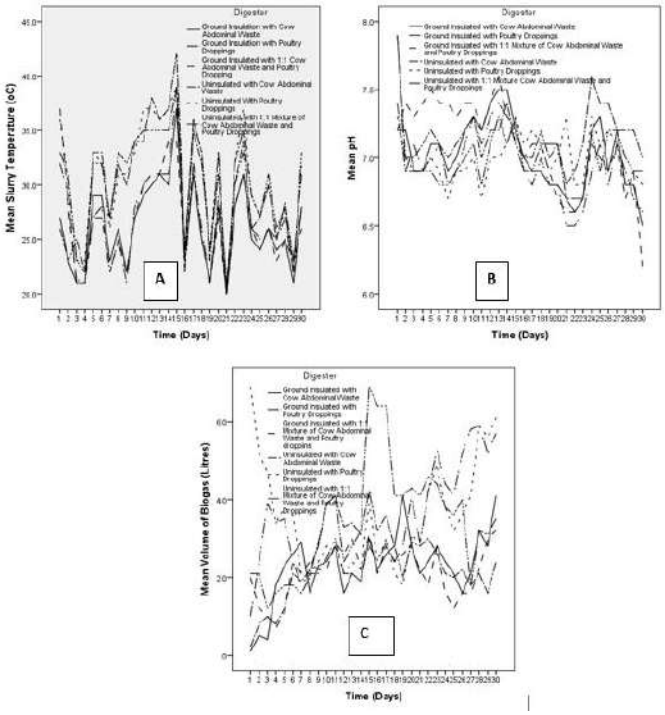

Fig.3 Comparison of the Effects of Ground Insulation of Digester and Feedstock on Measured Parameters During the 30 Days Anaerobic Digestion (A)Slurry Temperature (B)Slurry pH (C) Volume of Biogas Produced

3.3 **Statistical Analysis Results**

3.3.1 The ANOVA Results of the effect of ground insulation and feedstock on fixed dome biogas digester performance

The ANOVA Table of the Effect of Ground insulation and Feedstock on Fixed Dome Biogas Digester Performance at 5% Significant Level is also Presented in Table 1. Table 1 showed that ground insulation of digester and feedstock have significant effect on the performance of the fixed dome biogas digesters. Table 1 indicates that there are significant differences in the slurry temperature, volume of biogas produced and slurry pH respectively at 5% significant levels.

Table 1 ANOVA Table of the Effect of Ground insulation and Feedstock on Fixed Dome Biogas Digester Performance at 5% Significant Level

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	.829	5	.166	2.672	.024*
	Within Groups	10.789	174	.062		
	Total	11.618	179			
Volume	Between Groups	61.674	5	12.335	9.126	.000*
	Within Groups	235.176	174	1.352		
	Total	296.850	179			
ST	Between Groups	609.707	5	121.941	5.349	.000*
	Within Groups	3966.475	174	22.796		
	Total	4576.182	179			

*= Statistically significant at 5% probability(α=0.05)

3.3.2 Multiple Comparison of the Mean of Measured Digester parameters Using Duncan Multiple Range Test (DMRT)

The multiple comparison of the mean of measured digester parameters using Duncan Multiple Range Test at 5% significant level is presented in Table 2.

Table 2 Multiple Comparison of the Mean of Measured Digester parameters Using Duncan Multiple Range Test at 5% significant Level

S/No.	Insulation	Feedstock	pH	Volume of Biogas (Litres)	Slurry Temperature (^{O}C)
1	Ground Insulation	Cow Abdominal waste	7.023a	2.280a	26.167a
2	Ground Insulation	Poultry Droppings	6.973a	3.347b	26.967a
3	Ground Insulation	1:1 Mixture of Cow Abdominal Waste and Poultry Droppings	7.100ab	2.167a	26.567a
4	Uninsulated	Cow abdominal Waste	7.163b	2.403a	29.783b
5	Uninsulated	Poultry Droppings	7.000a	3.573b	30.467b
6	Uninsulated	1:1 Mixture of Cow Abdominal Waste and Poultry Droppings	6.990a	3.393b	30.333b

Mean values followed by the same lower-case letters are significantly the same at 5% probability level.

3.3.3 The mean plots of volume of biogas produced, slurry temperature and pH for the six different digesters

The mean plots of volume of biogas produced, slurry temperature and pH for the six different digesters studied are presented in Fig..4A, Fig.4B and Fig.4C, respectively. The Descriptive Statistics of the Performance of the Ground Insulated and Uninsulated Fixed Dome Biogas Digesters with Different Feedstocks showed that the range of values for pH, volume of biogas and slurry temperature were 6.973-7.163, 2.167-3.573litres and. 26.167-30.467^{o}C, respectively. The highest volume of biogas and slurry temperature were produced by digester 5 (Fig.4A and Fig.4B), indicating that the highest volume of biogas and slurry temperature were produced by uninsulated fixed dome biogas digester with poultry droppings feedstock. The highest slurry pH was produced by digester 4(Fig.4C), indicating that the highest pH evolution was from uninsulated fixed dome biogas digester with cow abdominal waste feedstock. The results generally indicates that the uninsulated fixed dome biogas digester performed better than the ground insulated fixed dome biogas digester with respect to the volume of gas produced, pH and Temperature evolution.

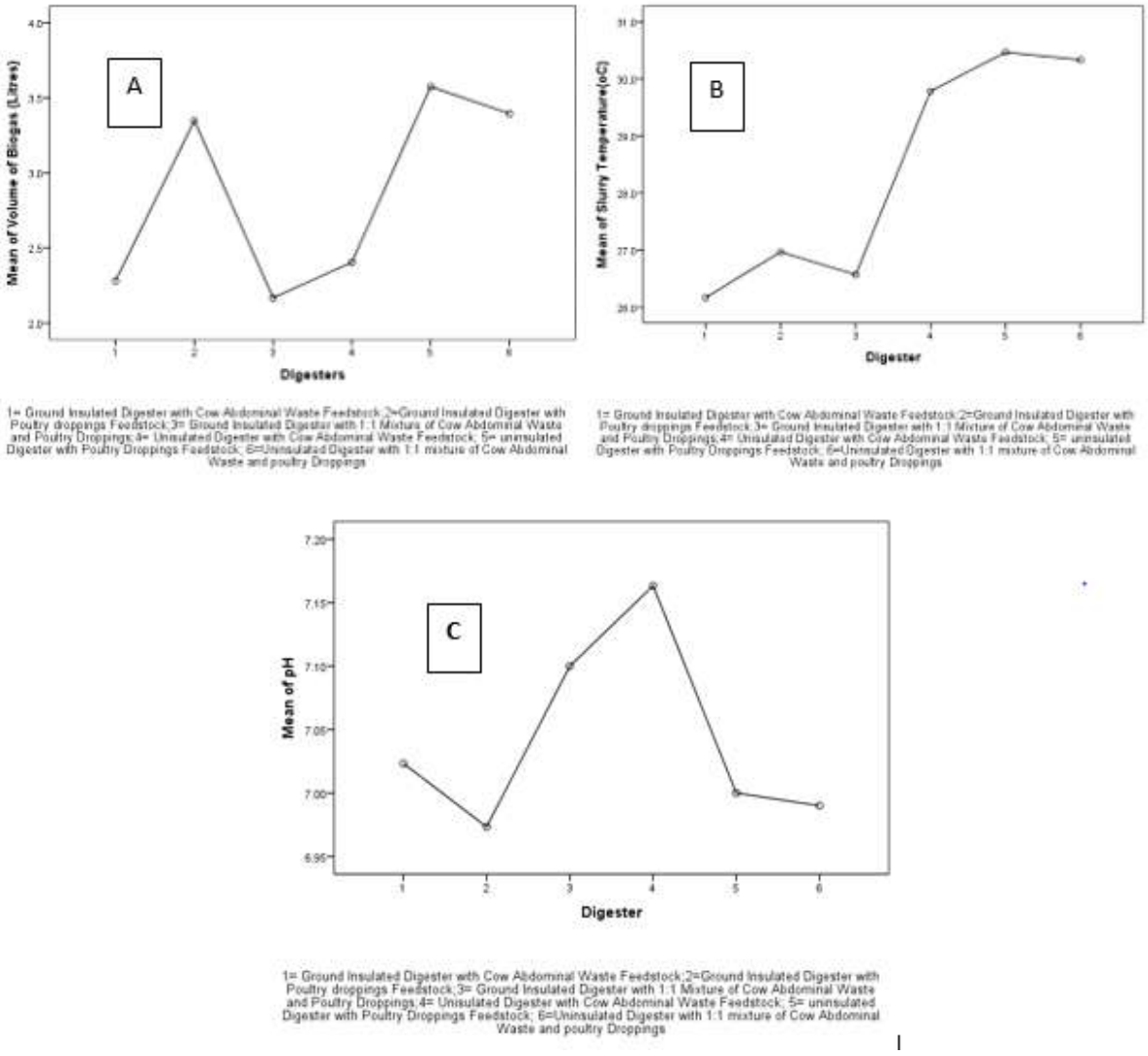

Fig.4. **Mean plots of parameters for the six different digesters studied (A) volume of biogas produced (B) slurry temperature evolution (C) pH evolution**

3.3.4 The ANOVA of the Effect of Feedstock on Fixed Dome Biogas Digester Performance at 5% Significant Level

The ANOVA Table of the Effect of Feedstock on Fixed Dome Biogas Digester Performance at 5% Significant Level is presented in Table 3. Table 3 indicates that Feedstock has significant effect on volume of Biogas produced by the fixed dome biogas digester (α=0.05) but has no effect on both pH and slurry temperature at 5% significant levels.

Table 3 ANOVA Table of the Effect of Feedstock on Fixed Dome Biogas Digester Performance at 5% Significant Level

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	.342	2	.171	2.687	.071^{NS}
	Within Groups	11.275	177	.064		
	Total	11.618	179			
Volume	Between Groups	38.104	2	19.052	13.033	.000*
	Within Groups	258.746	177	1.462		
	Total	296.850	179			
ST	Between Groups	16.936	2	8.468	.329	.720^{NS}
	Within Groups	4559.246	177	25.758		
	Total	4576.182	179			

*= Statistically significant at 5% probability(α=0.05);^{NS}= Not Significant at 5% probability(α=0.05)

3.3.5 Multiple Comparison of The Mean Response Of Parameters Due To Treatment Of The Digesters With Different Feedstocks Using Duncan Multiple Range Test

Table 4 showed the multiple comparison of the mean response of parameters due to treatment of the digesters with different feedstocks using Duncan Multiple Range Test at 5% significant level.

Table 4 Multiple Comparison of the Mean Response of parameters due to Treatment of the Digesters with Different Feedstocks Using Duncan Multiple Range Test at 5% significant Level

S/No.	Feedstock	pH	Volume of Biogas (Litres)	Slurry Temperature (^{O}C)
1	Cow Abdominal waste	7.093b	2.342a	27.975a
2	Poultry Droppings	6.987a	3.460c	28.717a
3	1:1 Mixture of Cow Abdominal Waste and Poultry Droppings	7.045ab	2.780b	28.450a

Mean values followed by the same lower case letters are significantly the same at 5% probability level

3.3.6 The Mean Plots of Volume of Biogas Produced, Slurry Temperature and pH For the Three Feedstocks Studied

The mean plots of volume of biogas produced, slurry temperature and pH for the three feedstocks studied are presented in Fig.4A, Fig.4B and Fig.5C, respectively. The Descriptive Statistics of the Performance of the fixed dome biogas digester due to the Different Feedstocks showed that the range of pH, Volume of biogas and slurry temperature (ST) in all the feedstocks (Cow abdominal waste, poultry droppings and 1:1 mixture of Cow abdominal waste and poultry droppings) were 6.987-7.045, 2.342-3.460 liters and 27.975-28.717^{o}C, respectively. The highest volume of biogas and slurry temperature were produced by feedstock 2 (Fig.5A and Fig.5B), indicating that the highest volume of biogas and slurry temperature were produced by poultry droppings feedstock. The highest slurry pH was produced by feedstock 1(Fig.5C), indicating that the highest pH evolution was from cow abdominal waste feedstock. The results generally indicates that the poultry droppings feedstock performed better followed by the cow abdominal waste feedstock in the biogas production Process.

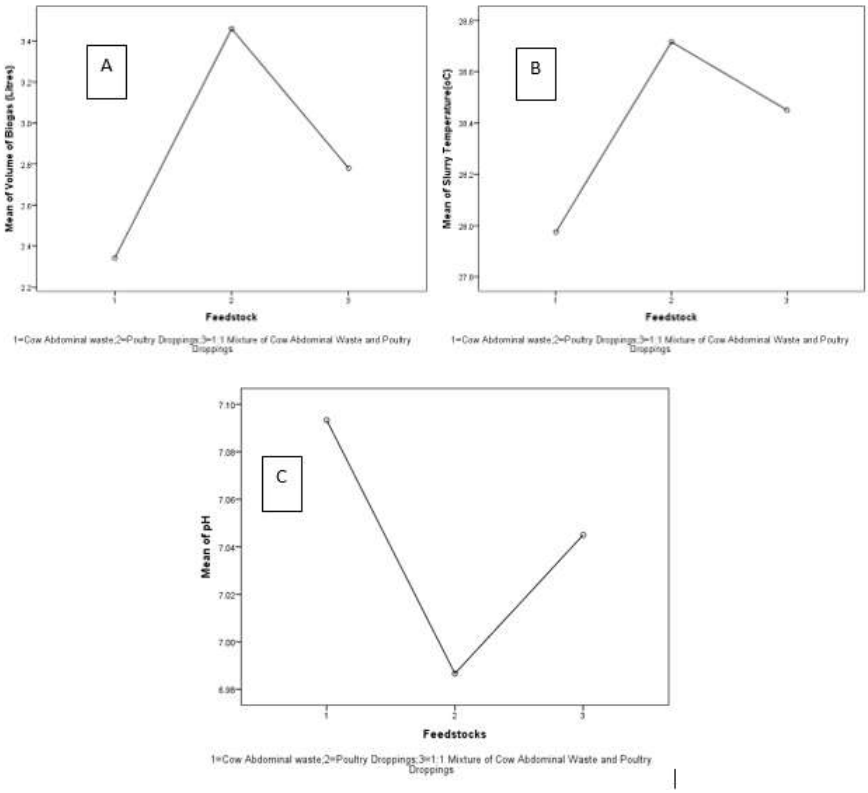

Fig.5. **Mean plots of parameters for the three different Feedstock studied (A) volume of biogas produced (B) slurry temperature evolution (C) pH evolution**

4.0 CONCLUSION

The study has showed that ground insulation of digester and feedstock have significant effect on the performance of the fixed dome biogas digesters, there are significant differences in the slurry temperature, volume of biogas produced and slurry pH respectively at 5% significant levels. The highest volume of biogas and slurry temperature were produced by uninsulated fixed dome biogas digester with poultry droppings feedstock. The highest pH evolution was from uninsulated fixed dome biogas digester with cow abdominal waste feedstock. The results generally indicates that the uninsulated fixed dome biogas digester performed better than the ground insulated fixed dome biogas digester with respect to the volume of gas produced, pH and Temperature evolution. The range of pH, Volume of biogas and slurry temperature (ST) in all the feedstocks (Cow abdominal waste, poultry droppings and 1:1 mixture of Cow abdominal waste and poultry droppings) were 6.987-7.045, 2.342-3.460 liters and 27.975-28.717oC, respectively (Table 4.4). Feedstock has significant effect on volume of Biogas produced by the fixed dome biogas digester (α=0.05) but has no effect on both pH and slurry temperature at 5% significant levels. The highest volume of biogas and slurry temperature were produced by poultry droppings feedstock. The highest pH evolution was from cow abdominal waste feedstock. The results generally indicates that the poultry droppings feedstock performed better followed by the cow abdominal waste feedstock in the biogas production Process. We recommend further research using more feedstocks, different mixing, ratios and different insulation methods with laboratory analysis of more physicochemical properties of the biogas production process.

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OPTIMISATION OF THE OIL YIELD FROM FLUIDISED CATALYTIC CRACKING OF OIL SHALE

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Abstract
Alternatively, an unconventional fuel oil is obtained by fluidised catalytic cracking of oil shale using abundant deposit of gypsum mineral resources as catalyst. Shale oil is an unconventional source of energy which is abundantly present in some parts of Nigeria like Abakaliki, Bida, Adamawa, Benue, Borno and among others as reported by olawuyi in 2014. The material is significant to Nigeria's economic sustainability but yet to be tapped efficiently. The aim of this work is to improve the yield of fuel oil from shale oil via fluidised catalytic cracking using abundant gypsum as catalyst. In this research work, oil shale sample obtained from Lokpanta area of the Abakiliki anticlinorium in Ebonyi State, an epicenter in the Lower Benue trough. Prior to the fluidised catalytic cracking of shale oil using a fabricated fluidised bed reactor, proximate and ultimate analysis was carried out to investigate the obtained shale oil. The total organic carbon content (TOC) is 1.564; experimental reports from Z.jiang et al. (2016) in Bonam Sag shows a TOC% Concentration range of 1-2%. Therefore the experimental result shows that Lokpanta has a good organic matter which makes it fit for the optimisation of oil yield via a fluidised catalytic bed reactor along with other analytical assessment in subsequent research findings.

Keyword: *Lokpanta, Oil Shale, Gypsum, Total Organic Carbon (TOC), Fluidised Catalytic Bed Reactor (FCBR)*

1. Introduction

The advent of oil and gas exploration in Nigeria dates back to 1908, when the Nigerian Bitumen Corporation commenced activities in the Araroni area (Daniel,2016). These pioneered effort ended abruptly because of the outbreak of the First World War in 1914. However, petroleum exploration activities in Nigeria reopened in 1937 when Shell-BP explored for oil in Owerri, Imo State. This effort expanded to other environs in the Niger Delta; and in 1956, they struck oil at Oloibiri in present day Bayelsa State. Thenceforth, the Niger Delta region became the Nation's bumper scene of intensive exploration and production of conventional oil and gas until the 1980s, when oil shale was discovered in the Benue Trough, Nigeria (Ehinola *et al.,* 2005)**.** Before then, oil shale deposits in the form of wide spread had been reported in many countries like USA, Estonia, China and Brazil (Liive, 2007). The United States has the largest oil shale resources in the world, with the total of 3340 billion tons; which constitutes 62% of the world's known recoverable oil-shale potential (Mason *et al;* 2015). Also, other countries with substantial oil shale reserves include: Israel, Romania, Egypt, Nigeria, Germany, Jordan, Morocco, Canada, Brazil and many others. In addition, Olawuyi (2014) mentioned that studies have suggested that shale deposits are abundantly located in Nigeria, mostly in Benue, Abakaliki, Borno, Adamawa and on other south-eastern and north-eastern parts of Nigeria.

Currently, Nigeria and the world face significant challenges to meet future demand for liquid fuels. These challenges are caused by rising demand for oil and other petroleum products. The world demand for petroleum is expected to continue to increase over the next twenty-five years from approximately 80 million barrels to nearly 120 million barrels-per-day by 2025 (Biglarbigi *et al.,* 2007). Therefore, the question now is, where will the additional supply comes from to cushion the increased demand? So far, the Organization of Petroleum Exporting Countries (OPEC) productive capacity has not increased as fast as production demand (Cameron *et al.,* 2006). In Nigeria presently, the oil and gas sector is being bombarded with numerous problems which include: the rising demand for oil, gas and other petroleum products, a turn-around decrease in conventional oil and gas reserves, worldwide volatility of oil prices, among others (Obasi, 2013). This situation has exposed the dependency of the Nation in conventional

crude oil to recession; as about 75 percent of Nigeria's revenue is from crude oil (Agbaeze *et al.*, 2015). On the other hand, Jaber *et al* (2008) presented an economic analysis of oil shale development in Jordan using various methods of extraction of the shale oil; this include; retorting, in situ process and surface mining. They establish that above ground retorting method at plant production capacity of 50,000 barrel – per-day of shale oil, seems promising for El Lajjun oil Shale deposit in Jordan. Therefore, this paper assessed the optimization of the production energy of shale oil using fluidized sets of different catalyst.

2. Experimental Methodology

2.1. Determination of moisture content

In determining the moisture content of Lokpanta oil shale, 1gm of the sample is measured into a crucible and placed in an oven drier operating under the temperature of 60^{o}C for an hour. The weight of the latter was measured and recorded. The percentage of moisture is calculated as follows:

$$\%\text{Moisture} = \frac{W2 - W3}{W2 - W1} \times 100$$

Where:

W_1=initial weight of empty crucible,
W_2=weight of crucible sample before drying,
W_3=Final weight of crucible + sample after drying.
% Total solid (dry matter) =100-%moisture

2.2. Determination of ash content

The determination of ash content is carried out by exposing the crucible containing 1gm of Lokpanta oil shale without the covering the crucible with a lid when heating inside a Bunsen Furnace. The percentage of ash is calculated as follows:

$$\%\text{Ash(dry basis)} = \frac{weight\ of\ ash\ \ formed}{weight\ of\ original\ sample} \times 100$$

$$\%\text{Ash(dry basis)} = \frac{W3 - W1}{W2 - W1} \times 100$$

Where:

W_1= weight of empty crucible without lid,
W_2= weight of crucible without lid + sample before drying and/or ashing.
W_3=weight of crucible without lid + ash

2.3. Determination of Volatile Matter

The determination of volatile matter is carried out by covering the crucible with a lid when heating inside a Bunsen Furnace. The percentage of ash is calculated as follows:

$$\%\text{Volatile Matter} = \frac{weight\ of\ Volatile\ Matter}{weight\ of\ original\ sample} \times 100$$

$$\%\text{Ash(dry basis)} = \frac{W3 - W1}{W2 - W1} \times 100$$

Where:

W_1= weight of empty crucible,
W_2= weight of crucible + sample before drying and/or volatising
W_3=weight of crucible + volatile matter

2.4. Determination of Total Organic Carbon

This analysis shows the amount of carbon that is found in an organic compound.

2.5. Determination of Percentage Fixed Carbon

The percentage of fixed carbon was determined using the relationship below:

$$\%\text{Fixed Carbon} = 100 - \%(Moisture + VolatileMatter + Ash)$$

2.6. Determination of Carbon Content

The percentage of Carbon is calculated as:

$$\%\text{ of Carbon} = \frac{weight\ increase\ \ of\ KOH}{weight\ of\ original\ sample} \times \frac{12}{44} \times 100$$

2.7. Determination of Hydrogen Content

The percentage of Hydrogen is calculated as:

$$\%\text{ of Hydrogen} = \frac{weight\ increase\ \ of\ Calcium\ Chloride}{weight\ of\ original\ sample} \times \frac{2}{18} \times 100$$

2.8. Determination of Nitrogen Content

The digestion of sample was first carried out on a ***Kjeldatherm Apparatus***. 1g of raw Lokpanta oil shale sample, ½ spoon of powdered copper sulphate ($CuSO_4$) and 15ml of sulphuric acid (H_2SO_4) were all measured out and mixed together. The solution was placed into a Kjeldatherm Apparatus and was allowed to digest for 3hours, so as to obtain a grayish coloured extract for nitrogen determination.

The long expected determination of nitrogen content was carried out on a ***Markham's Apparatus***, 10ml of the obtained digest was added to 10 ml of boric acid and while 40% of NaOH was added intermittently so as to produce a dark bluish colour before titration. Hydrochloric acid of 0.01molarity was used to titrate the obtained dark bluish extract. A light greenish colour was formed during the titration indicating the presence of Nitrogen.

The percentage of Nitrogen is calculated as follows:

$$\%\text{Nitrogen} = \frac{TV \times Nacid \times 0.01401 \times 5 \times 100}{W}$$

$T_V = V_S - V_B$

Where:

T_V= titre value
V_S=Vol. (ml) of acid required to titrate sample
V_B=Vol. (ml) of acid required to titrate the blank
Nacid= normality of acid (0.01N)
W=weight of sample in grams
Conversion factor=0.01401
Dilution factor=5

2.9. Determination of Sulphur Content

Bomb calorimeter is washed which contain sulphur which is precipitated as Barium Sulphate ($BaSO_4$) is filtered, ignited and weighted.

$$\%\text{ of Sulphur} = \frac{Weight\ of\ Barium\ Sulphate}{Weight\ of\ original\ sample} \times \frac{32}{233} \times 100$$

2.10. Determination of Oxygen Content

The percentage of Oxygen is calculated as:

$$\%\text{ of Oxygen} = 100 - (\%\ of Carbon + \%\ of Hydrogen + \%\ of Sulphur + \%\ of Nitrogen + \%\ of Ash$$

3. Discussion of results

The discussion centres on the proximate and ultimate analysis of Lokpanta oil shale.

3.1 Proximate and Ultimate analysis of oil shale

Table 3.1 Composition of Lokpanta oil shale

Proximate	Value (wt %)	Ultimate	Value (wt %)
Moisture Content	0.87	Carbon	49.239
Volatile Content	99.4	Hydrogen	5.123
Fixed Carbon	-94.57	Nitrogen	0.095
Ash Content	94.3	Sulphur	8.1175
TOC	1.564	Oxygen	37.426

The total organic carbon (TOC) is 1.564; the experimental result shows that Lokpanta has a good organic matter. The characteristic values of other parameters of the proximate and ultimate analysis support the TOC result, as compared to a paper reported by Zaixing Jiang and co. in 2016.

4. Conclusions

The proximate and ultimate analysis study shows that there is a great need for researchers to embark on the optimisation yield of oil from Lokpanta oil shale reserves. The first step in achieving this will be a Design of Experiment (DOE), which will enable the comparison between actual and approximate results. The second stage will be removal of moisture from the material which will be aided by a Fluidised Catalytic Bed Reactor. The result of the Total Carbon Content (TOC) which records 1.564 indicating its characteristics as a good organic material will be further justified by Theromogravimetric analysis (TGA), Fourier Transform infrared (FTIR) and Gas Chromatography/Mass Spectroscopy (GCMS).

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DEVELOPMENT OF AN INTERACTIVE DESIGN TOOL FOR A MEDIA BASED AQUAPONIC SYSTEM (ID-MAS)

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Abstract
Harnessing the numerous advantages of the aquaponics system needs an understanding of the system design. This can be achieved through experimentation and/ or modeling. Experimentation is time consuming, laborious and costly. Modeling could therefore be an alternative. This study aimed at developing an interactive design tool for a media based aquaponics system *(ID-MAS).* The mathematical relationship between input data such as fish stocking density, culture duration, type of crop, feeding rate, protein content of fish feed etc. and output information such as; number of plant, pond dimension, Total Ammonia Nitrogen *(TAN),* feed conversion ratio *(FCR)* etc. are coded with Microsoft Excel Visual Basic Application *(VBA)* to predict a hydroponic grow bed capacity that can handle effluent from given fish pond. The developed modeling tool; *ID-MAS* was tested and compared with an experimental data of a media based aquaponic system, gotten from HiPIC Research Group UNN. The predicted result was observed to have close range with the experimental result showing that the stocking density of Catfish is directly proportional to the number of plant to be introduced in the system (tomatoes and pepper plant) where other factors remains constant. Hence, *ID-MAS* when fully developed will assist farmers and other stakeholders in sizing and managing aquaponic farming.

Keywords**:** *Aquaponics, Media Based, Interactive Design tool, System*

1.0 Background and Motivation of the study

History has proven that fish has been a major source of protein for humans and its demand has risen higher than the rate of production (Pfeiffer 2010). Intensive fish production begun in the mid-1800s (Soderberg 1994), and currently the fish demand has risen to 88 percent (179 million tons) (FAO 2020), the demand and supply gap keeps widening. In order to upgrade the demand and supply curve, there is need to adopt innovative technology like Aquaponics. The term Aquaponics involves the cultivation of fish and plants together in a constructed, recirculating ecosystem, utilizing natural bacterial cycles to convert fish waste to plant nutrients (Spencer 2018). The system plan for aquaponics farming can be as simple as a single tank with plants floating above the fish culture tank, or more complex than entire warehouses converted to a vertical farming area with seed bed area filled with pebbles or stones (media base). Regardless of the complexity, the two main goals are to grow plants and seafood (fish) in optimum environment for profit. In view of this fish farmers have to make decisions that can help them overcome the intricate complexities and influencing factors such as the cultured fish, suitable quantity and quality of water, culture facility sizing, feed / nutrition, and management practices (Klontz 1991; Yin-Han 2006), which determines the final fish yield, productivity and profit margins. The interrelationships between these factors contribute to the high risk environment of the cultured crops, since better management involves the understanding and knowledge of the biological processes such as feeding, water quality monitoring and control, fish biomass etc. Predicting through experimentation of the interrelationships between these parameters to aid design of aquaponics system and subsequent monitoring are time consuming and labourous, and wrong prediction can lead to loss of crops.

Some previous models developed in Aquaculture include the following;

- In 1986, Mr. Dawson wrote a computer program using Applesoft BASIC language to determine the dissolved gas composition in water of a pond system (Yin-Han 2006).

- Fries (1994 developed a computer program named SAMCALC in QuickBASIC 4.0 which is compiled in Microsoft BASIC 7.1 and used to calculate statistical parameters and perform analysis of fish culture(Fries 1994)
- Anyadike modeled the fate and effects of feed-based pollutants on an intensive fish pond system (Anyadike 2013)
- Geelen, Caspar developed a dynamic Model of an INAPRO Demonstration Aquaponics System to determine the conditions of aquaponics system(Caspar 2016)
- Yin-Han Wang developed a Model and Software for Predicting Fish Growth in Trout Raceways using Excel VBA programming software(Yin-Han 2006)
- In view of this (Soderberg 1994) and David Haskell, in 1950, (Yin-Han 2006) established quantitative approaches to predict fish conditions

Knowledge Gap

- The reviewed models apart from some not being specifically developed for African catfish, does not predict the balancing of the system in terms of design, mass balancing of the nitrogen-waste i.e. the number of fish that will be able to supply enough nitrogen-waste which determines the number of plant to be introduced and the expected outcome.
- Point of diminishing returns remains unknown and optimizing yield in an economical way is still elusive.
- Farmers pay hidden cost due to lack of adequate knowledge on Aquaponics operational limits and design system. (how many fish to culture and the number of plant to introduce)

However, over the years increasing number of models and equations have been developed to predict various conditions in aquaculture, but there is the needs of appropriate model to answer the specific questions of how far can my current capital go, how many fish can I afford, how many plant can I introduce, what is should be the size of my fish pond and grow-bed. This information will provide solutions for better design and management of aquaponics system for African Catfish, especially in Nigeria where the enormous benefits of aquaponics system are yet to be harnessed.

The use of information technology tools such as computational algorithms, sensor networks, microelectronics, computer applications, cloud computing and internet of things in operational process control, engineering innovations, data analytics and decision support system for precision or smart aquaculture are the trend in boosting production systems. This study therefore aimed at developing a computer based interactive design tool for media based aquaponics system (*ID-MAS*) for African catfish (*clarias gariepinus*) using Excel VBA software. This tool will help farmers and stakeholders in sizing and managing the aquaponics system, thereby avoiding the trail by error (experimental) that fraught establishment of aquaponics system.

2.0 Aquaponics system Description and Working principle

Aquaponics is a combination of fish farming and plant cultivation in hydroponics. It is the resource-saving approach that saves water, energy and artificial fertilizer. In aquaponics, the feed is an input added to the fish pond or tank(Anyadike 2013; Spencer 2018). The fish effluent is channelled through a pump to a grow bed (for media based) where the effluent from the fish tank is acted upon by Nitrosomonas (converting ammonia to nitrite) and Nitrobacter (converting nitrite to nitrate) through nitrification by Nitrosomonas and Nitrobacter bacterial(Robert 1997; Anyadike 2013). The plant then takes up the nitrate as nutrient, and cleaner water is returned to the fish tank as seen in figure 1. The cycle (see Figure 1) idea ultimately makes aquaponics sustainable.

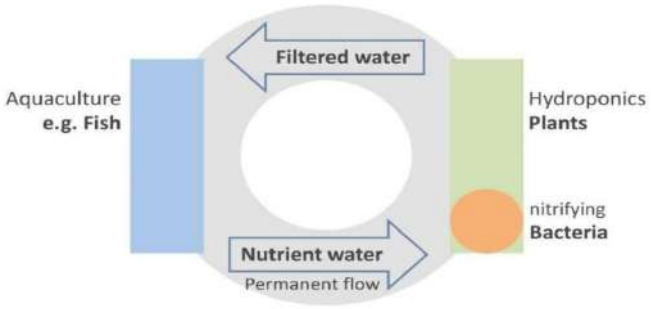


Fig. 1. Aquaponics Cycle

The number of fish that will be able to produce enough nutrients for a particular number of plants is a prime factor for the sizing of the grow bed in an aquaponics system. The input parameters include information on fish stocking density, the feeding rate, weight and size of the fish to determine the quantity of Ammonia-Nitrogen produced in the pond, which enters the grow-bed and the quantity of nutrient transferred from the pond will determine the plant conversion rate and its uptake, this gives an idea of the number of plant to be planted and the sizing of the grow-bed. The conceptual model of nitrogenous waste is as shown in figure 2. Therefore this software balances the number of fish to be cultured and the number of plant to be attached which determine the volume, the Area and depth of the grow-bed and fish pond (Fig.3).

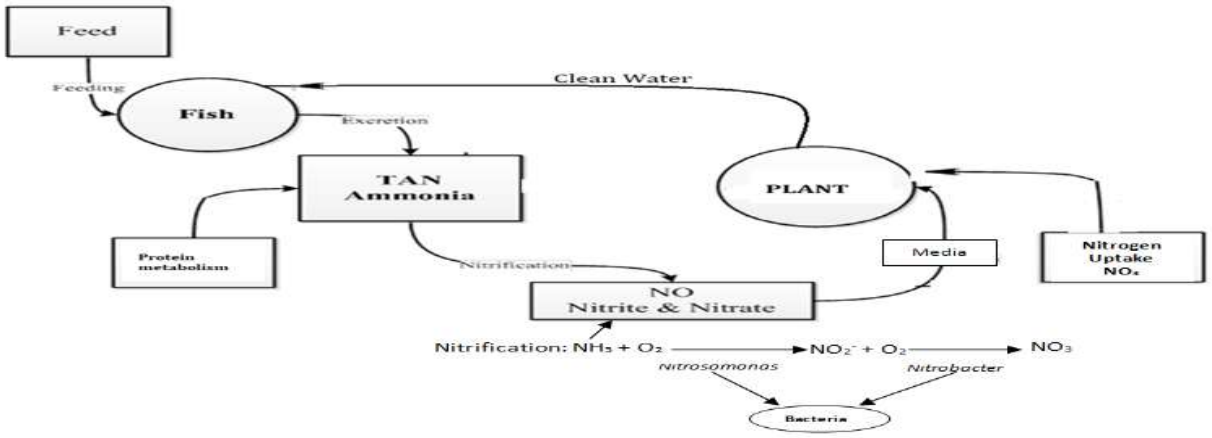
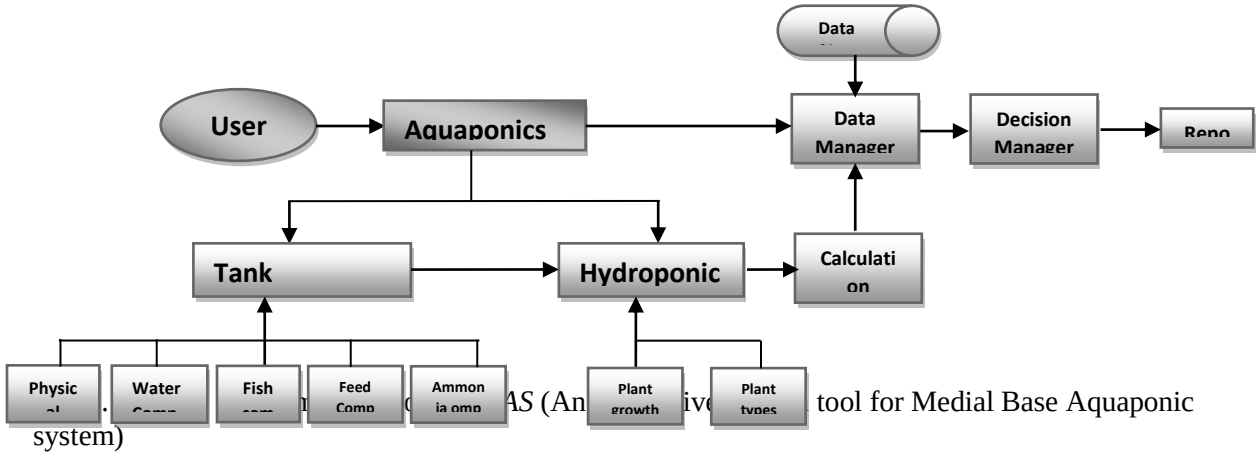


Fig. 2 The conceptual model of nitrogenous waste for aquaponic system

3.0 Model Development

The modeling tool therefore aims at developing a system that will be able to do a pre-calculation or inform of a decision support system for the farmer who wants to venture into Aquaponics system. This tool will assist the farmers to acquire good knowledge on the number of fish and the number of plant to culture in the system. This tool; just with a click on the number of fish you desire to rear, will give you information on the size of tank to use, the number of plant to cultivate, the planting depth and distance etc

The development of an interactive design tool for media based aquaponics system for African catfish *(ID-MAS)* involves balancing the design of aquaponics system (Fig 3), to be able to have a maximum yield without the usual field trial and error method or experimental method. Programmable software embedded in Microsoft Excel package called Visual Basic (VBA), was used to write a user interface program/code. This program involves the interaction between the fish pond and the grow-bed (i.e. fish and plant respectively; see Figure 3).



AS (An ive tool for Medial Base Aquaponic system)

3.1 Model development process equations and requirements

The routine equations for volume, number of fish, surface area, etc., as shown in equation 1 to equation 8 and other relationships were coded into the Excel VBA to enable the program compute the result of the quantity of ammonia generated and the number of plant that can sufficiently assimilate or take up the available nitrate. The aforementioned equations are as follows:

In the culture facility subroutine, the facility dimension;

- Tank water depth: [tank volume / L x W](m), tank water volume; L x W x b (m3).... [1].

The Number of fish to stock was calculated with equation 2. According to (Onuegbu 2011) a 1kg fish uses 4litres of water, and detention time is assumed to 2 hours (Aleece 2015).

$$N_{fish} = \left(\frac{SA \times csp}{W_{dh}}\right) + 0.1\left(\frac{SA \times csp}{W_{dh}}\right) \quad \text{..... ....} \quad [2]$$

where: N_{fish} = number of fish to be stocked (unitless), SA = surface area (m^2), csp = critical standing crop (g/m^2), W_{dh} = desired weight of fish at harvest (g), 0.1 = mortality coefficient (unitless)

- The surface area of the filter was calculated with equation 3. Biofilter volume was calculated according to (Bélair 2016; colt 2016) (see equation 4)

Surface Area of filter is (2.16TAN x 1000g/kg)/(Ammonia removal) (m2) ..... [3]

Biofilter Volume = Area of filter/surface area . [4]

- The Total Ammonia Nitrogen (TAN) Production was calculated with equation 5

TAN = 0.03 x wf/day, where; wf is the weight of feed..... [5]

Assuming 1kg of feed produces 0.03kg of Ammonia according to (colt 2016; Andrea 2018)

- The percent gain of growth parameters was measured using equation6;

  %gain = [(Final stage – Initial stage) / (Initial stage)] x 100.... [6]

- In the Food Subroutine; the feeding rate, feed Conversion ratio, feeding efficiency, and nutrition quality were considered

Feeding Rate; The feeding rate is dependent on the percentage of the body weight of the fish. Feed Conversion Ratio (FCR) : FCR can be calculated as feed consumed (g) / weight gain (g) wet or

$FCR = 1.29 + [(-0.548) / \{1 + (WT/121)^{6.51}\}]$ .... [7]

Where; WT is fish weight. (Yin-Han 2006)

- Feeding efficiency. FE = (1/FCR) x 100/1 (Yin-Han 2006) ..... [8]
- Nutritional quality according to (Steven Craig 2017) are as follows:

(a) Protein = 28 – 32% (b) lipids = 10 – 25%

(c) Carbohydrate = 15 – 20% (d) ash = <8.5

(e) Phosphorous = <1.5% (f) water = <10%

- The water quality subroutine consist of the water quality parameters is asummed to be at the desired level as follows; pH is 7.2, Salinity is 100-8000mg/liter and Total dissolved oxygen is 105%. (After Tucker, 1988 in Boyd, 1990, FAO 2017)
- The plant subroutine was created using Table 1 where the two specific plant in this studies were identified with their Nitrogen uptake, planting distance, temperature and planting depth.

Table.1: Requirement for growth of tomatoes and pepper considering Nitrogen

Plant	Nitrogen Uptake	Planting distance	Temp.	Plant depth
Tomatoes	4.4 -7.9g/plant (Manjurul 2017)	45cm/pot (Upendra 2003)	21 degree Celsius	20 – 25cm(shankara 2005)
Pepper(Bush pepper)	4.7 - 8.0g/plant (crop guide 2019)	45cm/pot (Thompson2020)	21 degree Celsius	20 – 25cm(shankara 2005)

Having considered the equations above the program logic is as shown in Figure 4

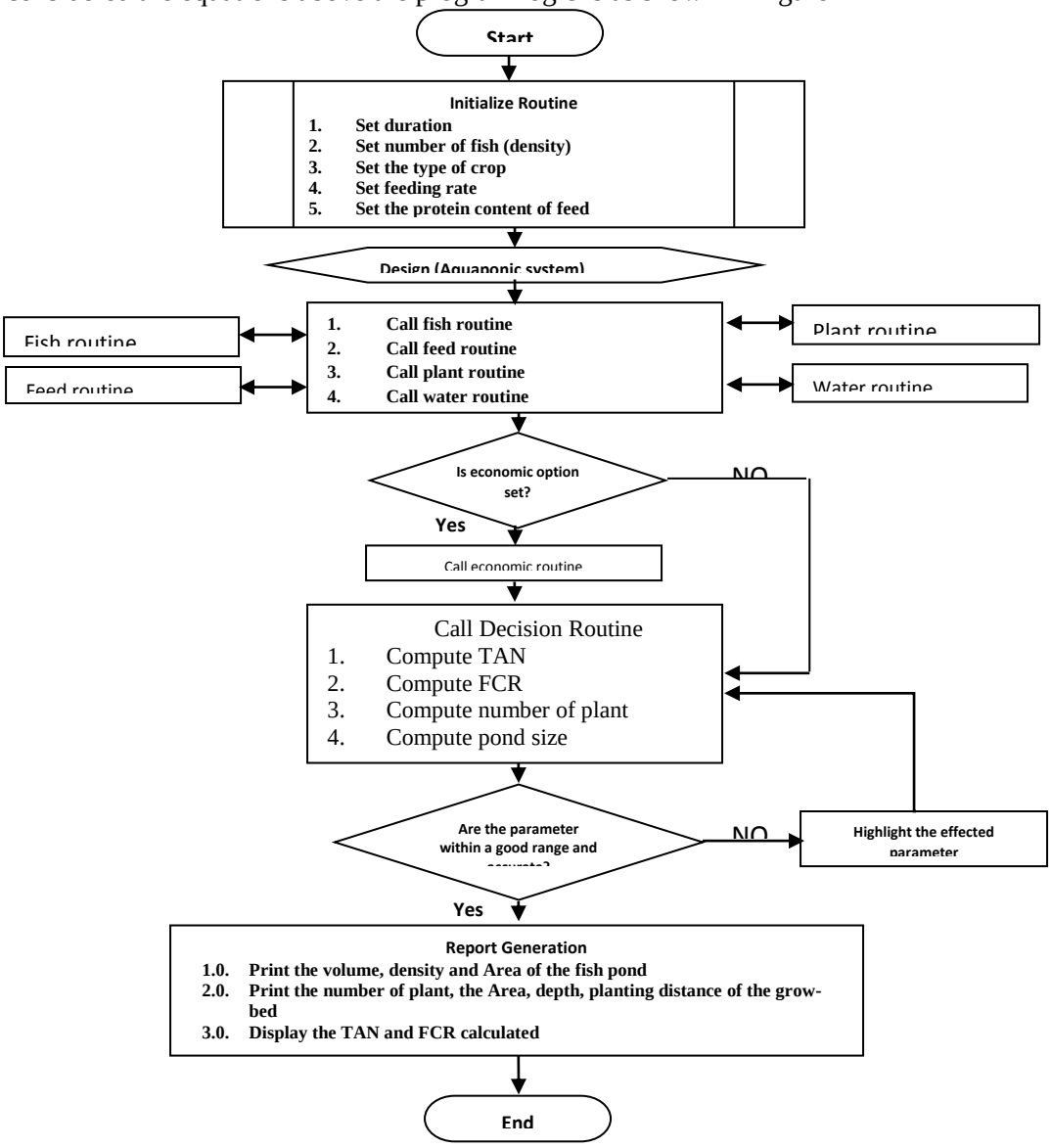


Fig 4:

Flowchart of main program for *ID-MAS*

4.0 Presentation and discussion of results

Figure 5a and 5b, shows the layout of *ID-MAS* with their input data and the output data. The input data contains the duration of culture, the number of fish to be cultured (stocking density), the type of fish to be cultured, initial weight of fingerlings, the target weight of the fish, the type of crop for the grow-bed, the feeding rate and the protein content of the feed.

The output data/information contains, the area calculated for the fish pond, the volume calculated for the fish pond, the depth of the fish pond, detention time for water recycling, the percentage weight gain, the number plant calculated, Area of the grow-bed, planting distance, TAN and FCR calculated. The above information assists farmers to make decision on the sizes of their system.

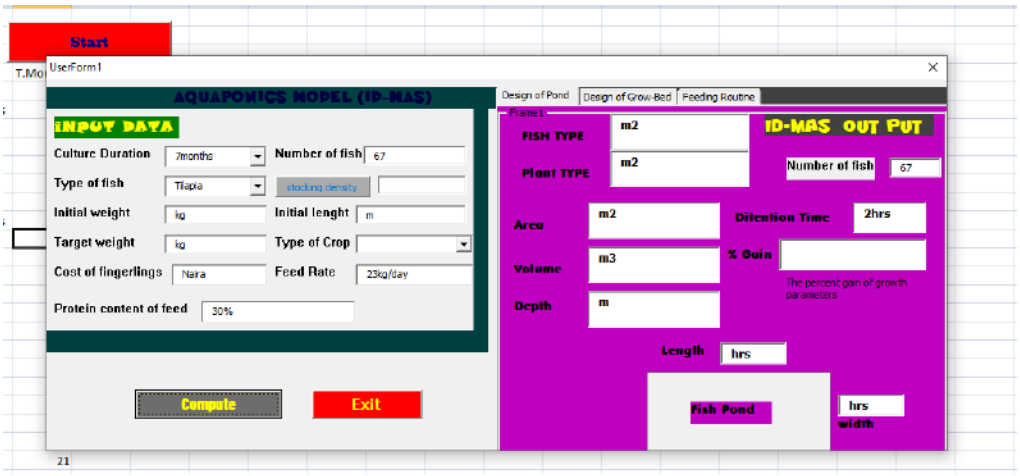


Fig. 5a: The layout of ID-MAS in a Excel VBA

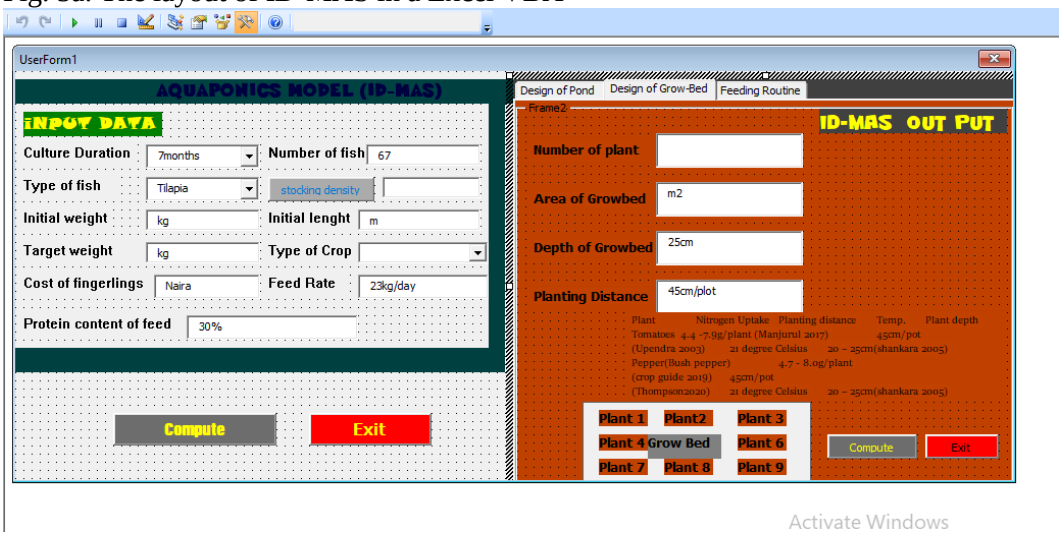


Fig. 5b: The layout of ID-MAS in a Excel VBA

The model was validated and calibrated with a field data as shown in table 2 and table 3. The *ID-MAS* used an input data similar to the experimental data from HiPIC research UNN as seen in table 2 and table 3. Table 2 contains *ID-MAS* input data forms which includes; duration, number of fish, initial weight, target weight, protein content of feed, and data output such as; Area of pond, volume of pond, depth of pond, Number of plant, depth of grow bed, TAN, FCR etc.

Relatively; the table 3 contains similar information as table 2, but the difference is that the information contained in table 3 are gotten from an experimental research conducted by HiPIC group, Department of Computer Science UNN 2021, which was piloted by Dr. Collins.

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Table 2. Showing the input and output of ID-MAS (simulated)

INPUT					OUTPUT						
Duration	No of fish	Initial weight(kg)	Target weight(kg)	Protein content of	Area(pond)	Volume(pond)	Depth (pond)	Number of plant	Depth (growbed)	TAN(max)	FCR
5	25	0.025	1	30	$2m^2$	$2m^3$	1.1m	3	25cm	16	0.76
5	50	0.025	1	30	$2m^2$	$2m^3$	1.1m	10	25cm	60	0.76
5	75	0.025	1	30	$2m^2$	$2m^3$	1.1m	22	25cm	135	0.76

Table 3. Showing data collected from HiPIC Research group, department of Computer Science UNN (Measured)

INPUT					OUTPUT						
Duration	No of fish	Initial weight(kg)	Target weight(kg)	Protein content of	Area(pond)	Volume(pond)	Depth (pond)	Number of plant	Depth (growbed)	TAN(max)	FCR
5	25	0.025	1	30	$2m^2$	$2m^3$	1m	10	25cm	17.2	0.76
5	50	0.025	1	30	$2m^2$	$2m^3$	1m	10	25cm	19.6	0.76
5	75	0.025	1	30	$2m^2$	$2m^3$	1m	10	25cm	23.4	0.76

Result Discussion

The result from the experimental data and Modeling data are presented in figured 6 and 7 in graphical charts having three different stocking densities (12.5kg/m^3, 25kg/m^3, 37.5kg/m^3). Figure 6, shows the relationship that exists between the number of fish and the number of plant for both *ID-MAS* (modeling data) and Experimental data (HiPIC UNN, data). Deducting from figure 6, there exist an intersection (agreement) at stocking density 25kg/m^3 (50fishes), which shows that the model is significant at stocking density 25kg/m^3. Deducting from the report from the experimental data, the number of plant was maintained constant through the three different stocking densities and report shows that the plants from the third stocking density (37.5kg/m^3) suffered nutrient deficiency. This is as a result of trial by error attributed to experimental research.

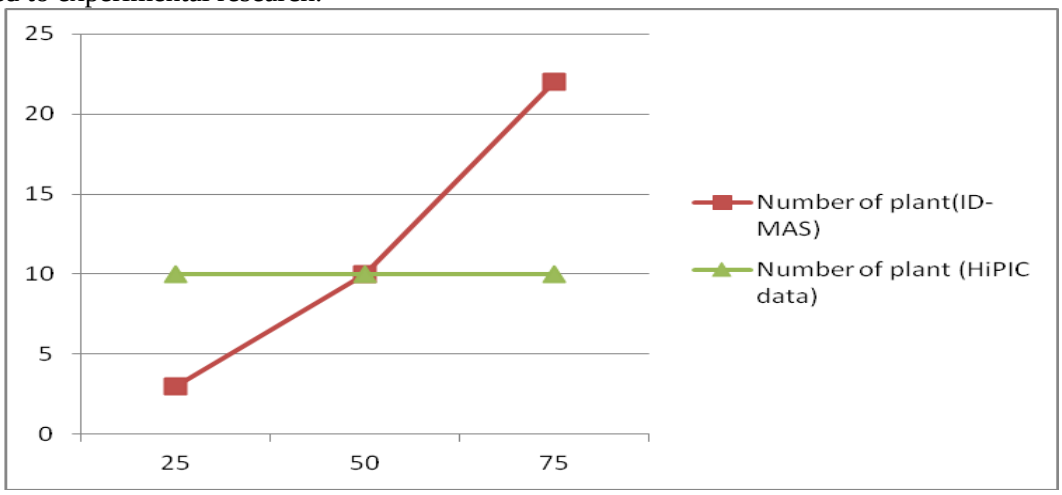

Fig.6: Relationship between the Number of fish and the number of plant For model *(ID-MAS)* and Experimental data (HiPIC)

Figure 7, shows the relationship between the number of fish in the tank to its TAN production for both *ID-MAS* and HiPIC experimental data. Figure 7 shows that, for the *ID-MAS;* the number of fish is directly proportional to the Total Ammonium Nitrogen (TAN). HiPIC experimental data from figure 7 show that there exists a slight change comparing the number of fish to the quantity of TAN produced. This shows that the higher the number of fish the higher the FCR and TAN.

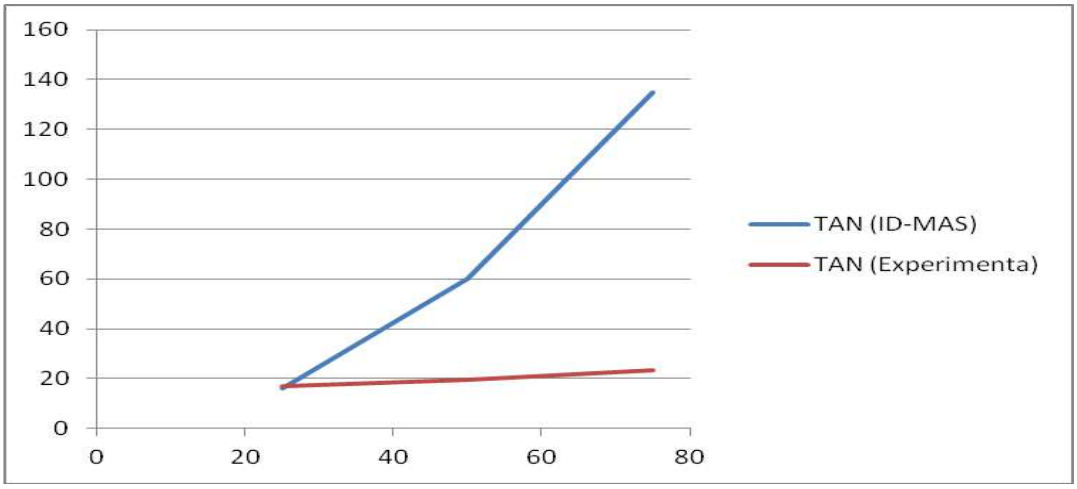

Fig.7: The relationship between the Number of fish and TAN for the Model *(ID-MAS)* and Experimental data (HiPIC)

5. Conclusion

ID-MAS software still under full development, when tested with experimental data showed a close trend with the model prediction for sizing the aquaponics. This showed that *ID-MAS* can be used as a decision tool to enhance sizing and management of an aquaponics system. Therefore a farmer having information on the number of fish he wants to culture or how much he has can use this modeling tool to get information on the size of the culture facility to use, the number of plant to introduce to balance the TAN produced from fish tank. *ID-MAS* when fully developed can assist a famer to establish an aquaponic system with ease.

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EFFECT OF REACTOR PROPERTIES ON THE YEAR-ROUND EFFECTIVENESS OF SOLAR DISINFECTION IN SOUTH-EASTERN NIGERIA

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Abstract

Solar Disinfection (SODIS) utilizes the UV and heat component of the sun to kill disease-causing microbes in drinking water stored in transparent plastic bottles (reactor), mostly polyethylene terephthalate (PET) bottles. The study investigated the seasonal effect of reactor properties on the die-off rate of faecal coliform by performing a 2^3 factorial experiment, including two levels of PET bottle size, PET bottle thickness, and PET bottle support surface uniquely mixed together to form eight SODIS units. The population of faecal coliform in samples collected at hourly interval from the eight SODIS reactors indicated that the die-off rate is dependent on available solar irradiance and maximum water temperature as influenced by the reactor properties. Analyses of experimental results suggested a two-way interaction effect between PET bottle thickness and PET bottle size and between PET bottle thickness and PET bottle support surface during January and December (450 – 500 W/m^2). The most significant factors were bottle size and bottle thickness. Exposing light plastic bottles on absorptive support could make SODIS applicable in regions and seasons whose sunlight intensity is lower than the recommended threshold of 500 W/m^2 for 5 h.

Keywords: *Solar Disinfection; Factorial Experiment; Drinking Water; Faecal Coliform; Diarrhoea*

1. Introduction

According to World Health Organisation (WHO) more than two-thirds of the 663 million people with only assess to drinking water from sources of questionable quality live in the rural areas of developing countries (WHO, 2017). This is also the case in Nigeria, which accounts for more than one-third of water-related infant diarrhoea deaths around the world (WHO & UN-Water, 2014). To tackle this problem, WHO has recommended the use of self-sustaining, household-based methods for treating drinking water, including boiling and chlorine disinfection. One household-based method that has gained in popularity in recent decades is solar water disinfection (SODIS) (WHO, 2007). SODIS can disinfect small quantities of water stored in transparent plastic bottles and exposed to about 6 h of strong sunlight, after which all the disease-causing microorganism are destroyed (Luzi et al., 2016). Disinfection is achieved by the actions of UV and heating effects of the sun. While UV generates Reactive Oxygen Species (ROS) that attack cell DNA, increased water temperature kills microorganisms by denaturing their cell proteins (Leuenberger et al., 2017; Sinha & Häder, 2002). SODIS was recommended as an affordable and effective point-of-use, water-disinfecting method in 2007 (WHO, 2007), mostly for populations whose drinking water sources are questionable or unprotected. SODIS processes do not impart taste to water and has been shown to have better taste when compared to chlorinated and boiled water (Heri & Mosler, 2008).

Transparent polyethylene terephthalate (PET) container has emerged as the container of choice due to its chemical stability, high UV transmittance, availability, and capacity to resist scratches during extended use. Other plastic containers, especially those made from polycarbonate (PC) and Polyvinyl chloride (PVC) that could release bisphenol-A are not recommended for SODIS. Bisphenol-A is carcinogenic compound not found in PET (Luzi et al., 2016).

SODIS is most effective at water temperature values above 50 ^{o}C (Nwankwo et al., 2019; Sommer et al., 1997). Water temperature values in this range can easily be achieved in the Tropics by exposing SODIS bottles on absorptive support-surface. On the other hand, reflective support surface can boost the amount of radiation received by SODIS bottles. Kehoe (2001) showed that die-off rate of bacterial pathogens

could be increased by a factor of 0.85 if SODIS bottles are supported reflective aluminium foil. Another physical property of SODIS reactor that can influence the bacterial die-off rate is the thickness of plastic container because of the control it has on UV transmission capacity (Mani et al., 2006). No valid conclusion on the effect of container size has been reached amongst studies that investigated the effect bottle size and the associated depth of light path it provides. Conflicting findings from two studies (Dessie et al., 2014; Kehoe et al., 2001) suggested that the influence of bottle size on SODIS effectiveness vary, depending on season and the available solar irradiance. The recommended maximum diameter of a SODIS container is 10 cm (Luzi et al., 2016). The penetration of UV is considerably attenuated for higher container diameter. Valid conclusions can only be drawn from a study the considered a variety of experimental conditions and reactor properties.

There is no knowledge of the optimum combination of container size, container thickness, and support-surface that maximizes the pathogen die-off rate under various weather conditions. The rate of pathogen die-off is controlled by these factors through their influence on temperature and the solar energy received by SODIS water. The question of whether certain mix of container size, container type, and support-surface will have interaction effect on pathogen die-off rate under specific weather conditions has not been addressed. For these reasons, the aim of this study was to investigate the seasonal effect of reactor characteristics on pathogen die-off rate constant of feacal coliform using factorial experiment. Factorial experiments are used to test for the presence of interaction effect among the factors of interest (Montgomery, 2013). Factorial designs have the capacity to detect statistical significance even for small number of experiments (Collins et al., 2014).

2. Materials and Methods

2.1 Factorial design, experimental setup and microbial examination

The study was structured as a 2^3 factorial experiment, which lead to eight SODIS reactors/experimental units as depicted in Figure 2. Each experimental unit represents a disparate mix of bottle thickness, bottle size, and support-surface as shown in Table 2. The eight disparate SODIS systems were included in the design to accommodate all the possible mix of PET bottle types and support-surfaces used in the experiment. Table 2 presents a detailed definition of the properties and objectives of the eight SODIS system used in the experiment..

Figure 2: Experimental setup (temperature bottles)

Table 2: Properties and objectives of the SODIS reactors

Reactor Number	Treatment Combination	Combination Objective	Average Volume of PET Bottle (litre)	Average Diameter of PET Bottle (cm)	Average Density of PET Bottle (g/l)	Average Thickness of PET Bottle (mm)	Surface Condition of PET bottle
1	Big Coca-Cola on Aluminum Foil	Big/Thick/Reflective	1.5	8.0	29.4	1.8	Clear/corrugated
2	Big Aqua-Rapha on Aluminum Foil	Big/Light/Reflective	1.5	7.7	24.2	0.6	Blue tinted/corrugated
3	Small Coca-Cola on Aluminum Foil	Small/Thick/Reflective	0.6	6.1	31.6	1.2	Clear/corrugated
4	Small Aqua-Rapha on Aluminum Foil	Small/Light/Reflective	0.5	5.5	26.3	0.5	Blue tinted/corrugated
5	Big Coca-Cola on black polythene	Big/Thick/Absorptive	1.5	8.0	29.4	1.8	Clear/corrugated
6	Big Aqua-Rapha on black polythene	Big/Light/Absorptive	1.5	7.7	24.2	0.6	Blue tinted/corrugated
7	Small Coca-Cola on black polythene	Small/Thick/Absorptive	0.6	6.1	31.6	1.2	Clear/corrugated
8	Small Aqua-Rapha on black polythene	Small/ Light /Absorptive	0.5	5.5	26.3	0.5	Blue tinted/corrugated

The water used for the experiments is a potable water that was sterilized before its contaminated to the tune of 10^5-10^6 CFU/ml using pure culture of faecal coliform to simulate worse-case contamination. The initial sample was taken from the reactors prior to solar exposure. Subsequent samples were taken at intervals that depended on the amount of UV dose that has been received since the last sample was drawn. The faecal coliform population of the samples were counted using McConkey agar and drop plate method. The bacteria colonies were counted after incubation at 44.5 ± 0.2 ℃ for 24 h. Daily values of radiation intensity, air temperature, humidity and wind speed were collected from the Energy Centre weather station, University of Nigeria, Nsukka, located at about 250 m from the location of the experiment.

2.2 Data and analysis

The results of the experiments were analysed using multiple regression method in such a way that factors and factor interactions that are significant can easily be identified (Montgomery, 2013; Kugler et al., 2018). Equation (1) is the regression model for a 2^3 factorial design.

$$\mu = \beta_0 + \beta_A X_A + \beta_B X_B + \beta_C X_C + \beta_{AB} X_{AB} + \beta_{AC} X_{AC} + \beta_{BC} X_{BC} + \beta_{ABC} X_{ABC} \quad (1)$$

where μ is the observed response, which is the die-off rate constant of faecal coliform in this study; X_A, X_B, and X_C are the main effect variables; X_{AB}, X_{AC}, and X_{BC} are the two-way interaction effect variables; X_{ABC} is the three-way interaction effect variable; β_A, β_B, β_C, β_{AB}, β_{AC}, β_{BC}, and β_{ABC} are the corresponding regression coefficients. A total of 57 experiments (i.e., the experimental setup was exposed 57 times) were conducted between November 2017 and October 2018. The die-off rate constants (μ) for each of the eight experimental units were computed for all the experiments assuming the classic first-order rate kinetic. Equation (1) was written for each of the eight experimental units used in the experiment which amounts to 456 equations (eight experimental units multiplied by 57 experiments conducted year-round). The equations belonging to different months (January to December) were solved separately for the regression coefficients.

To solve Equation (1), the variables were replaced with dummy variables in a process termed "coding". Table 4 presents a demonstration of coding process, showing the coded level of the eight experimental units using the "effect coding" method explained in Kugler et al. (2018) with die-off rate constant as the response variable. In effect coding method, the two factor levels of A, B, and C are either codded with -1

or 1 as shown in Table 3 and demonstrated in Table 4. The terms AB, AC, BC, and ABC were obtained by multiplying the codes of A, B, and C of interest

Table 3: Factor levels using effect coding

Factors	Factor Levels	
	Low (-1)	High$(+1)$
A – Rear surface	Reflective	Absorptive
B – PET bottle size	Big PET bottle	Small PET bottle
C – PET bottle thickness	Thick PET bottle	Light PET bottle

Table 4: Effect coding method

Reactor Number	Experimental condition	Effect codes							Rate constant (h^{-1})
		A	B	C	AB	AC	BC	ABC	
1	$-,-,-$	-1	-1	-1	1	1	1	-1	μ_1
2	$-,-,+$	-1	-1	1	1	-1	-1	1	μ_2
3	$-,+,-$	-1	1	-1	-1	1	-1	1	μ_3
4	$-,+,+$	-1	1	1	-1	-1	1	-1	μ_4
5	$+,-,-$	1	-1	-1	-1	-1	1	1	μ_5
6	$+,-,+$	1	-1	1	-1	1	-1	-1	μ_6
7	$+,+,-$	1	1	-1	1	-1	-1	-1	μ_7
8	$+,+,+$	1	1	1	1	1	1	1	μ_8

A – Rear surface; B – PET bottle size; C – PET bottle thickness

3. Results and Discussion

Table 5 presents the summary of results and the effect estimates obtained from the regression analyses, including their p-values of significance. The values under the effect estimate (E) equal the regression coefficients (β) multiplied by two. The factor level that increases or decreases the die-off rate constant is indicated by the algebraic signs. For example, a positive main effect estimate means that "high level (+1)" of that factor increases the die-off rate on average; whereas a negative effect estimate means that the "low level (-1)" of that factor increases the die-off rate on average. The relationship between the algebraic sign of the factor levels with direction of their effect on die-off rate constant was described in Table 3.

Table 5: Summary results and effect estimates

Months	Overall mean		X_A			X_B			X_C			X_{AB}			X_{AC}			X_{BC}			X_{ABC}		
	β_0	p	β_A	E_A	p	β_B	E_B	p	β_C	E_C	p	β_{AB}	E_{AB}	p	β_{AC}	E_{AC}	p	β_{BC}	E_{BC}	p	β_{ABC}	E_{ABC}	p
Jan	1.146	0.000	0.033	0.065	0.484	0.148	0.297	0.003	0.126	0.252	0.011	0.067	0.133	0.157	0.080	0.160	0.093	0.106	0.212	0.029	0.084	0.168	0.780
Feb	1.848	0.000	0.080	0.160	0.249	0.237	0.474	0.003	0.176	0.351	0.018	-0.020	-0.040	0.771	0.042	0.083	0.542	0.092	0.184	0.186	0.018	0.037	0.785
Mar	1.754	0.000	0.065	0.131	0.464	0.071	0.141	0.430	0.052	0.104	0.560	0.071	0.141	0.430	-0.001	-0.003	0.989	0.047	0.093	0.600	0.047	0.093	0.600
Apr	2.337	0.000	0.131	0.263	0.113	0.194	0.388	0.025	0.096	0.193	0.237	-0.014	-0.028	0.859	0.048	0.096	0.547	0.082	0.164	0.311	0.034	0.068	0.672
May	1.968	0.000	0.062	0.124	0.450	0.049	0.098	0.552	0.202	0.404	0.017	0.033	0.065	0.691	0.056	0.112	0.493	0.033	0.065	0.691	0.049	0.098	0.552
Jun	1.580	0.000	-0.074	-0.148	0.513	0.040	0.080	0.723	0.088	0.176	0.435	0.005	0.009	0.968	0.036	0.071	0.751	0.014	0.028	0.903	0.031	0.061	0.786
Jul	1.287	0.000	-0.229	-0.459	0.001	0.000	0.000	1.000	0.069	0.139	0.269	0.000	0.000	1.000	-0.026	-0.051	0.681	0.000	0.000	1.000	0.000	0.000	1.000
Aug	1.297	0.000	-0.196	-0.392	0.067	0.020	0.041	0.845	0.077	0.153	0.466	0.020	0.041	0.845	-0.006	-0.012	0.953	0.020	0.041	0.845	0.020	0.041	0.845
Sep	0.964	0.000	-0.062	-0.125	0.350	0.060	0.119	0.370	0.203	0.407	0.004	0.006	0.012	0.930	0.018	0.035	0.791	0.048	0.096	0.469	0.017	0.035	0.792
Oct	1.376	0.000	-0.089	-0.177	0.058	0.017	0.034	0.706	0.112	0.224	0.018	-0.009	-0.018	0.841	0.062	0.124	0.176	0.002	0.004	0.964	0.006	0.012	0.895
Nov	1.847	0.000	-0.028	-0.057	0.689	0.017	0.035	0.805	0.151	0.303	0.039	0.007	0.014	0.919	-0.061	-0.122	0.392	-0.041	-0.083	0.560	-0.031	-0.062	0.661
Dec	1.352	0.000	0.010	0.019	0.902	0.191	0.382	0.023	0.283	0.566	0.001	0.072	0.145	0.366	0.019	0.038	0.809	0.152	0.303	0.065	0.032	0.064	0.689

X_A, X_B,X_C are the main effect variable and β_A , β_B , $\beta_C$are the estimate of regression coefficients; X_{AB}, X_{AC},X_{BC} are the interaction effect variable and β_{AB} , β_{AC} , β_{BC} are the estimates of two-way regression coefficients; X_{ABC} is the three-way interaction variable and β_{ABC} is the estimate of three-way regression coefficient; E_A , E_B , E_C , E_{AB} , E_{AC} , E_{BC}, and E_{ABC} are the corresponding effect estimates ; p – probability of no effect. Note that the value of E is twice the value of β.

Figure 3 shows the Pareto charts of standardized effects for each month. Pareto chart uses bars to show the magnitude and the importance of the factors and factor combinations from left to right in descending order. The most suitable combination of reactor properties could be discerned from the chart. The height of the bars is proportional to the absolute value of the estimated effect (E), divided by the standard deviation. The dotted horizontal line is the reference line of significance, and it depends on the selected significance level (α). An effect estimate is significant if the bar that represents it makes contact with the reference line of significance. One limitation of the Pareto chart is that it displays only the absolute values of the effect but does not indicate which effect decreases or increases the response (die-off rate constant in this case). This study introduced two shades of grey in the chart to indicate which factor level increases the rate constant. The light-grey bars suggests that it is the "low level (-1)" of that factor that increases the rate constant; whereas, dark-grey bars suggest that it is the "high level (+1)" of that factor that increases the rate constant. For the months in which no significant difference exist and the available evidence could not establish the superiority of any particular factor level, convenient and available reactors should be used. For example, big PET bottles should be pursued for larger volumes of water.

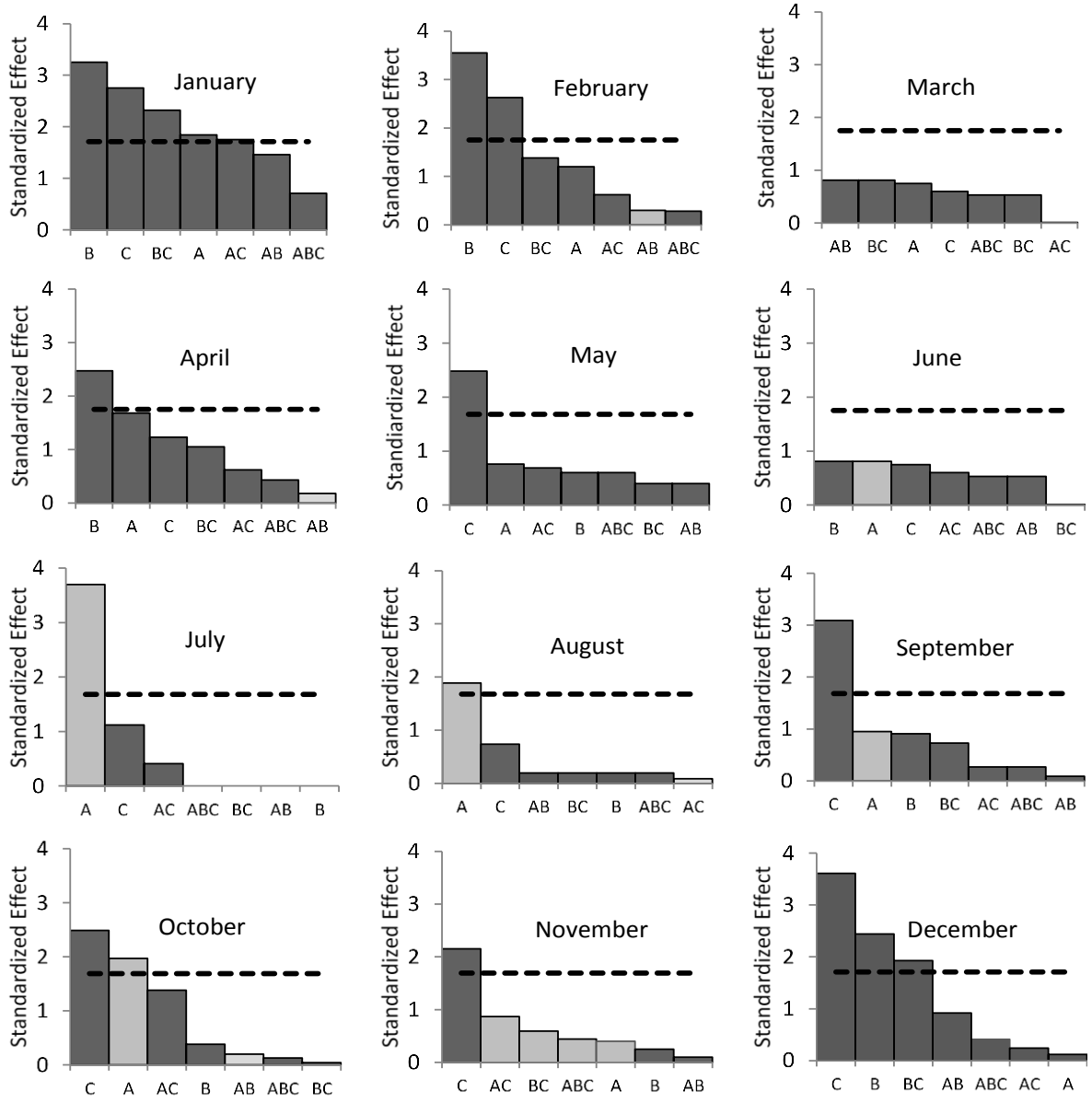

Figure 3: Pareto chart of standardized effect (January to December)

■ – High level (+1) of the factor increases rate kinetics; ■ – Low level (-1) of the factor increases rate kinetics; – – – – Reference line of significance; A – Rear surface; B – PET bottle size; C – PET bottle thickness.

A significant interaction effect estimate is an indication that combining factors at a particular factor level has a significantly different die-off rate than the sum of their separate effects. The reactors placed on absorptive support-surface were favoured by the comparatively high air temperature and low solar irradiance measured during January and December when compared with other months. This may explain the interaction effects which was observed only during January and December. Another explanation for this observation is that January and December correspond with the period of reduced sunlight and the proportion of UV in solar radiation is minimal. This suggest that temperature effect might dominated the pathogen removal process during this period.

4. Conclusions

A factorial study has proven to be an effective and efficient way of discovering the best mix of reactor properties that are most effective for different periods of the year. Investigation of SODIS effectiveness across different levels of different factors could help uncover factors and factor levels that interact to enhance the disinfection efficiency of SODIS process. Under less favourable conditions, especially during the period of reduced ambient and water temperature, the combination of lighter PET bottles and reflective rear-surface enhancement is crucial for SODIS effectiveness if SODIS must be used. Bigger PET bottles should be pursued for higher treatable volumes during cloudy spells and periods of reduced sunlight intensity because smaller PET bottles are not more effective at removing pathogens under such conditions.

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PUMPS USED IN HOUSEHOLDS AND BOREHOLES WITHIN NSUKKA

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Abstract

Pumps are used in almost every home as a domestic water suction device for daily living It can also be used industrially. It can be used to boost the water or submerged in the water. A survey was conducted in Nsukka environ to ascertain the type, make, cost, maximum discharge head, maximum pressure and horsepower of the pumps used. The coordinates of each location and the elevation above sea level were also noted. The study concluded that it was basically centrifugal pumps that were in use; using a rotating impeller to accelerate a fluid and increase its pressure.

Keywords: *Centrifugal pumps, Household, Borehole, Horsepower, Nsukka*

1.0 INTRODUCTION

A pump is a device that moves fluid i.e. liquids or sometimes slurries by mechanical action. Pumps can be classified in to three major groups according to the method they use to move the fluid. There is direct lift, displacement and gravity pumps.

1.1 Working principle of a pump

It works on the principle of forced vortex flow. The forced vortex flow means when a certain mass of fluid or liquid is allowed to rotate by an external torque, then there is a rise in pressure head of the rotating liquid. This rise in pressure head is used to deliver water from one location to another. It is centrifugal force acting on the fluid that makes it to flow within the casing (Rajput 2004; Khurmi 2003; William and Arthur 1988).

Pumps are used in almost every home as a domestic water suction device for a daily life use. Industrial applications of pumps include: pressure boosting, heating installations, fire protection sprinkler systems, drainage, air conditioning Industry and Water engineering - boiler feed applications, water supply (municipal, industrial), wastewater management, irrigation, sprinkling, drainage and flood protection, the Chemical and Process Industries (paints, chemicals, hydrocarbons, pharmaceuticals, cellulose, petro-chemicals, sugar refining, food and beverage production); hence the need to survey the pumps used in households and boreholes in Nsukka environs.

1.2 Components of Pump

Pump is made of two major components: (1) Motor: This is the power source of the pump which drives the shaft. AC motors and DC motors are the most common power sources for pumps, but internal combustion engines (ICEs), hydraulic power, and steam power are other possibilities. (2) Impeller: This is a rotating disk with a set of vanes coupled to a shaft. When the impeller rotates, it imparts energy to the fluid to induce flow. Flow characteristics of the pump vary widely based on the impeller design.

1.3 Centrifugal Pumps

A centrifugal pump is a device that is used to transfer fluids. It is a device that makes use of centrifugal force with the help of an impeller which rotates to relay velocity and transfer water as well as other types of fluids. This type of pump is a popular choice, and it is used whenever fluids need to be transferred from one place to another. Centrifugal pump is generally used in the agricultural sector, industrial sector, as well as power generation plants.

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This type of pump is used to transfer fluids that have low viscosity such as water or light oil. For fluids that have a higher viscosity than water or light oil, a displacement pump is preferred since it helps in minimizing energy costs. Centrifugal pumps are preferred where a large quantity of fluid needs to be transferred. These pumps also provide a high rate of flow which can be adjusted over wider ranges.
Since centrifugal pumps are also a machine it too demands a little bit of maintenance and care. With routine maintenance, you will be able to make the pump function properly in its top condition thus increasing its life. Here is what you should check when performing a routine check-up for your pump.
Monitoring the pump speed, discharge pressure, power, flow, pump efficiency, and suction pressure is a must. By monitoring these six key parameters, you can easily find out the condition of the pump (Rajput 2004; Khurmi 2003; William and Arthur 1988).

1.4 Types of Specifications for Categorizing Centrifugal Pumps

Pumps have been a part of industrial and residential applications since the era of the industrial revolution. Since then there have been multiple innovations for a boosted efficiency of the pump and its simple operation. One of the standard pump types used in various industries is the centrifugal pump.
This has one or several impellers that impel energy to a fluid. The energy consequently guides the fluid's discharge to a collector. A submersible pump supplier is basically selling a variant of centrifugal pumps whose components are entirely installed under water (Pelikan 2017; Ray and Phil 2011). These pumps have to be fully submersed in the water in order to draw in the water and pump it to a particular location. A submersible pump is typically used where there is ample water to cover it. Submersible pumps are thus used for pumping sewage from septic tanks, and water from flooded basements, irrigation systems and above and underground water treatment systems. Booster pumps are used to increase pressure within liquid circulation systems, either for distributing to tanks and storage units fed by the systems that require the higher pressure, or for increasing the distance the system is required to carry the liquid at the circulation pressure. Booster pumps are designed to smooth out water pressure in areas where the flows are highly variable. There are two types of booster pumps: single stage and multiple stage. Most people use these booster pumps for light irrigation purposes.

Centrifugal pumps are classified based on various specifications (Gülich 2008; Gülich 2010; Moniz et al 2004; Larry and Angle, 2003).

1.5 Specifications for classifying pumps

The following are the specifications used to classify the pumps.

1.5.1 Number of Impellers

The impeller in your centrifugal pump rotates to generate a force that propels the fluid into the volute chamber. Centrifugal pumps are categorized according to the number of their impellers into three classifications. These include single stage, two-stage, and multi-stage pumps.
Single stage pumps have one impeller and simple designs. They are ideal for low-pressure and high flow-rate applications. Two-stage pumps have two impellers and suffice for medium pressure applications. Multi-stage impellers have at least three impellers and are used in high-pressure environments.

1.5.2 Split Case Types

Centrifugal pumps have a split case. This offers them a balanced design featuring maintenance-friendly casing, robust bearings and impellers mounted on shafts and supported by bearings on either side. Based on the orientation of their split case, pumps are categorized into axial and radial split pumps.
Axial split case pumps are mounted horizontally and have their volute casing axially split at the pump shaft's midpoint. In radial split pumps, the volute casing is perpendicularly split to the pump shaft's center line.

1.5.3 Volute Type

The volute in your pump receives the fluid pumped from the impeller. Based on the volute, centrifugal pumps are classified into single and double volute pumps. Single volute pumps are designed for low capacity pumps that have high radial loads.

Double volute pumps, on the other hand, have two partial volutes 180 degrees apart contributing to balanced radial loads. These are the more prevalent of the two.

1.5.4 Location of Bearing Support

Bearings in centrifugal pumps keep the rotor or shaft in proper alignment with your pump's stationary parts under the actions of axial and radial loads. The location of your bearings' support will be used to classify centrifugal pumps into between-bearing and overhung pumps.

In overhung pumps, the bearings will support the impellers located on one shaft end from one side. In between-bearing pumps, the impeller will be located between the bearings and thus have support from both ends while mounted on a shaft.

The centrifugal pump options on the market are vast, and it is easy to get overwhelmed when shopping for one. Thankfully, with an understanding of the above specifications used to classify your pump, you are now better placed to make the right choice.

Centrifugal pumps irrespective of their type are renowned for their low power consumption combined with high efficacy. They are also low maintenance and durable owing to their simple design.

1.6 Explanation of motor nameplate abbreviations and terms (Robert 2010; Karassik 2007; Australian Pump Manufacturers' Association 1987; Baha 2004; Gas Processors Suppliers Association 2004).

1.6.1 Model Number and Serial Number

The model and serial number are usually a sequence of letters and numbers determined by the manufacturer. Having just the model number can help the auditor track down motor specifications even when all other information is missing.

1.6.2 Motor weight

Motor weight must specify pounds or kilograms. Larger electric motors (e.g., 100 HP) used for irrigation can easily weigh 1,300 pounds.

1.6.3 Rating or AMB

AMB stands for ambient temperature. The rating or AMB is the maximum room temperature or air space where the motor is located and time it can safely operate under those conditions. The common rating of 40C-AMB-CONT means continuous operation at 40 C. Motor life will be longer if ambient temperatures are less.

1.6.4 FLA, voltage and Hz

FLA is an abbreviation for the Full Load Amp rating. Motors are designed to operate at 50 to 100 percent of their rated load. At FLA, the motor runs at 100 percent of its rated load and the label specifies the current it will draw. Many electrical components like wiring, circuit breaker and starter are sized based on FLA.

Most electric motors are designed to operate at a specific voltage. Motors can run safely at ±10 percent of the rated voltage. Exceeding the specified range can cause permanent damage. Some motors are designed to operate at dual voltages, i.e., 230V and 460V, depending on the selected wiring. For a dual voltage motor, the nameplate should have wiring information for the desired voltage at the bottom of the nameplate

The abbreviation Hz is the Hertz or input voltage frequency of the motor. Motor speed is directly related to the line input voltage frequency. In the U.S., 60 Hz is the standard frequency while 50 Hz is common elsewhere.

1.6.5 HP, phase and RPM

Output horsepower, or HP, is the motor output at its rated load. It is dependent on the kilowatts, or KW, demanded by the motor along with efficiency, power factor and actual load. In energy audits conducted in central, northwest and Panhandle regions of Oklahoma, the horsepower of electric motor-driven irrigation pumps varied from 14 to 100. As the depth to water table (pumping depth) increases, higher motor HP is required. One can easily determine groundwater depth using a water level meter, then determine required motor horsepower.

Generally, electric motors are either single phase or three phase. Motors larger than about 30 HP are usually three phase. Three-phase motors typically can be wired for different voltages and amperages described above.

RPM stands for revolutions per minute and is the shaft speed of the motor at the rated HP load. Depending upon the number of poles, frequency, design and motor slip (described below), the RPM will vary slightly for each manufacturer. For a four-pole motor operating at 60 Hz, the (no-load) RPM would be 1,800.

1.6.6 Service factor

Service factor, or SF, is a number that indicates how much overloading a motor can handle without causing permanent damage. For example, 1.15 SF means the motor can be loaded 15 percent over its maximum rated load for a short time until its internal temperature becomes excessive. This means a 100 HP motor with a SF of 1.15 can operate at 115 HP load for some time before overheating. Continuously operating the motor at its SF will adversely affect its efficiency and reduce useful life.

1.6.7 Duty, insulation and code

Duty is the duration of safe motor operation. Most motors operate continuously without requiring a cooling period. Others operate intermittently, and require a cooling period between on/off cycles. For larger motors, continuous duty is common.

2.0 MATERIALS AND METHODS

2.1 Description of Study Area

The study area is Nsukka; situated in Nsukka local government area of Enugu State. Nsukka is a small University town with three main communities; Nru, Ihe and Nkpunano. This small town is the host of the prestigious University of Nigeria; hence one of the renowned centers of learning in the country. The town is strategically situated between the Northern and the Southern part of the country making it a major transportation hub especially for the movement of students and university staff; with major roads linking the northern and southern parts of the country passing through the town.

2.2 Field Survey/Trip

A survey was made to different parts of Nsukka metropolis to ascertain the type, capacity (in horsepower), pressure, market price, discharge head, purpose of pump installed there. Global Positioning Instrument (GPS) was used to take the coordinates of each area. The survey involved visitation of sites, interviews and physical examination of the pumps. About seven pumps were examined at different locations in Nsukka and detailed information about them noted (Table 1, figs 1-7).

3.0 RESULTS AND DISCUSSION

3.1 RESULTS

Fig1a

Fig1b

Fig1c

Figure 1a,b,c: Pictures of Booster Pumps taken at Borehole Close to UNN 1st Gate and Ratings

Table 1: Detailed description of visited household and borehole pumps

S/N	Name/Location	Description/Rating of Pump
1	Booster pumps taken at borehole close to UNN 1st gate	Name of Pump: UEG Centrifugal Water Pump Elevation: 420m above sea level Location: 6° 51' 27.5" North, 7° 23' 48.1" East. Max Pressure: 10 bar Capacity: 600m3/hr, 10000l/min, 600,000l/hr Horse Power: 200hp Max Discharge Head: 100m Pressure: High Pressure Current Market Price: $1300, N550,000 Certification: CE
2	Submersible pump taken at borehole close to UNN 1st gate	Make of Pump: GRUNDFOS Pumps Location: 6° 51' 27.5" N, 7° 23' 48.1" E. Elevation: 420m above sea level Max Discharge Head: 1000ft Current Market Price: N5,000,000 Horsepower:75 hp
3	Household pump at No.5 Ugwuogbodo Street, off Amoke Lane, Nsukka, Enugu State	Name/Brand: DAB (made in Italy) Elevation: 427m above mean sea level GPS Information:6.8565708°N, 7.3997748°E Max. height = 53.8m Number of floors served: Two Floors Horsepower: 1 hp; 50Hz Current Market Price: #25,000 - #45,000 Quantity of water pumped: 1200 gallons
4	Household pump at Hilltop, Ihe Owerre Nsukka, Enugu State.	Name/Brand: ATLAS 125 GPS Information: 6.8667° N, 7.4098° E Elevation: 442m above mean sea level Number of floors served: Three floors; Bungalows Current Market Price: # 30,000 – 50,000 Quantity of water pumped: 1000L Horsepower: 1 horse power; 50Hz frequency and 2850 rpm speed.
5	Household pump located at Cartwright, UNN	Name/Brand: ROBIN PUMP (made in Japan) GPS Information: 6˚85′65″N, 7˚2′16″E Elevation:489m above mean sea level Current Market Price: #45,000 Quantity of water pumped: 10000L Horsepower: 1 hp; Max. height = 53.8m
6	Household pump located at Barracks, Nsukka	Name/Brand: DIVINE SUPER PUMP (made in China) GPS Information: 6˚21′0″N, 7˚84′56″E Elevation:432m above mean sea level Current Market Price: #50,000 Quantity of water pumped: 60 m3/h Horsepower: 1 hp; Max. height = 30m
7	Household pump located at Eze-Opi; UNN	Name/Brand: PARSUN PUMP (made in Japan) GPS Information: 6˚51′24″N, 7˚24′35″E Elevation:420m above mean sea level Current Market Price: #80,000 Quantity of water pumped: 1000L/min Horsepower:1 hp; Max. height = 30m

Fig2a (An abandoned one)

Fig 2b: The one in use

Fig 2c

Fig 2d

Figure 2a,b,c,d: Pictures of submersible pump taken at borehole close to UNN 1st gate

Figure 3: Household pump at No.5 Ugwuogbodo Street, Off Amoke Lane, Nsukka, Enugu State

Figure 4: Picture of household pump at Hilltop, Owerre Nsukka, Enugu State.

Ihe

Figure 5a,b:Picture of *household pump located at Cartwright, UNN*

Figure 6a,b: Details of household pump located at Barracks, Nsukka

Figure 7a,b:Picture of household pump located at Eze-Opi; UNN

3.2 Discussion

The submersible pump currently in use at borehole close to UNN Ist gate (fig. 2b) is of 75-horsepower inserted into the ground (vertically oriented) to a depth of 510 ft and connected to 17 pipes of 30ft each up to the ground surface. The pump draws the water and transfers it to the tank shown in fig.2d. The work of the booster pump (in figure 1) is then to pump the water from the tank to various residential buildings in town, connected to the pipe network.

It can be seen (from figs 1-7) that each pump has specification ranging from brand name, type, cost, maximum discharge head, maximum pressure, and horsepower. The survey revealed that the pumps are working effectively and are generally of the centrifugal type; using a rotating impeller to accelerate the fluid and increase its pressure. The submersible and booster pumps at the borehole close to UNN Ist gate is operated using gasoline. The household pumps located at Barracks and Cartwright use prepaid electricity metering while those at located at Eze-Opi, Ugwuogbodo Street and Hilltop use postpaid electricity billing. Pumping requires high electrical energy consumption. Most pump users prefer postpaid electricity billing to prepaid electricity billing since prepaid pricing is based on usage/consumption rate. The more you use in a month, the higher the cost.

4.0 Conclusion

The existing pumps are operational and efficient in service. They are either using gasoline, prepaid electricity metering or postpaid electricity billing.

5.0 Recommendation

Recent and digital pumps of lesser horsepower should be put in use since their electricity consumption is low.

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SESAME IRRIGATED YIELD UNDER DIFFERENT FERTILIZER APPLICATION RATE AT BADEGGI.

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Abstract
This work was done to evaluate the growth, yield of irrigated sesame under different fertilizer application rate at National Cereals Research Institute (NCRI) Badeggi. The experiment was carried out with Ex-Sudan sesame variety using N P K 15:15:15 fertilizer at the rates of 40, 60, and 80 kg per hectare with 0 kg per hectare as control, and surface irrigation was used. The crop was irrigated 5 days and 7 days depending on the crop stage (vegetative, reproductive and maturity stages respectively). Application of 60 and 80 kg/ha of NPK on irrigated sesame crop resulted in increased plant height and wider leaves, with the average plant height of 125cm throughout the experiment. Increasing the NPK fertilizer rate to 80 kg/ha gave higher yield which was significantly the same with the yield recorded for the plots that receive NCRI recommended rate (60 kg/ha) and an output of 1008kg/ha which is within the expected output of the variety in custody, that is 1000 – 1200kg/ha.

Keywords: *Sesame, Irrigation, Fertilizer, Application rate, Yield*

1. *Introduction*

Sesame (*Sesamum indicum L.*) is one of the world's most ancient oilseed crops with evidence that it originated in India (Bedigian, 2015). Sesame otherwise known as Sesamum or Benniseed, belong to the family *Pedaliaceae*, and is one of the most ancient oil seeds crop known to mankind (Malum *et al.*, 2019). The major world producers are: India, Sudan, China, Burma (who contribute about 60% of the total world production) and Ethiopia (ElKhier *et al.*, 2008). Sesame is an important agricultural crop in Nigeria; it is extensively cultivated in middle and northern Nigeria mainly as commercial crops for export (Chemonics, 2003). The sesame plant is usually 60 to 120 cm tall, with an average maturity period of 120 days and the fruit is a dehiscent capsule which shatters, when ripe, to release small seeds. The core of the seed is protected by a hull which may be white, brown or black depending on the variety. The sesame contains a 48 – 55 % oil, which is higher than other oilseeds (e.g. canola seed yields 44% oil), and proteins including amino acids (Eskandari *et al.*, 2015; Pathak *et al.*, 2014). The international standard of oil content is 52%, 48%, and 45% for first, second and third grades of sesame respectively. The allowable moisture content for all grades of sesame is 6 – 8 % (Abebe, 2016). Sesame is commonly categorised into two main market segments based on the seed coat colour, being white sesame and black sesame. In Nigeria, the local names of the seeds include '*ridi'* (Hausa), '*eluru*' and '*ekuku*' (Yoruba) and '*isisa*' (Igbo). The seeds are consumed dried, fried, and fresh or blended with sugar. They are also used for soup preparation after grinding it into smooth paste. Sesame is a cherished soup condiment in some Northern and eastern parts of Nigeria and some parts of Cross-River State (Agiang *et al.*, 2010) as well as Abia State. The soup is eaten with carbohydrate foods such as pounded yam, garri and other flours made into foofoo. Sesame is a good source of plant protein and healthy fat, and can act as an alternative to animal proteins and animal fats in human diets. Sesame is also a good source of vitamins, minerals and fibre (Elleuch *et al.*, 2011; Zebib *et al.*, 2015). The protein has disable amino acid profile with good nutritional value similar to soybean (NAERLS 2010). The specific objective of this research was to assess the irrigated sesame yield under different inorganic fertilizer application rate.

1.1 Types of Irrigation

The different types of irrigation are listed below:
Surface irrigation: Surface irrigation entails water flowing by gravity over soil. Water is usually supplied by gravity from the water source through canals, pipes or ditches to the field. In some locations, however,

water may need to be pumped from the source to a field at a higher elevation. Types of surface irrigation systems include furrow, basin and border irrigation. Surface irrigation systems are typically used for field crops, pastures and orchards. Efficiency of surface irrigation systems vary tremendously because of variations in soil type, field uniformity, crop type and management. Surface irrigation is often considered less efficient than sprinkler irrigation or micro-irrigation because soil, not a pipe, conveys the water within surface irrigated fields. However, a well-managed surface irrigation system on a uniform soil with a runoff reuse system can approach 90% application efficiency.

1.1.1 Sprinkler irrigation: Sprinkler irrigation applies water to soil by spraying or sprinkling water through the air on to the soil surface. Water is pressurized and delivered to the irrigation system by a mainline pipe, which is often buried so it does not interfere with farming operations (Waller and Yitayew, 2016). Three main categories of sprinkler irrigation systems are solid-set, set-move and moving. Sprinkler irrigation is used for a wide variety of plants including field crops, vegetables, orchards, turf and pastures. Sprinkler systems are also installed for applying wastewater, protecting plants from frost, and dust control in confined animal operations.

1.1.2 Micro-irrigation: Micro-irrigation applies water at low rates and pressures to discrete areas so irrigation water reaches the root zone with minimal losses. Water drips from emitters in plastic pipe or tape, or bubbles or sprays from small emitters that only wet a portion of the soil surface. Micro-irrigation systems are popular for permanently installed systems that irrigate trees, vineyards, orchards and shrubs. These systems are typically automated so that water is applied frequently (e.g. daily or multiple times per day) to maintain optimum soil water content near the plants. Filtration is important for micro-irrigation because sediment and algae can plug the small openings on drip emitters, bubblers and micro sprays. Chemical treatment may also be necessary to reduce salt or mineral deposits that can plug emitters. Drip irrigation emitters are pre-installed within polyethylene pipe at regular intervals or emitters are attached to the outside of the pipe at desired locations.

1.1.3 Sub-irrigation: Sub-irrigation applies water below the soil surface to raise the water table into or near the plant root zone. Water is made available to the crop root system by upward capillary flow through the soil profile from a controlled water table. Each irrigation method and irrigation system has specific site applicability, capability, and limitations. Sub-irrigation is not often used in arid or semi-arid irrigated areas where irrigation is often needed to germinate crops. It is typically used in conjunction with subsurface drainage, or controlled drainage. Subsurface drainage lowers the water table and removes excess water through open ditches or perforated pipe. Water table depth can be controlled by installing a weir on the drainage system. During wet periods, the water table is lowered so the root zone remains unsaturated. During dry periods, water is pumped into the drainage system to raise the water table and provide additional water for plant growth. In some situations, drained water can be stored for use when irrigating.

1.2 Irrigation Water Quality

Surface water quality is a very sensitive and global conservational issue that is important for long-term economic growth and environmental sustainability (Nagy-Kovács *et al.*, 2019). Alertness and attention to water irrigation quality have increased worldwide in recent years, and new approaches have been developed to achieve the sustainable management of water resources (Shirmohammadi *et al.*, 2020). In the same context, the shortage of water resources has become a big problem in numerous countries, particularly under continued population growth, accelerated industrialization, rapid urbanization, and global climate change (Osman *et al.*, 2016). Therefore, water scarcity and sustainable irrigation water management have become global challenges for sustainable agriculture development in order to produce sufficient food to satisfy the population's food requirements (Wallace, 2000).

Irrigation water contains several dissolved salts (Kurunc *et al.*, 2020). The characteristics and amount of these dissolved salts depend on the water source and its chemical composition. The most ordinarily dissolved ions in water are calcium (Ca^{2+}), sodium (Na^{+}), magnesium (Mg^{2+}), sulfate (SO_4^{2-}), nitrate

(NO_3^-), chloride (Cl^-), boron (Br), carbonate (CO_3^{2-}), and bicarbonates (HCO_3^-). The proportion and concentration of these dissolved ions are used to determine the suitability of water for irrigation (Sarkar and Islam, 2019). Water irrigation quality for agricultural use is determined based on its impact on crop yield (quality and quantity), as well as its impact on soil physiochemical properties. Most soil problems (e.g. salinity, sodicity, contamination, and restricted infiltration) are due to the use of low-quality water for irrigation (Ucan *et al.*, 2007).

1.2.1 Importance of Irrigation Water Quality

Understanding irrigation water quality is critical to determining appropriate crop and soil management practices that are necessary for long-term productivity. Water quality affects:
Fertility needs of the crop, Crop yield, Soil physical conditions, Soil salinity, Irrigation system performance and longevity and Water application method

2. Materials and Method

2.1 *Experimental site description*

The experiment was conducted on the upland sugarcane experimental field of National Cereals Research Institute (NCRI) in Badeggi, Niger State. The sugarcane field is about 12 hectares in size, consisting of sandy-loam soil and a small slope towards the river having coordinates of latitude 9.0568^0 N and longitude 6.1434^0 E. The site lies on 70.57 m above the sea level with the physicochemical properties shown in table 1 below. The climate has distinct dry and wet season with maximum temperature of 35^oC. The field site was cleared, ploughed, harrowed, levelled and watered before planting of Sesame, as heavy pre-irrigation is very important to Sesame. The variety of sesame planted was E8 popularly known as S-Sudan, under irrigation with different N. P. K 15:15:15 fertilizer application rates of 0 kg per hectare, 40 kg per hectare, 60 kg per hectare and 80 kg per hectare. The layout was set in a randomized complete block design (RCBD), consisting three replications each with four plots of 5 m x 5 m, alleyway of 0.5 m and water channel of 1 m with a total plot size of 365.5 m^2. Each row is 5m long with inter row distance of 50 cm, there was no specific intra row spacing as drilling method of planting was used. The plants were thinned to the required number three weeks after planting, analysis on the physical and chemical properties on the soil of the location was conducted, yield parameters were also recorded. Irrigation schedule was 5 days at vegetative stage, 7 days at reproductive and ripening stages and ANOVA was used to carry out the result analysis.

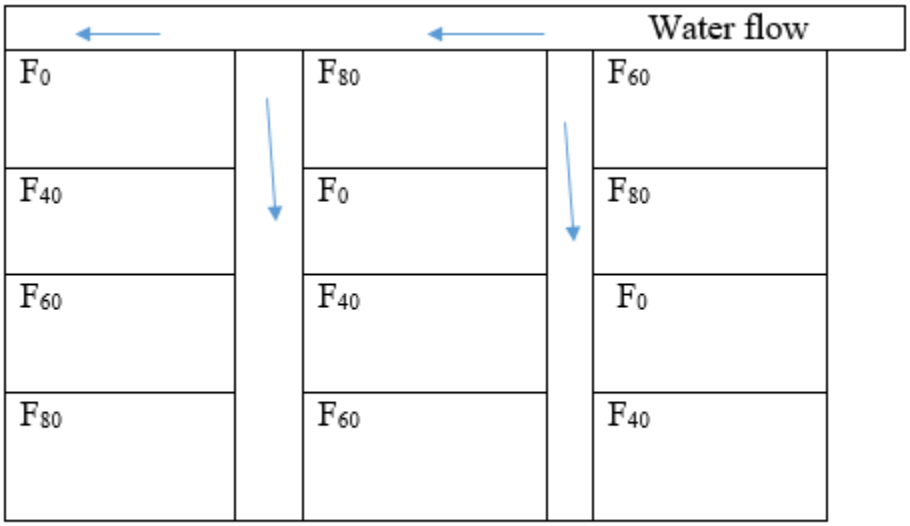
Data collected were plant height, leave area and grain yield.

$$\text{Leaf Surface Area (LSA)} = \frac{3(L \times W)}{4} \quad (1)$$

$$\text{LSA} = L \times W \times 0.75 \quad (2)$$

Where: L = Length of leaves (cm)
W = Width of leaves (cm)
0.75 is the coefficient
LSA = Leaf surface area (cm^2) (Malum et al., 2019)

2.2 Experimental Layout



**F_0 = 0 kg per hectare, F_{40} = 40kg per hectare, F_{60} = 60 kg per hectare and, F_{80} = 80 kg per hectare.

Figure 1: Late blooming stage

Figure 2: Early blooming stage

Figure 1: Late blooming stage

Figure 2: Early blooming stage

3. Result and Discussions

Table 1. Physico-chemical properties of the soil at the experimental site

Sand (%)	72.2
Silt (%)	18.3
Clay (%)	9.5
pH (H2o)	6.0
O C (%)	0.83
O M (%)	1.48
Total N (%)	0.07
Av. P (cmol kg-1)	0.03

Table 2. Mean values of morpho-agronomic characters of irrigated Sesame crop at different fertilizer levels

TREATMENTS	LEAVE AREA AT 8 WAP	LEAVE AREA AT 10 WAP	PLANT HEIGHT AT 9 WAP	PLANT HEIGHT AT 11 WAP	YIELD (KG)
0 kgha^{-1}	28.33 c	37.67 c	92.67 c	134.00 b	2.52 b
40 kgha^{-1}	34.00 bc	46.00 bc	98.33 bc	145.33 ab	2.87 b
60 kgha^{-1}	42.33 ab	55.33 ab	106.00 ab	152.00 a	3.68 a
80 kgha^{-1}	46.50 a	57.67 a	113.67 a	156.67 a	3.95a
SE±	4.55	4.0	3.36	5.55	0.16
CV (%)	14.75	9.96	4.01	4.62	6.20

Means with the same letter are not significantly different

*WAP = weeks after planting

From the table 2 above, it revealed that there was no significant difference in the leave area at 8weeks and 10 weeks after planting for treatment 1 and 2 (0kgha^{-1} and 40kgha^{-1}), as they all gave closely similar leave areas. Also, treatment 3 and 4 (60kgha^{-1} and 80kgha^{-1}) for the leave area at 8weeks and 10weeks after planting are highly significant from treatment 1 and 2, but there was no significant difference between them (treatment 3 and 4). Same trend was also true for plant height at 9 and 11weeks after planting, there was not significant difference between treatment 1 and 2 (0kgha^{-1} and 40kgha^{-1}), while application of NPK 80kgha^{-1} significantly gave the best plant height and was highly significant from plant height recorded for plots that received 0 kgha^{-1} and 40 kgha^{-1} NPK. The result of this study confirms the report of Budi and Moch, 2010 studied the response of sesame promising lines to nitrogen in irrigated wetland after paddy. The researcher further revealed stated that the effect of N fertilizer significantly increases plant growth. Haruna had also reported that sesame plant height increased from 85.48cm to 116.73 with increase N fertilizer rates from 0 through 100 kg/ha respectively. Abdel Rahman and El Mahdi 2008, also noted that increasing rates of N and P resulted in increasing plant height. Almost the same scenario in the yield, Application of 40 kgha^{-1} NPK does not significantly increase sesame yield under irrigation. While sesame plots that received 60 and 80 kgha^{-1} NPK fertilizer significantly yielded better when compared with plots that received 0 kgha^{-1} and 40 kgha^{-1} NPK application. This agrees with the report of Amare *et al*., 2019 who documented that largest seed yield per ha was recorded when nitrogen and phosphorus were applied at the highest rate of the treatment (128 kg N/ha and 92 kg P/ha). Meanwhile, irrigation was significant to sesame production as the output clinched above 1000kg/ha, which is within the range of maximum expected output of the variety in question.

4. Conclusion

The study was to assess irrigated sesame yield under different fertilizer application rate precisely, N P K 15:15:15. The rate are National Cereals Research Institute (N C R I) Badeggi recommended rate, below the recommended rate, above the recommended rate and control. From the result in table 2 above, it

shows that the control and below recommended rate (0kgha^{-1} and 40 kgha^{-1}) are closely performing the same. Likewise, the recommended rate and above the recommended rate (60 kgha^{-1} and 80 kgha^{-1}) are performing closely the same. So, it can be concluded that increase in fertilizer rate (above the recommended rate) will reasonably lead to sesame yield increase. Though from this experiment, the optimum fertilizer application rate in respect to plant height, leave area and yield is 80 kgha^{-1} as it is seen in table 2.

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SOCIO-TECHNO ECONOMIC IMPORTANCE OF SOLAR DESALINATION OF LOCAL WATER BODIES: A CASE STUDY OF UBURU AND OKPOSI LAKES, EBONYI STATE, NIGERIA

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Abstract
A survey of socio-economic importance of solar energy desalination of saline lake waters at Uburu and Okposi communities, Ebonyi State, Nigeria was conducted. Survey Research Design was adopted for this study. This was done with the assistance of a Non-Governmental organization (NGO) – Centre for Small Industry Research and Training (CENSIRT). The NGO equally validated the questionnaire, the instrument used for the study before it was administered in the survey area. The survey showed that about 1,200 women were involved in the salt production activity utilizing about 26,000 tons of fuel wood per year. Translated to monetary terms this amounts to about US$$1.5 million per year. Socio-economic lives of people in the communities were negatively affected because fuel wood utilization in salt production adversely results to deforestation, environmental pollution and high cost of fuel wood in the communities. The quality and quantity (output) of salt recovering process were not commiserating to time, energy and monetary input in the process. It was observed that the distillate (freshwater portion) of the salt recovery process was not considered as an important component of the salt extraction process because the salt producers were only interested in salt extraction only. The study showed that salt processing was the major income generation activity among women of the area. For sustainable salt production and freshwater recovery from the lake saline waters, solar desalination method was recommended for salt processing in the communities.

Keywords**:** *Socio-Economic, Importance, Solar, Desalination, Study*

1.0 Introduction

Water is one of the most important components of the Earth and life activities. Due to rapid increasing population and water pollution, shortage of freshwater has become very common to many nations, mainly to arid and semiarid regions of the world where about 25% of the world population lives, with total lack of good quality water supply. The Earth on its own is covered with about 75% of brackish and brine water which renders it inadequate for drinking and therefore not potable unless treated or processed further (Eze *et al.,* 2011). About 1.76 billion people live in areas already facing a high degree of water stress (Vorosmarty *et al.,* 2001). ‘‘Water stress’’ is at the top of the international agenda of critical problems, at least as firmly as climate change (Vaknin, 2005). Because of this, the need for desalination is increasing, even in regions where water supply is currently adequate.

To overcome the growing issue of freshwater shortage, saline water could be processed through the desalination application to obtain freshwater. Desalination has become one of the sources of water supply in several countries of the world today especially in the Middle East and North Africa region. Desalination is a technique where the excess salts are removed from sea water or brackish water converting it into safe potable or usable water (Widiasa *et al.*, 2009).

Desalination methods are categorized into thermal and membrane processes. These methods include multi-stage flash distillation (MSFD), multiple-effect distillation (MED), reverse osmosis (RO), solar desalination etc. (Lu *et al.*, 2007; Akgul *et al.*, 2008; Gilau and Small, 2008; Greenlee *et al.*, 2009). These methods of water purification have been proved to be the best way to solve the freshwater shortage confronting many nations (Eze and Ojike, 2012[a]).

However, there is a great potential to develop solar desalination technologies especially in the regions where solar resource is abundantly available. To make best use of the concept of desalination for freshwater production, solar still can be employed. At present, various researches have continued to improve its thermal efficiency (Eze and Ojike, 2012[b]). Many design changes are being made in solar still to make it applicable at large scale. This is part of the long term project of the United Nations Industrial Organization (UNIDO) in Uburu and Okposi communities of Ebonyi State, Nigeria. This will enhance salt production, availability of fresh water and boast the economic activities of the local people more especially the women folk. The present study is part of the project which is aimed at first understanding the perception of the communities to the project. The study involved the survey of the salt manufacturing communities to identify, ascertain and intervene in order to make salt manufacturing easy in the communities.

Desalination is energy intensive venture. In thermal plants about 14 kilowatt-hours of energy is required to produce 1,000 gallons of desalinated seawater (Eze and Ojike, 2012[b]). Cost of distillation is high because a notable large amount of electricity is needed to heat water that can generate high pressure.

Salt extraction and production a hereditary skill and a major profession only known exclusively as the primary occupation of the women folk in the communities. Traditionally, the salt water taken from the lakes are boiled over hours, fuelwood being the only energy source of heating. This has adversely affected the communities not in small measures but with the great consequence of deforestation, air and environmental pollution. Moreover, much time, energy and resources are expended to extract salt from the lake water.

However due to the tedious nature, crude traditional techniques of the process, ever increasing cost of firewood, time and energy sapping, modern development and poor income generation, many women have left the age long hereditary profession for other professions like trading on articles, farming, teaching etc. Presently, only few women are engaged in salt manufacturing in the communities. Among this number, majority combines salt production with other economic generating activities in order to earn a living and take care of their families. This therefore calls for an intervention for sustainability, profitability and poverty alleviation among the people more especially the women folk in Uburu and Okposi communities.

In response to the above needs, the United Nations Industrial Organization (UNIDO) in an effort to impact positively and sustain continuity of salt production in Uburu and Okposi communities, Ebonyi State, initiated action plan to introduce solar crystallization technique for salt manufacturing in order to improve and maintain the age long profession of the community women. The study involved the survey of the salt manufacturing communities to identify the level of energy input (fuelwood) involved in salt manufacturing. This was with a view of determining the appropriate technology to be introduced to help women folk in the production process. The primary objective of the survey was to promote solar desalination method for salt manufacturing in the communities.

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Other objectives include to:

1. To improve on the traditional methods of salt manufacturing in Uburu and Okposi Communities of Ebonyi State.
2. To eliminate firewood utilization in salt manufacturing in the communities.
3. To enhance profitability and efficiency in salt manufacturing
4. To reduce environmental degradation due to fuelwood utilization and deforestation in the communities.

2.0 The Study Area

The study area comprised Uburu and Okposi autonomous communities in Ebonyi State, Nigeria. These communities are best known to have salt lakes and ponds (Fig. 1). Because the available water bodies are salty the people trek several distances in order to search for freshwater for domestic and industrial applications. The two communities have closely related dialects and therefore speak similarly with much cultural affiliations. Their land is fertile; as a result, farming is the major occupation of the inhabitants.

About 90% of the people are involved in agricultural production, but the bulk of the farming activities are done by peasant households who use local implements to farm. Vegetation is generally thick and greenish during the raining season but scanty as dry season approaches. The land area is more or less undulating. The soil type ranges from fertile clayloam to lateritic clay causing water to stagnate on the surface of the soil. Average annual rainfall is 750mm while temperature range through the year is between 25 – 33^{o}C with average solar radiation intensity of 550W/m^2. Solar radiation is available throughout the year round. Minimum and maximum solar radiation intensity ranged between 370 – 780W/m^2. The communities lie within the tropical zone of the world on latitude 8^{o} 30'E and longitude 6^{o} 2'N. These climates provide favourable agricultural practices in the communities. Crops such as yam, cassava and rice are produced in commercial quantities.

Apart from agriculture, the communities are naturally endowed with saline (salty) ponds and lakes usually referred in the communities as "Mmahi" (salt lakes). There are three major salt ponds, lakes or springs in Ebonyi State in general which includes Uburu, Okposi and Enyigba. Other less ones are located at Ukawu, Idembia, Onicha and Inyaba.

Fig. 1: Uburu (left) and Okposi salty lakes of Ebonyi State, Nigeria

3.0 Methodology

Survey Research Design was adopted for this study. This research design enables specific issues to be investigated through information gathering on people's opinions and believes over a wide population (Okonkwo, 2005). This technique was relevant to this study because it involved sampling of opinions of stake holders (women, community leaders etc.) on the art of salt making in the communities.

In order to gather sufficient information on the salt manufacturing communities of Uburu and Okposi in Ebonyi State, survey instrument (Questionnaire), designed for the purpose was used. The questionnaire were administered to the women (respondents) who are directly involved in the salt processing activities in the communities. This was done with the assistance of members of a Non-Governmental organization (NGO) – Centre for Small Industry Research and Training (CENSIRT), State and local committee members, which were constituted for the purpose. The NGO equally validated the questionnaire before it was administered in the survey area.

3.1 Administration of Questionnaire

Based on the population of women engaged in salt production, total number of seventy (70) women was selected at random for the two communities at 40 and 30 for Uburu and Okposi respectively and the questionnaire were administered to them respectively. The questionnaire has sections A –F covering general information on the respondents, Social and occupational, salt production, Energy input, information on the community and technology of salt making in the communities. The survey was

constrained to elderly (married) women of age range between 23 years and above as a true reflection of those involved in salt manufacturing. The administration of the questionnaire was conducted and administered in groups. Women in each community were gathered together in the Village Square and the questionnaires were administered to the respondents who filled them there and returned them thereby. This was to make sure that accurate information was collated and also to avoid any possible manipulation and non-return of survey questionnaires by the respondents. Oral interview was used to extract information where possible. Members of CENSIRT and committee members were on hand to help the women who could not read nor write to fill the questionnaire (see Fig. 2). The completed copies of the questionnaire were analyzed using simple statistics such as frequency counts and percentages, and tables were provided where necessary.

3.2 Survey Instrument

The instrument used for data collection was questionnaire. A 43 items structured questionnaire was designed. The questionnaire was divided into 2 sections. Section 'A' sought for information on personal (Demographic) data of the respondents. Section "B" sought for information on the use of water from the local salt lake to produce salt.

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Fig. 2: Facilitators gathering information from local women salt manufacturers at Okposi

3.3 Validation of the Instrument:

A pretest of the study was conducted using ten (10) salt producers from both communities to test the validity of the questionnaire. This enabled the researcher to ascertain whether or not the questions asked would generate the required data. However, the results of the validation of the instrument revealed that all the questions in the questionnaire were able to generate required response. Hence, the instrument was able to measure the variables in the study.

3.4 Data Analysis

Social and Occupational indicators

The social and occupational indicators were obtained by taking the statistics of the respondents on the questionnaires as administered. The indication by some respondents as engaged in other occupations in addition to salt production was taken into account in the evaluation. The General formula used to estimate the percentage of each set of respondent on each question was given by

$$Y = \frac{Y_1}{X} X\,100\%$$

Where

Y = information sort for
Y1 = number of respondents in the group
X = Total number of respondents, for Uburu = 40, and Okposi = 30

General Information

The survey was limited to women folk who are the people directly involved in salt production in the communities. Although the sampling of respondents was basically on women, attention was paid on age distribution as age range between 0 – 15 were regarded as children whereas 16 and above were taken to be adult, the result however showed that 100% of the women respondents were resident in the communities. Evaluation indicates that all the respondents were within the age bracket between 23 – 85 years. These further stress that salt manufacturing in the communities is a profession of old women. Out of 40 women respondents in Uburu, 4 (10%) were below 30 years, 15 (37.5%) fell within the age range of 31 – 45 years, 14 (35%) were within the age range of 46 – 65 years old while 7 (17.5%) were above 65 years old.

In Okposi out of 30 women respondents, 3 (10%) were below 30 years old, 12 (40%) were within the age bracket of 31 – 45 years old, 10 (33.3%) were between 46 – 65 years old and only 5 (17.7%) were above 65 years old. It was observed that the majority of the respondents were within the age range of 31 – 65 years old demonstrating the age of active participation of women in the art of salt manufacturing.

The marital status of the respondents showed that 100% were married and none was single. While the general level of education/literacy was such that in Uburu community, of the 40 respondents about 60% were literate in vernacular. About 30% were found to have completed or attended primary education, 10% attended secondary education while none was found to have attended tertiary education.

With regards to education of the respondents in Okposi community, about 43.3% out of the 30 respondents were illiterates. They can neither read nor write. Only 46.7% have attended or completed primary education, while only 3% completed secondary education and none had tertiary education.

The understanding was that the women in the communities with higher or tertiary education found better profession in other areas either within or outside the local government areas such as in teaching, civil service or private sector other than salt manufacturing. A deliberate effort is thus required to give special incentives to the women no-matter their level of education to bring them back to traditional profession, if improved salt manufacturing is to be achieved in the two communities.

4.0 Results and Discussion

4.1 Economic Activities

Statistics indicate that salt processing was the major income generating activity among women of both Uburu and Okposi communities. However, because of development and prolonged periods coupled with cost of energy input and crude method of salt manufacturing the women either are engaged in some other activities in order to meet with the family demands. Such economic activities could be found in farming, trading, tailoring or civil service. In Uburu and okposi communities 80% and 70% of the respondents showed that salt production was their main occupation while 20% and 30% respectively stated other profession as their major occupation but taking salt production as a part-time economic activity. More so, 65% and 66.7% of the respondents combine salt manufacturing with farming activities respectively in Uburu and Okposi while 12.5% takes farming as the major occupation in Uburu. At Okposi 10% of respondents were engaged in trading, 3.3% were in civil service while 32.%in Uburu combine salt manufacturing with tailoring and only 2.5% is in civil service.

The above analysis therefore indicated that salt manufacturing is the major economic activity of women in both Uburu and Okposi communities. Any other activity is done as part-time or in combination with salt manufacturing. Only the elderly (married) women are involved with may be one or two little girls who help in fetching salt water from the lake. And it was only the traditionally made pots (the earthenware) are allowed to be used to fetch water from the lakes.

4.2 Price of Cake of salt

A market survey during the cause of the study at the area showed that salt is produced in solid form and moulded in sizes. The size of salt determines the market price at which the salt cake is sold. A Cake of salt in moulds weighs and ranged between 3.2 kg to 23 kg while the prices ranged from $ 0.8 – 8 US dollars. Monthly income from salt vary and ranged between 4 – 32 US dollars. All the women respondents (100%) in both Uburu and Okposi respectively indicated that they were not satisfied with the market price of salts considering the drudgery, fuelwood and time consumption. It was observed that most of the women were processing the salt at no or low profit margin. The general consensus was a price increment.

It was also a general consensus by both the respondents in both Uburu and Okposi communities that the most difficult and very expensive input in the production of salt was getting the firewood.

4.3 Firewood Usage in Desalination of the Saline water

From the survey analysis, fuelwood constitutes the only source of energy input in salt production in both Uburu and Okposi communities. It takes about 112kg bundle of firewood to produce 23kg of salt. In a year 21.67 tons of firewood is what it takes to fully engage in salt production business. For salt production 26,000 tons of firewood is utilized by 1200 women in the business for salt production annually. This when translated in monetary value gives a total sum of about $$1.5 million per year. This is the amount that could be saved if there is an alternative to fire wood input.

Apart from the indication that fire wood was the most difficult and expensive aspect of salt production in the communities, 100% of the respondents indicated the use of fire wood only as the energy input in boiling the salt solution. 95% of the sample survey in Uburu showed that between 3 – 5 bundles of fire wood were utilized in salt production while 5% indicated using 6 and above bundles of fire wood or trip of fire wood. Of the 30 sample survey in Okposi 80% used 3 – 5 bundles of fire wood while 6.7 % indicated between 6 – 10 bundles, 3.3% used 10 bundles and above, and 10% of the respondents bought the fire wood in trips.

4.4 Application of Solar Desalination Method in Distilling and Salt Production

Solar energy radiation in Uburu and Okposi communities was estimated to be at an average of 4.5kW/m^2/day. This is available for about 6.5hours on a daily basis and throughout the year. There was evidence that solar energy is being used in the communities in such areas as crop, cloth, fish and meat drying activities. However, there was no trace of use of solar energy either to boil or evaporate salt solution in both communities. The technology of solar still/distillation technology is not a common knowledge among the community members. Of the 40 and 30 survey sample respondents in Uburu and Okposi communities 30 (75%) and 26 (86.7%) indicated no knowledge of solar still or desalination technology while only 10 (25%) and 4 (13.3%) respectively indicated knowledge of solar still or desalination technology. All or 100% of the respondents in both communities indicated the willingness to accept solar technology that can save them fuelwood utilization in salt production. However, 95% and 80% of the respondents also indicated their willingness to pay for such technology if made available to them while 5% and 20% of the sample survey indicated no willingness to pay for such technology.

4.5 Sources of Potable Water for the Study Areas

Potable water supply was one of the major problems identified facing both Uburu and Okposi communities. This is because water from the lakes is very salty and therefore unfit for drinking and other domestic purposes. Major sources of water supply in the communities include manually operated borehole, streams/rivers, lakes and rainfall.

47.5% and 23.3% of sample survey respondents in Uburu and Opkosi respectively indicated getting their water supply from manually operated bore hole, while 47.5% and 50% indicated rain harvest as one of the sources of getting their water supply. Only 2.5% in Uburu indicated lake as source of water supply and buying freshwater from tanker supplies. However, all the respondents in both communities indicated

streams/rivers as one of the sources of getting water supply. The streams are between ½ - 3km radius depending on the location of the household. One thing that was common to all was the neglect of the water component of the traditional method in use that allows the steam of the boiling saline water to evaporate into the air. The steam could constitute freshwater if properly channeled and collected. This could save some amount of money, time, and energy of trekking long distance in search of water.

4.6 Other Environmental Challenges in the Study Area

Apart from water supply problem other problems identified were environmental related. While deforestation was evident as result of falling of trees for fuelwood, bush burning and air pollution from fuelwood usage in salt manufacturing, waste dumping were observed to constitute a threat to the environment. Of the 40 and 30 sample respondents from Uburu and Okposi communities 42.5% and 70% indicated deforestation as problem in the community, 10% and 33.3% responded bush burning to be a problem, 72.5% and 72.5% also showed air pollution resulting by fuelwood usage producing smokes to be a major problem while 17.5% and 3.3% indicated waste dump.

Whether there was any community plan to boast salt manufacturing 35% and 13.3% of Uburu and Okposi survey samples indicated there was no plan, while 65% and 60% of the respondents indicated that they are waiting for government to come and help them, 32.5% and 33.3% were of the opinion that there was no financial support from anybody to encourage them, and 47.5% and 46.7% said they are doing the salt production on individual basis respectively.

It takes a long time for new ideas, concepts or technologies to have an impact on an environment but salt manufacturers in Uburu and Okposi communities of Ebonyi State are already well aware of the drudgery involved in the current method of salt production in their communities. This results to the manufacturers' indication of innovative technology into the salt manufacturing process. Majority is aware of the potential of solar energy resources in the locality. Solar radiation is available all the year round.

5.0 Conclusion and Recommendation

5.1 Conclusion

This study showed that salt processing was the major income generating activity among women folk of both Uburu and Okposi communities of Ebonyi State, Nigeria. Whereas the drudgery of salt making in the study area was noted, the utilization of fire wood as a major source of energy input was observed to have affected the salt production adversely. While many women had left the age long profession of salt making and some doing it on part-time basses, firewood supply was regarded as a scarce resource, which has no substitute at the present. Supply by retailers is very costly. Its utilization in the communities is very competitive. Firewood is the major household energy consumption for domestic cooking, boiling and frying apart from the utilization in salt making. Okonkwo (2005) showed that about 1200 women in the communities comprising Uburu and Okposi are involved in salt production. Salt production in the communities is seasonal. Salt is produced only during the dry season when the environment is dry and brighter than the rainy season. In order to eliminate the drudgery involved salt making and improvement on the current system, an alternative option for sustainability of the profession and system environmentally friendly therefore is needed. This formed the base for this report study. Solar crystallization method has the potential of replacing age long fuel wood utilization in the salt manufacturing process. This represents alternative that could be more economical, environmentally friendly and sustainable.

5.2 Recommendations

Since from the sample survey it takes about a week for a salt manufacturer in the study area to produce about 23 kg of salt using the traditional method of salt processing, it is therefore recommended that a solar crystallization salt processing system that can produce at least the same quantity of salt (23 kg)

within the same period developed as an intervention to eliminate the drudgery involved in salt production in the communities. Other recommendations are as follows:

1. Establishment of solar equipment manufacturing centre that will take the responsibility of developing and manufacturing solar still for salt extraction in Nigeria.
2. Installation of six (6) and four (4) pilot solar crystallization plants in Uburu and Okposi communities close to the saline lakes respectively.
3. Training of local people on the technology, fabrication and installation of solar still.
4. Provision of micro credit for the purchase and fabrication of solar stills.
5. Empowerment of the local salt producers economically.

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SUSPENDED SEDIMENT MASS CONCENTRATION (SSC) MEASURING TECHNIQUES: A REVIEW

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Abstract

Sedimentation is a major environmental, engineering, and agricultural problem that is affecting people all over the world. However, since 1983, the amount of data collected to create solutions to sedimentation problems has decreased by around three-quarters. Suspended sediment surrogates can acquire sediment data with more precise approaches, have a temporal resolution and higher spatial, and are slighter labour-intensive, expensive, and dangerous. However, accurate measurements or estimates of this characteristic are frequently difficult to obtain when utilizing traditional methods of determination from collected water samples or optical sensors. The extremely variable character of suspended particles is undersampled by water analysis, and optical sensors are frequently rendered worthless by biological fouling in highly productive places. As a result, dependable real-time readings of suspended sediment mass concentration (SSC) and particle size distribution are needed (PSD). This review looked at the following equipment for SSC measurements: (1) Turbidimeters, (2) Laser Diffraction and LISST, (3) Acoustic Techniques, and (4) Differential Pressure. In addition to concentrations, LISST gave PSDs. Gravimetrical examination of automatically collected water samples yielded the reference SSCs. In contrast to commonly used turbidimeters and the single-frequency acoustic approach, SSCs acquired using LISST showed that particle size fluctuations had little or no effect on the pressure sensors. In comparison to acoustic or optical techniques, pressure sensors permitted a higher SSC measurement (without dilution). Pressure sensors capable of measuring SSC of less than 2 g/l were discovered. Coriolis Flow and Density Meters (CFDMs) and Vibrating Tube Densimetry, Automatic Water Sampling, Spectral Reflectance - Based, Digital Image Capturing - Based, and Electrical characteristics - Based CMTs are among the other continuous measurement technologies (CMT) examined in this research. The measuring procedures, tools, setup, and data treatment methods are provided and addressed in this work.

Keywords: *Sedimentation, Suspended Sediment, Mass Concentration, Measurement, Technologies*

1. INTRODUCTION

Sediment measurement is both difficult and expensive. A few of the expense is attributed to the reason that streams convey more than half of all silt during flood episodes (Nelson & Benedict, 1950). Collecting sediment samples is difficult unless an automated measuring device is utilized because these massive flows typically occur at night and are hard to forecast. Even now in perfect situations, the time and effort required to collect sediment samples add to the expense. Even though aggregates are frequently broken up during sample collection and handling, these ex-situ procedures also change the particle size distribution. Other scholars have stressed the need of quantifying particle sizes for fine sediments without disrupting aggregates (Droppo & Ongley, 1992; Walling & Moorehead, n.d.; Walling & Woodward, 1993; Woodward & Walling, 1992). Allowing the particles to settle, on the other hand, may result in the formation of more aggregates than in the initial sample. According to Phillips and Walling, settling for one hour and then resuspension can result in up to a 24 per cent increase in volume mean particle size (Phillips & Walling, 1995). They proposed that suspended-sediment fines measurements be taken in situ based on their findings. The natural physical processes of the riverbed, the quality of river ecosystems, and numerous human activities related to river management are all influenced by quantitative aspects of fluvial sediment flow (Landers, 2012). For instance, sediment resuspension from bed material produces riverbed deepening (Park et al., 2019), which, if persistent, can lead to a fall in low-water levels (*What Causes Streambed Erosion? Fact Sheet*, 2001) and, as a result, decreased groundwater levels (Koczka Bara et al., 2014; *What Causes Streambed Erosion? Fact Sheet*, 2001), altering the conditions for possible water extraction. The erosion of the main riverbed affects the water supply of tributaries and floodplains

(*What Causes Streambed Erosion? Fact Sheet*, 2001), which can cause tributaries and branch systems to become isolated. Fine suspended sediment transport (silt and fine sand) can degrade habitat quality in tributaries toer et al., 2018) sedimentation in the main riverbed can affect bank filtration systems (Gillefalk et al., 2018; Goldschneider et al., 2007), and changes flood conditions in floodplains (Nones, 2019). Fluvial sediment monitoring is thus a critical responsibility.

Nevertheless, specialized approaches, such as indirect methods, are required to set up and operate a well-functioning sediment monitoring system. In fact, in sediment monitoring, indirect approaches such as optical and acoustic methods are commonly used.
Acoustic methods and systems for assessing SSC as well as particle size distribution (PSD) are currently being developed. A single frequency cannot be used to determine SSC and PSD at the same time.

2. MEASURING TECHNIQUES

The SSC measuring techniques are as follows:

2.1 Turbidimeters

Turbidity is affected by particle size, shape, and colour in addition to SSC (Downing, 2006). As a result, if these particle properties change over time and are not linked with SSCs, biases in SSCs derived from turbidimeters are to be expected. Two basic measuring techniques of turbidimeters: scattering and transmission, which are dependent on the source, detector, and beam arrangement.

2.1.1 Scattering of Light-Based Turbidimeter.

The SSC value is computed using a turbidity-measuring apparatus with a diffraction gratings photodetector (see Figure 1). The angle used in the Nephelometer is 90 degrees, which is the most constant light scatter angle from the originating beam (Bin Omar & Bin MatJafri, 2009; Merten et al., 2013). The strength of light scattered is represented as follows (Sutherland et al., 2000):

$$F = 1.5 \times V \times C \times E \times \frac{Q_s}{(\rho \times D)} \quad (1)$$

The dispersed flux from suspended matter is denoted by F.

E is the light source's irradiance,
V represents the dispersing volume,
C represents the SSC,
D represents the diameter of the particle,
ρ is the density of the particle, and
Qs represent disperscolourfficiency.

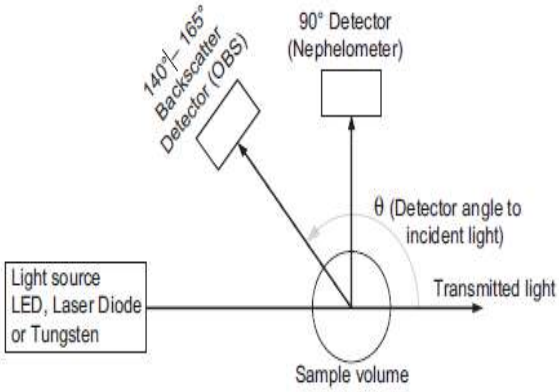
2.1.2 Transmission of Light-Based Turbidimeter

The Lambert-Beer law applies to transmission sensors that collect data on the intensity of transmitted light in water in the following manner (Ochiai & Kashiwaya, 2010).

$$I = I_o \times e^{-k \times c \times l} \quad (2)$$

Where I represent the intensity of light that is transmitted,
I_0 represents the intensity of light that is incident,
c represents the concern light-Basedsediment,
l represents the optical path length and

k represents a constant. As shown in Figure 1b, SSC can be calculated from transmission



intensitymeasurements using known value of constant k.

Figure 1a

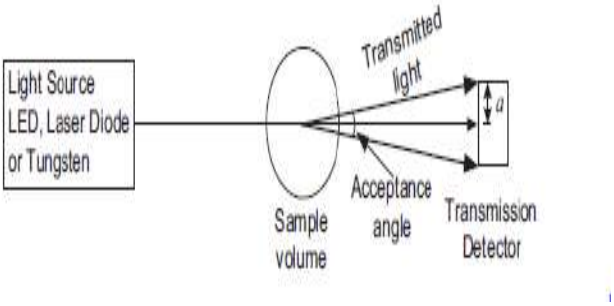


Figure 1b

Figure. 1a: After Bin Omar and Bin MatJafri, the source beam and detector sites for light scattering turbidimeters were adjusted (Bin Omar & Bin MatJafri, 2009).

Figure. 1b: After Anderson, the source beam and detector positions for light transmission turbidimeters were adjusted (Anderson, 2005).

2.1.3 Pros and Cons of Turbidimeters

The following are some of the benefits of technology associated with turbidite y-based continuous measurement:

1. Turbidimeters can collect data quickly, are simple to deploy, and have no mechanical parts.
2. For field situations, operating turbidimeter standards are provided (ISO, 1999; ASTM, 2009, 2014).
3. For obtaining SSC values from turbidimeters, no further measurements such as temperature, pressure, or other factors are necessary.
4. Turbidimeter is the least expensive of all CMTs

The optical technique has several drawbacks, including the following:

1. The area of suspended particles, the existence of bubbles, the size, colour, and shape of suspended particles, and the index of refraction all affect light transmission and scattering.

2. Due to the flow intrusive nature of the turbidimeter, they can only measure SSC at a single spot, which may not be typical of SSC across the entire study volume.

3. The possibility of biological contamination, which tends to modify the result from the calibration curve, is a fundamental restriction of optical continuous measurement(Gray & Gartner, 2010).

4. Diverse manufacturers' turbidity readings are not similar.

2.2 Laser Diffraction and LISST

A laser beam is directed into the sample volume in laser diffraction, where particles in suspension scatter, absorb, and reflect the beam (Fig. 2). Laser diffraction is commonly employed in laboratories for particle size distribution (PSD) measurement, in addition to sieving, hydrometer, and image analysis. The scattering (diffraction) of a laser beam at small angles (less than 9°) and its attenuation, induced by suspended particles, are studied in LISST equipment. The particle volume concentrations in 32 logarithmically spaced size classes (also known as size bins) are calculated using the software provided by the manufacturer using these light intensities. The PSD and total volume concentration (TVC) are calculated from the volume concentrations of each size bin. The TVC is then transformed to SSC in the final step (concentration by mass). SSCs can be measured using LISST equipment up to a limit set by a minimum optical transmittance. SSCs in rivers and hydropower plants (HPPs) may briefly surpass the measuring range of most LISST models when turbidity is high. A particular type of LISST gadget with a dilution chamber is available to test even greater SSCs (Agrawal et al., 2012).

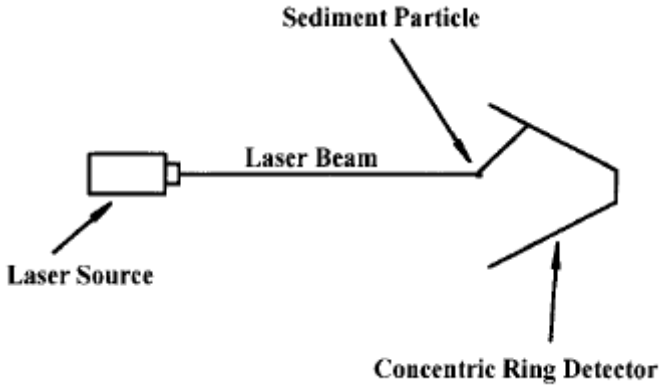


Figure 2. Laser Diffraction

2.2.1 Merits and Demerits of Laser Diffraction

Merits

Particle-size dependency is not a consideration. Instead, the concentration is computed based on the volume of the particles. (Agrawal & Pottsmith, 1996; Cao et al., 1991). The refractive index of the particles does not affect the readings of laser diffraction instruments (Agrawal & Pottsmith, 1996).

Demerits

The cost of laser diffraction devices is high and larger particles require longer focus lengths for measurement (Witt & Rothele, 1996). Laser diffraction devices are flow invasive because the measuring volume is so near to the instrument. They are complex gadgets that may necessitate specific training to operate and analyze data. The statistical techniques used to interpret the data do not yield a single concentration measurement.

2.3 Acoustic Techniques

Acoustic technology-based instruments use a piezoelectricity functioning transducer to fire a sound pulse into the substrate. Some of the pulse energy is reflected back by particles in the medium (Fig. 3). Ultrasonic signals are used in a variety of ways for SSM, the most common being Acoustic Doppler Current Profilers (ADCPs). Acoustic backscatter intensities and reference SSCs (in-situ calibration) are used to calculate SSCs (Guerrero et al., 2013). SSM can also be done with acoustic discharge measuring systems (ADM), which are common in bigger HPPs. (Gruber et al., 2016) discusses this form of single-frequency acoustic attenuation technique, as well as other acoustic ways.

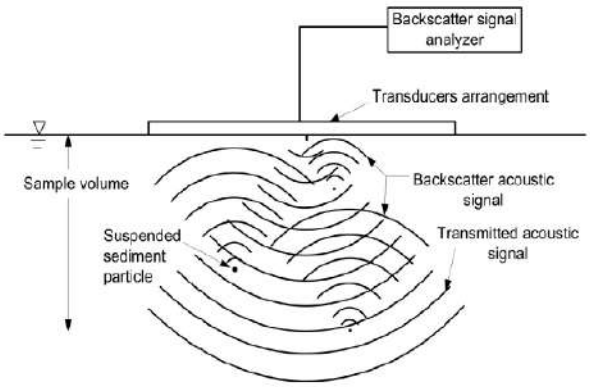


Figure 3: Acoustic Technique

2.3.1 Benefits and Limitations of Acoustic Technique

The following are the benefits of continuous measurement based on acoustic technology:

1. Many research has been published that discuss the theoretical elements of acoustic CMT (Kuhnle & Wren, 2005; Thorne & Hanes, 2002; Thorne & Meral, 2008).

2. Acoustic instruments are less prone to biological contamination than optical instruments since they are non-intrusive.

3. Acoustic CMT has a particular benefit over other CMTs in that it can evaluate sediment properties across a cross-section.

The acoustic technique has the following drawbacks:

1. Complex methods are used to convert measured backscatter signals to SSC. For assessing sediment properties, the algorithms require adjustment for both ambient water parameters and instrument features (Moate & Thorne, 2012; Thorne & Hanes, 2002). As a result, supplemental measurements such as temperature and salinity are required.

2. It is difficult to tell the difference between PSD and SSC with an acoustic instrument measuring on single-frequency (Agrawal et al., 2011).

3. At higher SSC, the backscatter-intensity response from acoustic instruments is nonlinear (Thorne & Hanes, 2002). With changes in PSD, the errors in SSC measurement with acoustic equipment rise. Because it relies on particle size, the acoustic approach is best for measurements in a small size range (Thorne & Hanes, 2002). For a certain PSD value, there is an ideal acoustic frequency (Thorne & Hurther, 2014).

4. When particles are smaller than 10 lm, the acoustic technique is ineffective (Costa et al., 2012).

2.4. Differential Pressure

Two pressure sensors with high sensitivity are positioned at separate fixed heights in a water column to make a difference in pressure-based CMT (Figure 4). Another SSM technique is the differential pressure. SSC is calculated using pressure data from two sensors deployed at two levels in a fluid column with a known variation in elevation. The headwater level and static pressure at the downstream end of the penstock (upstream of the turbines) are measured using this technique at the penstock of an HPP. The pressure difference between the top and lower sensors is greater when the water in the penstock contains suspended material than when the water is clear. In quasi-steady-state conditions, these pressure variations are translated to SSCs using the densities of clear water and particles (Felix et al., 2016).

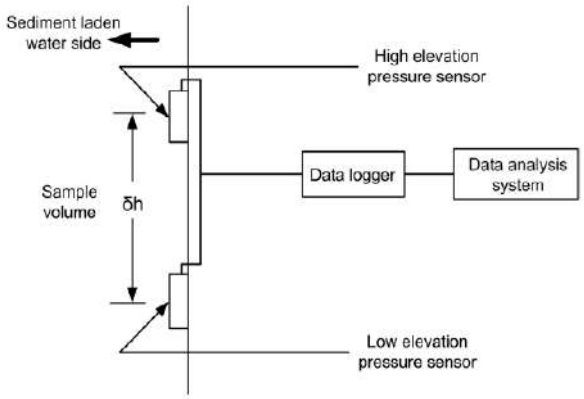


Figure 4: Pressure Difference Technology

2.4.1 Pros and Cons

The following are the benefits of pressure difference-based CMT:

1. The capacity to measure SSC above 10 g/l is a major benefit of pressure differential technology.

2. The reliability of CMT based on the pressure difference is relative with minimal biological fouling or signal drift issues (Gray & Gartner, 2009).

3. CMT based on the pressure difference is less expensive.

This methodology has the following drawbacks:

1. The notion that the SSC in the vertical profile above the lower pressure sensor stays unchanged for the computational principle of the technology may not be correct.

2. The sensitivity of flow turbulence, pressure transducers, fluctuations in water density, dissolved solid concentrations, and the density of the suspended particles all play a role in pressure difference technology.

3. Because of the low signal-to-noise ratios at low SSC, this technology is inefficient (Gray & Gartner, 2010).

2.5 Other CMTs

2.5.1 Vibrating Tube Densimetry and CFDMs

The density of the water-particle mixture can be used to determine higher SSCs. Continuous in-line density measurements are often performed in the process industry with 'Vibrating Tube Density Meters' (also known as 'oscillating U-tubes') or 'Coriolis Flow and Density Meters' (CFDMs) (Fig. 5). The density is determined in the first type of instrument using the natural frequency of the measuring tubes, which decreases as the mass of the fluid in the tubes increases. The Coriolis Effect is used to calculate the mass flow rate in CFDMs, and the density is calculated using the tubes' inherent frequency (Kalotay, 1999).

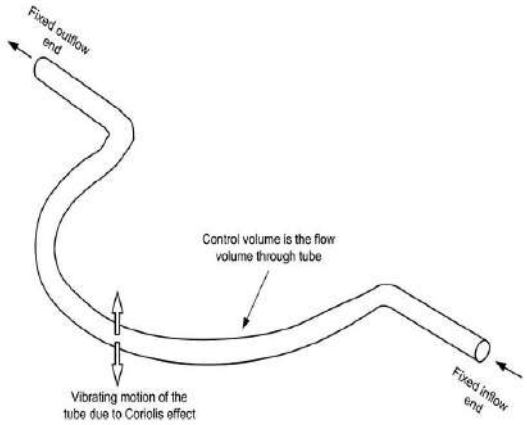


Figure 5: Vibrating Tube Densimetry

2.5.2 Automatic Water Sampling

The indirect SSC measuring procedures discussed above use gravimetric analysis of bottled water samples in the lab as a reference. Higher SSCs are likely to be overlooked in field investigations with manual bottle sampling since they are uncommon. The use of an automatic water sampler activated by SSC can help to solve this problem (or indicators for high SSC) (Felix et al., 2016).

2.5.3 CMT Based on Spectral Reflectance

SSC is calculated using a site-specific empirical model based on the amount of radiation reflected from the water within the sample volume by CMT based on spectral reflectance. Long, Pavelsky (Long & Pavelsky, 2013) gathered empirically established models that relate SSC or turbidity to water surface reflectance at various site conditions. As seen in Fig. 5, the spectrometer collects the reflected radiation. In most cases, the sensor catches radiation in the visible or infrared spectrum. Furthermore, the spectral reflectance approach has limited sensitivity (Wren et al., 2000). This device could be used to monitor reservoir siltation in hydropower, which is a serious issue for most dams around the world.

2.5.4. CMT Based on Digital Image Capturing

This device collects SSC, PSD, and particle shape data by taking and analyzing digital, high-quality photos of sediment-laden water. A lens, a fibre-optic link, a specifically constructed flow-through cell, a computer-connected camera, and a frame grabber are included in the system, which may gather two-dimensional or holographic images of suspended particles (Gooding, 2010; Graham & Nimmo-Smith, 2010). High turbidity levels, particles that are partially buried, and other irregularities that impair measuring accuracy are some of the major challenges for this technique. Inaccurate results could be caused by organic aggregates, stagnant material, or air bubbles in the sample region.

2.5.5. CMT Based on Electrical Properties

Based on electrical properties, the apparent dielectric constant change of distinct suspended sediment (sediment-laden flow) is employed to get continuous SSC monitoring in CMT. A signal generator, oscilloscope, and sensing probe make up the setup circuit, as shown in Figure 6.

For continuous SSC measurement, Chung and Lin (Chung & Lin, 2011) employed a widely viable Time Domain Reflectometry (TDR) instrument which is routinely used for cable fault identification. Chung and Lin (Chung & Lin, 2011) observed that TDR could detect large SSC readings (in the band of 2–300 g/l) in laboratory investigations, but that the readings were strongly impacted by changes in temperature. The salinity of the water, as well as the presence of algae, air bubbles, and debris in water ladened with sediments, influence these measurements (Chung & Lin, 2011). The approach is also obtrusive and susceptible to biological contamination.

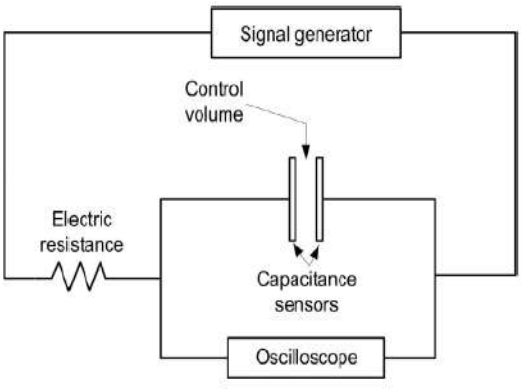


Figure 6: Measurement circuit using capacitive sensing technique.

3 CONCLUSIONS

Changes in climate, environmental monitoring, stringent building codes, and heavy rainfall have all increased the demand for high-resolution SSC data. CMTs have been discovered as a feasible option for such SSC data with high resolution. This review article provides a thorough summary of the many challenges surrounding CMTs for SSC. The basic principle of operation, applicability, availability, calibration requirements, benefits, and drawbacks of CMT's were all covered in depth. CMTs dependent on acoustics, turbidity, pressure difference, and laser diffraction is often employed, whereas technologies based on image capture, spectrum reflectance, electrical characteristics, and vibration tubes are in development. The turbidity-based approach is the most widely used and least expensive of the many CMTs for SSC measurement. Acoustic-based technology is the greatest solution for constant SSC monitoring. PSD values are obtained within the instrument measurement range, and SSC measurement using laser-based CMT is relatively accurate. CMTs at the research stage must be evaluated in a range of scenarios. Technologies based on spectral reflectance and capturing of images are ideal for constant SSC monitoring in their particular application regimes among the several evolving CMTs. At this time, it appears that using LISST in conjunction with a holographic camera is the best solution. However a lot of work has been done recently in the field of continual SSC measuring, more study and work are needed to increase measuring accuracy and range.

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EVALUATING THE SKILL OF THE MESOSCALE HYDROLOGIC MODEL (MHM) FOR DISCHARGE SIMULATION IN SPARSELY-GAUGED BASINS IN NIGERIA

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Abstract
In this study, the ability of four gridded-rainfall datasets for discharge simulation in Kaduna, Hadejia and Jamaare River Basins using the Multiscale Parameter Regionalization (MPR) technique were assessed. Rainfall products produced varying results with GPCC datasets presenting a KGE > 0.5 in most locations. mHM performances when forced with different rainfall products in a default and optimization setup showed significant improvement in streamflow simulations. A reasonable result (KGE = 0.5) was also achieved when optimized values obtained from Jamaare and Kaduna River Basins were using to validate discharge simulation in the Hadejia River Basin. This supports the need for more research in the area of hydrologic predictions in ungauged basins.

Keywords : *Mesoscale Hydrologic Model (MHM), Discharge , Simulation, Sparsely-Gauged Basins, Nigeria*

1. Introduction

The declining economic conditions in many sub-Saharan African (SSA) countries has resulted in about 50% - 60% of their workforce depending on agriculture (subsistence farming) as a source of livelihood (Poméon et al., 2018). In the era of increasing, global warming, rainfall variability and more frequent hydrologic extremes (flood and drought), the source of livelihood of a great majority of the population in this region is threatened (Dembélé & Zwart, 2016).

Availability of high quality rainfall data is essential for water-related research and to support policy-making in this sector (Akinsanola et al., 2018). The emergence of gridded rainfall products at high spatio-temporal resolutions and the development of distributed hydrological modelling procedures have created possibilities for water resources modelling in ungauged basins (Dembélé et al., 2020; Ogbu et al., 2020). Spatial rainfall data provides spatial homogenous coverage over inaccessible locations and has an advantage over in-situ data. However, many authors (Samaniego et al., 2010) noted that problems of model nonlinearity, scale, uniqueness, uncertainty and equifinality have not been satisfactorily addressed by the development of these complex distributed hydrologic models and their application at the mesoscale. Issues of over-parameterisation and equifinality of feasible solutions aid the production of unreliable hydrologic outputs even when a good fit between observed and simulated discharge is achieved, thereby creating uncertainties (Schoups et al., 2008). Even when model parameters are deduced through optimization, these values cannot be transferred to ungauged basins or to other scales other than that used during model calibration (Kumar et al., 2013; Samaniego et al., 2010).

Parameterization techniques that are geared towards reducing the number of free parameters and model complexity have been developed in the past (Kumar et al., 2013; Samaniego et al., 2010). The mesoscale Hydrologic Model (mHM) (Samaniego et al., 2010) employs the Multiscale Parameter Regionalization (MPR) technique to aid the transferability of parameters to other scales and also to ungauged basins. Detailed information on the MPR-mHM is explicitly explained by (Kumar et al., 2013; Samaniego et al., 2010). This study assessed the flow simulation capability of the mHM model when optimized parameters are transferred to an independent basin.

2. Methods

2.1 Study Area

The geographical location of Nigeria (Fig. 1) gave rise to the Inter-Tropical Discontinuity (ITD) which is the region of lowest atmospheric pressure which separates the dry northeast trade winds from the Sahara Desert, from the wet southwest monsoon from the Atlantic Ocean (Akande et al., 2017). The study basins are the Kaduna, Hadejia and Jamaare River Basins which are located in the semi-arid northern region of Nigeria (Figure 2). This region is characterised by sparse vegetation with scattered shrubs occasioned by frequent droughts and high rainfall variability (Adeyeri et al., 2019). About twenty million persons dwelling in the Hadejia-Jamaare river basin are involved in cattle rearing, aquatic agriculture, cropland farming and trading as sources of income (Adeyeri et al., 2019).

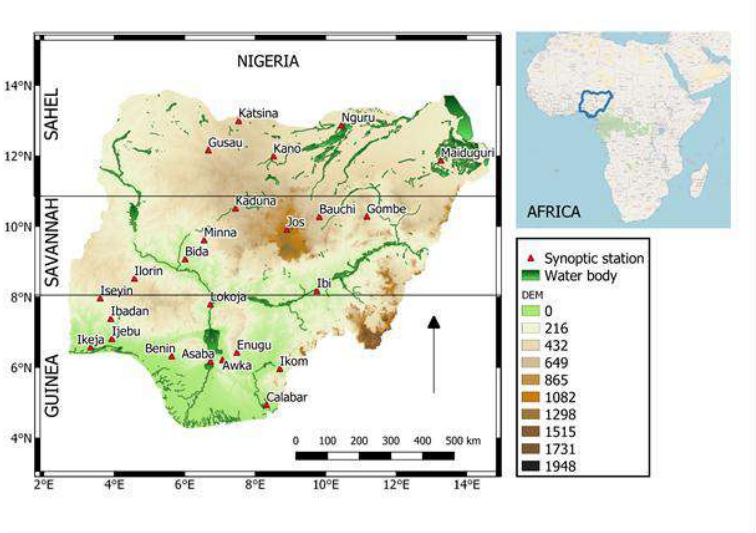

Fig. 1. Synoptic station locations in Nigeria

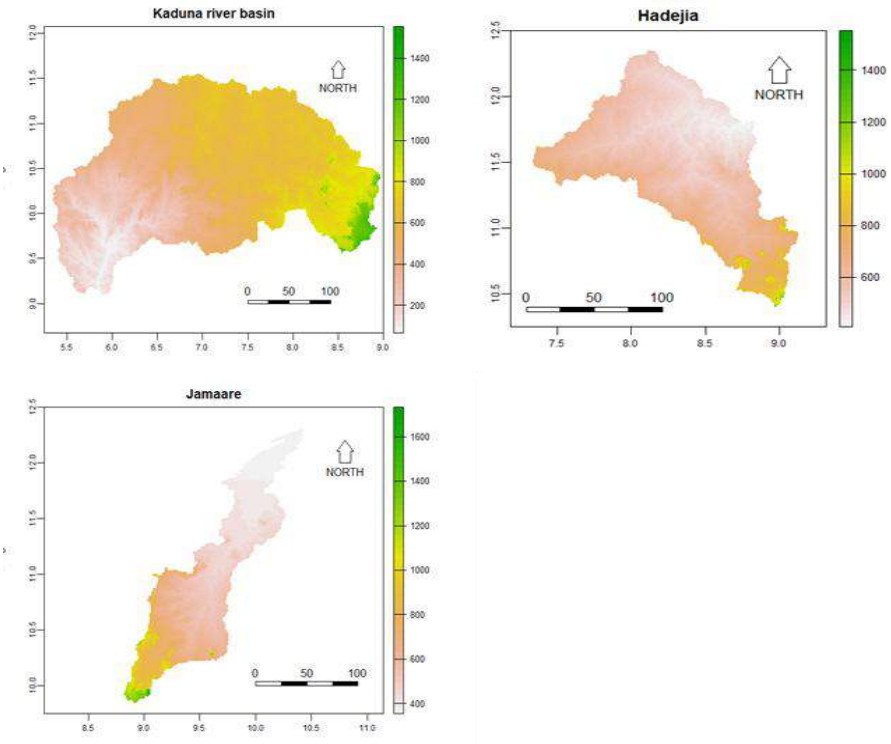

Fig. 2: Kaduna, Hadejia and Jamaare River Basin

2.2 The mesoscale Hydrologic Model (mHM): Description

The mesoscale Hydrologic Model (mHM) is a grid-based, spatially-explicit conceptual hydrologic model forced with precipitation, temperature and potential evapotranspiration datasets (Kumar et al., 2013). Its mathematical formulations are based on numerical approximations of dominant hydrologic processes as found in Hydrologiska Byrans Vattenbalansavdelning (HBV) (Lindström et al., 1997) and Variable Infiltration Capacity (VIC) (Liang et al., 1994) models. Three mHM levels (Level-0, Level-1 and Level-2) (see Figure 3) are used to represent the spatial variability of state and input variables. In other to reduce the number of free calibrated parameters vis-à-vis the prediction uncertainty, the MPR was employed to link model parameters at coarser grid (Level-1) with model parameters at a finer resolution (Level-0) using upscaling operators. Interested readers can find a detailed description of mHM-MPR in previous studies (Samaniego et al., 2010, 2017).

2.3 Data and Inputs

Information on the different gridded precipitation datasets, which was evaluated against gauge-based records, are shown in Table 1. In addition to climate datasets (rainfall and temperature), an ensemble of datasets (as shown in Table 2) are important for the set-up of mHM model.

Table 1: Precipitation products evaluated in this study

Precipitation product	Data Sources	Spatial Coverage	Spatial resolution	References
ERA5	Reanalysis	Global	0.25°	(Hersbach et al., 2020; Muñoz-Sabater et al., 2021)
CHIRPS	Satellite, gauge, reanalysis	50° N – 50° S	0.05°	(Funk et al., 2015)
GPCC	Gauge	90° N – 90° S	1.0°	(Schamm et al., 2014)

MSWEPv2.2	Satellite, gauge, reanalysis	Global	0.1°	(Beck et al., 2019)

Table 2: mHM Modelling Datasets

Variables	Products	Resolution	References
Elevation, slope aspect, flow direction and accumulation	SRTM	90 m	http://srtm.csi.cgiar.org/
Soil depth, bulk density, sand and clay content	Soil Grids	250 m	(Hengl et al., 2017)
Landuse/cover	Globecover 2009	300 m	(Bontemps et al., 2011)
Leaf area index	GIMMS	8 km	
Streamflow	GRDC	Point	(Fekete et al., 2002)
Rainfall and temperature	Guage	Point	Nigeria Meteorological (NiMet) Services Agency

2.4 Modelling Framework

Four (4) gridded precipitation products (Table 1) comprising of satellite, reanalysis and gauge datasets were evaluated over three distinct climatic regions in Nigeria. Daily rainfall data (1983 – 2013) from twenty-four (24) synoptic station (see Figure 1) were used to evaluate these gridded datasets at grid-to-point scale. Results were evaluated using metrics such as kling-gupta efficiency (KGE), correlation (r), percent bias (PBIAS) and root mean square error (RMSE) (Kling et al., 2012; Moriasi et al., 2015). A modelling experiment was developed to assess twelve (12) different discharge simulations while varying precipitation datasets (CHIRPS, ERA5, GPCC and MSWEP) across three (3) river basins and using default model parameters. All the model set-ups were further optimised and performances for discharge simulated evaluated. Model optimisation was performed using the Dynamically Dimensioned Search (DDS) (Tolson & Shoemaker, 2007) algorithm. Once the most performed gridded dataset is established, it is used in the next stage of modeling experimentation. Thirdly, a multi-basin mHM setup was developed by setting-up mHM for three (3) different basin combinations (Basins 250 + 410, Basins 572 + 410, Basins 250 + 572) using only CHIRPS datasets in other to infer unique model parameter sets for every basin combination. Lastly, optimized parameter sets obtained from each of the two-basin combinations were used to evaluate discharge in the third (3rd) basin. This approach is necessary to assess mHM capability for discharge simulation using optimised parameter values from independent basins.

3 Results and Discussion

Taylor diagrams showing time series of daily gauge rainfall in comparison to grid-based products for stations for some synoptic stations are shown in Figures 3. In the Sahel, only GPCC was able to record satisfactory correlation (r > 0.5) and RMSE (RMSE > 12) for all locations under consideration. This trend was also the same in the Savannah region with correlation values above 0.6 (i.e. r > 0.6) and lower RMSE values (RMSE > 9). In the Guinea coast region, acceptable result (r > 0.9, RMSE > 5) were obtained in Lokoja (Figure 6).

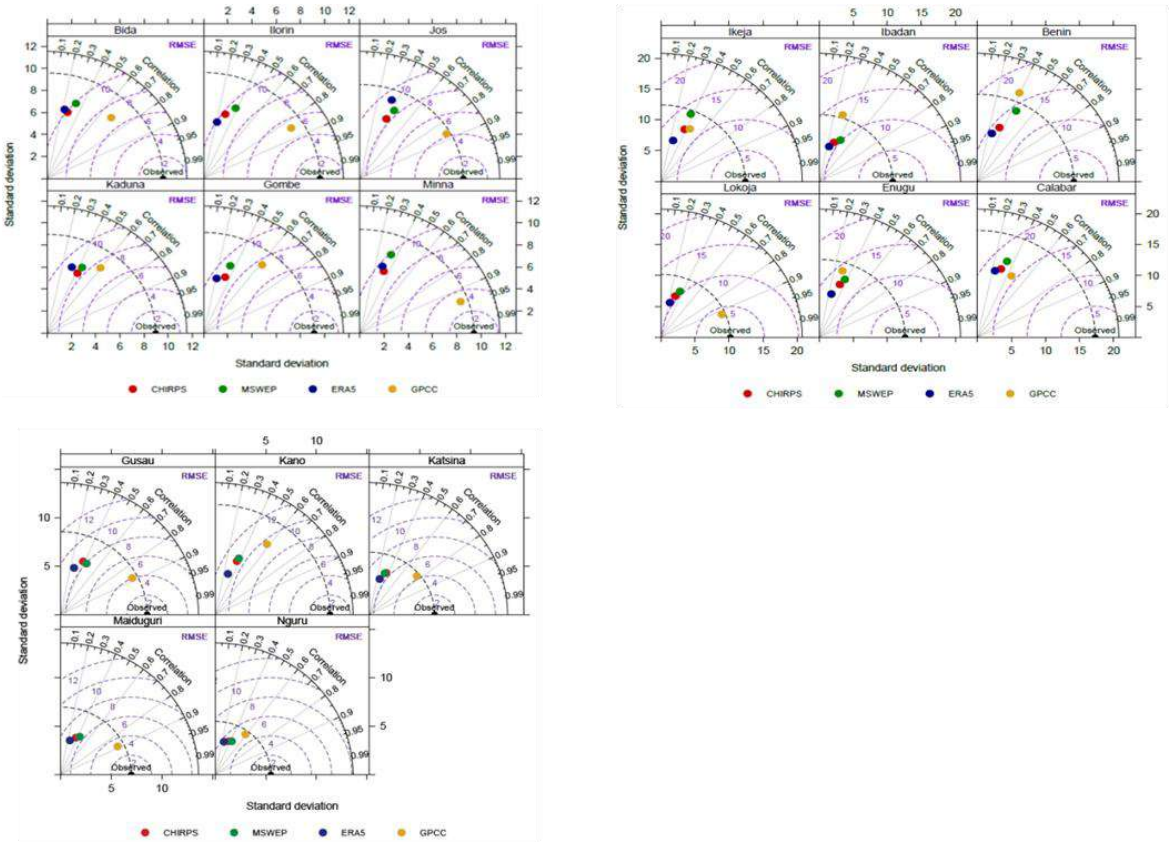

Fig. 4: Taylor diagrams showing grid products against gauge rainfall data

3.2 Exploratory and Optimized Model Results

During mHM exploratory runs, discharge simulations were performed using default model parameters while varying precipitation inputs across three (3) different basins. Result of exploratory mHM simulations using default parameter values are shown in Table 2. Acceptable KGE values as recommended in a previous study (Knoben et al., 2019) were obtained for discharge simulation in the Jamaare river basin when forced with CHIRPS (KGE = 0.68437) and MSWEP (KGE = 0.65066). In Hadejia and Kaduna river basins, none of the gridded rainfall products produced satisfactory results except ERA5 in Hadejia (KGE = 0.68170).

Furthermore, mHM was calibrated for discharge simulation using different rainfall forcing. KGE values during optimized mHM runs are shown in Table 2. Satisfactory calibrated discharge results was produced by CHIRPS (KGE > 0.5) in all three basins, with ERA5 in Jamaare (KGE = 0.75) and Hadejia (KGE = 0.64). MSWEP produced a KGE > 0.5 in the three basins while GPCC gave KGE value of = 0.63 in Hadejia river basin. In comparison with default mHM parameter simulation, optimised discharge simulation results (KGE values) showed an increase of 15.85% in Jamaare, 155.62% for Hadejia and 123.11% in Kaduna basin when forced with CHIRPS. For ERA5, a decrease of 6.43% was obtained in Hadejia while an increase of 1155.44% and 124.98% were observed in Jamaare and Kaduna basins respectively. These improvements in discharge results when compared to that from default mHM runs were also obtained when optimizations were performed with MSWEP (17.31% - 241.1%) and GPCC (4.57% - 132.64%) forcings in the three basins.

Table 2: KGE results for default and optimized mHM discharge simulations

Simulation using default mHM parameters			Simulation using optimized mHM parameters			Meteo
Jamaare (Basin 250)	**Hadejia (Basin 410)**	**Kaduna (Basin 572)**	**Jamaare (Basin 250)**	**Hadejia (Basin 410)**	**Kaduna (Basin 572)**	
0.68437	-1.1822	-2.2168	0.79285	0.65755	0.51219	CHIRPS
0.0597	0.68170	-1.7754	0.74950	0.63787	0.44349	ERA5
0.65066	-0.52586	-1.7784	0.76328	0.74201	0.51867	MSWEP
0.42895	-1.3434	-1.4972	0.44857	0.62539	0.48870	GPCC

3.3 Multi-Domain Optimization

Three (3) different multi-domain mHM combinations (Basins 250 + 410, Basins 572 + 410 and Basins 250 + 572) were set-up and forced with the CHIRPS precipitation product. Discharge calibration showed acceptable KGE values only in one combination (Basin 572 + Basin 410) as presented in Table 3.

Table 3: Optimized mHM Results (KGE) from Multi-Domain Combinations

Domain	Multi-domain combinations			Meteo
	Domain 250 + Domain 410	**Domain 572 + Domain 410**	**Domain 250 + Domain 572**	**CHIRPS**
1	0.33267	0.51074	-0.03320	
2	0.64324	0.50516	0.58442	

Having calibrated each of the muti-domain mHM setups for discharge simulation, optimized values from Domain 250 + 410 were transferred to Domains 572 for discharge simulation. Also, calibrated mHM parameters from Domains 572 + 410 were used for flow simulation in Domain 250 while optimized parameters from Domain 250 + 572 were transferred to Domain 410. Optimized model parameters from domain combination of Basins 250 + 572 produced accepted KGE when its parameters were transferred to Basin 410 as shown in Table 4.

Table 4: mHM validation Results on Independent Basins

Domain	Single Domain mHM Simulaions			Meteo
	Domain 572	**Domain 250**	**Domain 410**	
KGE	0.024519	-0.12124	0.54387	**CHIRPS**

Hydrographs of daily, monthly and annual flow cycle for Basin 410 (Hadejia River Basin) are shown in Figure 5. The monthly discharge (Figure 11) show slight underestimation of observed discharge but with acceptable performance (KGE = 0.61, r = 0.78). At daily time step, observed and simulated discharge exhibited similar trend but with significant peak mismatches.

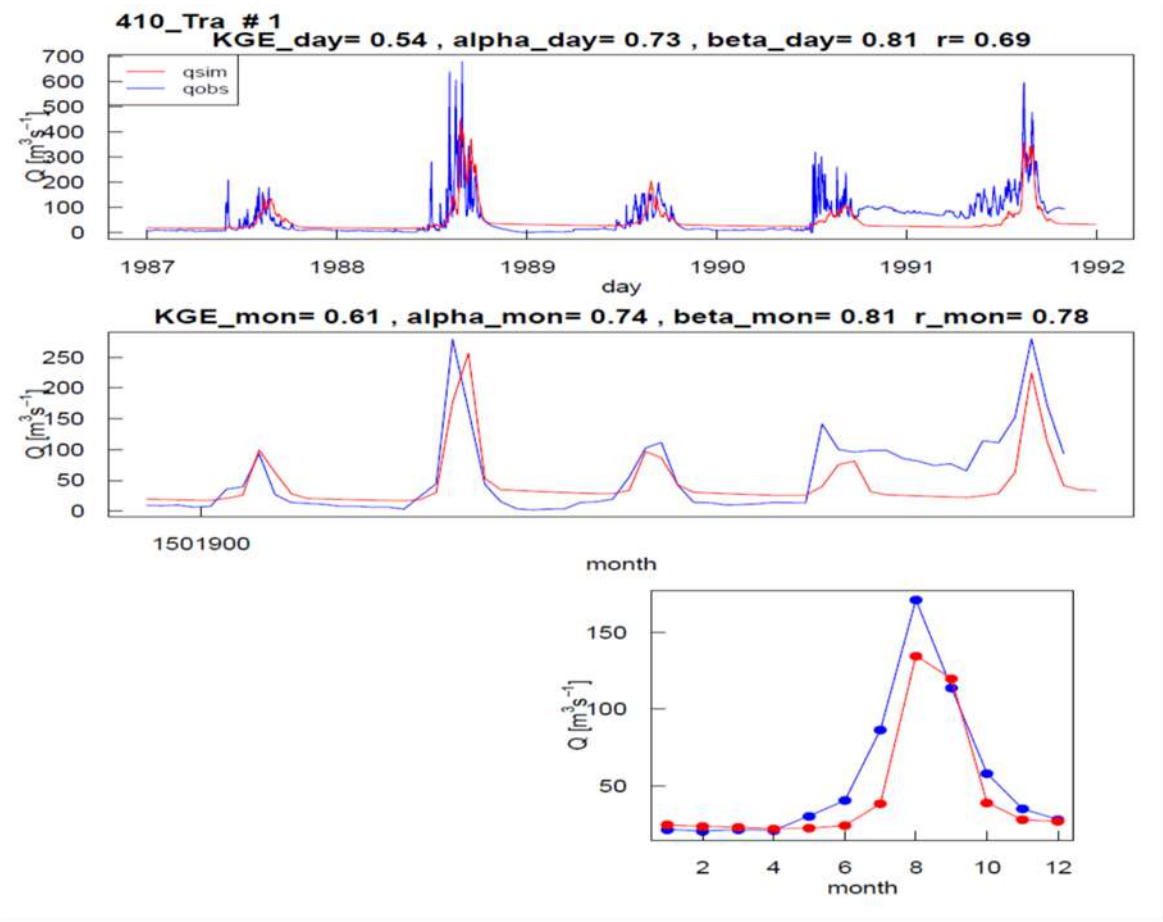

Fig. 5: Validation at Daily, Monthly and Mean Annual Cycle for Hadejia River Basin

Conclusion

Sparse or non-existent hydro-meteorological gauging networks have greatly limited hydrologic modelling in Nigeria. This has major implications for water management at the mesoscale at a period when hydrologic extremes occasioned by climate variability have become more frequent. This study evaluates the skill of mHM to use optimized parameters from a modelled basin for discharge simulation in another basin using grid-based precipitation datasets. CHIRPS precipitation datasets was selected as model forcing after evaluating four grid-based precipitation products. Findings also showed that CHIRPS produced satisfactory results during default and optimized mHM discharge simulations. In all evaluated basins, Hadejia River Basin showed acceptable results when mHM was evaluated using model parameter values obtained from Kaduna and Jamaare River Basins.

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DEVELOPMENT OF A GREENHOUSE SYSTEM FOR MANURE DRYING OPERATIONS

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Abstract
Improper handling and disposal of animal manure could lead to air, water and environmental pollution by the actions of pathogenic microbe activities. The resultant effects of this could be disease outbreak and transmission within animal clusters which could later translate to high mortality rates among others. However, for better management, transportation and storage handling many farmers engage the services of drying systems either by conventional or non-conventional energy systems. Among these, non-conventional energy powered systems has proven a better option and attractive because it is environmentally friendly and could mitigate climate change and global warming. In this report, a passive greenhouse solar powered dryer for drying poultry manure was developed at the Department of Agricultural and Bioresources Engineering, University of Nigeria Nsukka latitude 7^{o} N in the south eastern, Nigeria. The Solar powered greenhouse system consists of a drying chamber which is made up of manure drying trays. The internal dimensions of the drying system are 3.08 m x 2.09m x 3.31 m respectively. The body of the system is formed with a 5 cm and 2.5 cm angle iron for rigidity and firmness while the entire framework is covered with 5 mm thickness transparent glass that allows direct solar radiation into the drying chamber. Inlet and chimney (outlet) openings measuring 4800cm^2 and 4654 cm^2 respectively were provided for air draught. . The system is capable of handling about 200kg poultry manure at a batch of 8 hours drying period under bright sunshine weather. The preliminary test performance results of the system using poultry manure is also presented in this report. Application and utilization of greenhouse solar powered drying system in poultry production will enhance odor reduction in poultry farms and improves poultry production environment as negative effects of climate change will be mitigated.

Keywords: *Poultry, Manure, Drying, Greenhouse, Solar Energy*

1.0 INTRODUCTION

Manure drying has become so important because of enormous challenges associated with handling the raw and wet manure. Improper handling of raw poultry manure can cause environmental problems because of its associated air, water and soil pollution (Benali and Kudra, 2002). Raw poultry manure contains some microorganisms and pathogens (Ghaly *et al*., 2013) which emits ammonia gas as it undergoes decomposition. Ammonia in high concentrations, can have adverse effects on the health and productivity of birds as well as the health of the farm workers and other nearby inhabitants (Zhang and Lau, 2007; Amon et al., 2006) Raw and wet poultry manure is heavy due to its water content which makes it cumbersome when being used as organic fertilizer in farms. In other to overcome the handling and other challenges associated with wet and raw poultry manure, the water component needs to be reduced by drying. Drying is the removal of moisture from the manure in order to minimize the rate of deterioration from chemical and biological processes (Ghaly and MacDonald, 2012). During drying, the heated air passes through the manure and results in higher rates of oxidation and pathogen destruction (loehr, 1977). Drying of manure reduces its weight, it deactivates its contained pathogens and microorganisms by dehumidification. The essence of poultry manure drying is to reduce health risks associated with handling wet manure, meet man's desire for fertilizer that could be neatly handled (Bernhart and Fasina,2009) and also to secure food for other animals. Drying of upgrading (Benali and Kudra, 2002). manure is an essential step in manure

Dried poultry manure is relatively light and easy to transport because it has lost over 50% of its weight as raw manure has been found to contain between 25% to 70% moisture which could be removed through drying. Dried manure is an asset for commercial purposes like feeding of other animals (Alam et al., 2008), It is used in supplementing nutrient requirement when compounding fish feeds in other to reduce the feeding cost and also to form a good ecological cycle between chicken and fish farming. Dried manure is being used as urban organic fertilizer without the harmful and pungent ammonia smell (Thomas et al., 1972) In furtherance, a lot of research has been carried out for feeding of ruminants, DeBoer on the use of dried poultry manure (1981) conducted series of digestibility experiments on dried poultry manure feeding to ruminants and reported that the results of dried poultry manure feeding to ruminants showed an average net energy content of about 6400 kJ/kg of dried manure and an average protein content of about 300 g/kg of dried manure. (Ghaly and MacDonald 2012a) stated that results of dry poultry manure feeding experiments with young fattening bulls showed no effect on their carcass-quality, or taste and smell of its meat, Thomas *et al.* (1972) also reported that feeding caged layer waste to dairy cattle did not affect the composition or flavor of their milk. These thereby supports the use of dried poultry manure for feeding of ruminants considering its high nitrogen/protein content as stated by (Alam *et al*., 2008). Manure drying requires the passage of higher temperature unsaturated air through the surface of the manure to be dried, the drying air can be heated using solar energy source, electricity, natural gas, biogas, oil and other fossil fuels, etc. Using solar energy as a source of heat for drying offers the advantages of availability especially in the tropics, high oxidation rate, good waste stabilization, cheapness and affordability. Based on dryer classifications by Pranav et al.,2015 there are so many types of solar is one of them. manure dryers and greenhouse dryer Greenhouse manure dryers are buildings that are wholly glazed with transparent glass or plastic to maintain thermal conditions within desired temperature range necessary for drying, it allows short-wavelength visible light to pass through the transparent glazing to the interior surfaces which heat up and emit long-wave infrared radiation. If a greenhouse manure dryer is operated under natural convection mode of heat transfer, then it is called a passive mode greenhouse dryer. Passive mode greenhouse dryers are provided with outlet chimneys and air inlet channels to create thermosiphon drift of air by natural convection. If it is operated under forced convection with blowers (fans) attached, it is an active mode greenhouse dryer. Passive mode greenhouse dryers are more appropriate for large-scale drying of the agricultural produce (Prakash and Kumar 2014a).

2.0 MATERIALS AND METHODS

2.1. Description of the Greenhouse Poultry Manure Dryer

The greenhouse poultry dryer is a passive solar energy powered system for manure drying. The system consists of a drying chamber with three layers of drying trays with a total drying surface area of 10080 cm^2. The internal dimensions of the drying system are 3.08 m x 2.09m x 3.31 m respectively. For rigidity and firmness, the body of the system was formed and supported with a 5 cm and 2.5 cm angle iron while the entire framework is covered with 5 mm thickness transparent glass that allows direct solar radiation into the drying chamber. Inlet and chimney (outlet) openings measuring 4800cm^2 and 4654 cm^2 respectively were provided for air draught.

The greenhouse solar manure dryer was designed to handle about 300 birds manure generation per batch of drying period. According to Poultry International (1985) reported manure production for layers in cages is 1 ton/ 1000 birds per week. For the study, the expected manure to be generated (output) by 300 birds is given by,

300/100 = 0.3 tons per week (1)

At 70% moisture content with density of 1 ton per cubic meter, the volume of 0.3 tons of poultry manure dryer was given by

0.3/1 = 0.3m3 = 0.3 x 10^6 cm^2 (2)

Using an optimum drying dept of 3cm for maximum drying efficiency (Ghaly *et al*., 2012).

the area of drying tray was

(0.3/3) x 10^6 =100,000 cm^2 (3) The trays were located at both sides of the drying chamber with a central walk way measuring 60 cm by 140. The total drying surface area was 100,800 cm^2.

2.2: Measurement

Fresh samples of poultry manure were collected from National Centre for Energy Research and Development, University of Nigeria, Nsukka (NCERD, UNN) poultry farm and dried simultaneously in two batches of 200g each. The both samples were placed to occupy an area of 314.2 cm2 thereby having a manure thickness of above 2cm. One was dried inside the greenhouse dryer while the other was dried using the traditional direct open-air drying. Both samples were weighed every 15 minutes using M-Methlar Electronics compact scale (Model M-411l). The various temperatures at various parts of the dryer and the ambient as well as the open-air sample was taken using a multi-channels temperature meter (Appelent product AT4208). The corresponding weather parameters were obtained from Davis USA, weather station installed within NCERD, UNN Biomass block. The drying was conducted for six hours consecutively between 10:30am and 4:30pm at UNN, Nsukka located within Latitude 6.80N and Longitude 7.30E and about 488m above sea level. The sample was dried until it attained equilibrium moisture content and was carried out repeatedly and the averages computed.

RESULTS AND DISCUSSION

Figure 1. below shows the relationship between the temperature inside the dryer, the dryer exhaust air and the ambient air. From the results obtained, the dryer average temperatures of 37^0C and 37.7^0C of the drying air in the chamber and the exhaust air in chimney respectively when compared with the mean ambient air temperature of 30.7^0C, it translates to about 23.3 percent temperature gain in the dryer. Based on this, it is obvious that the dryer has provided a warmer environment conducive for drying agricultural products.

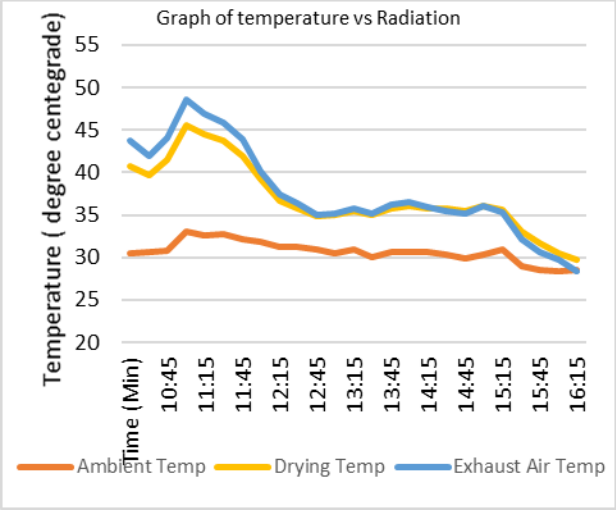

Figure 1. Graphical representation of the relationship between the dryer temperatures and solar radiation.

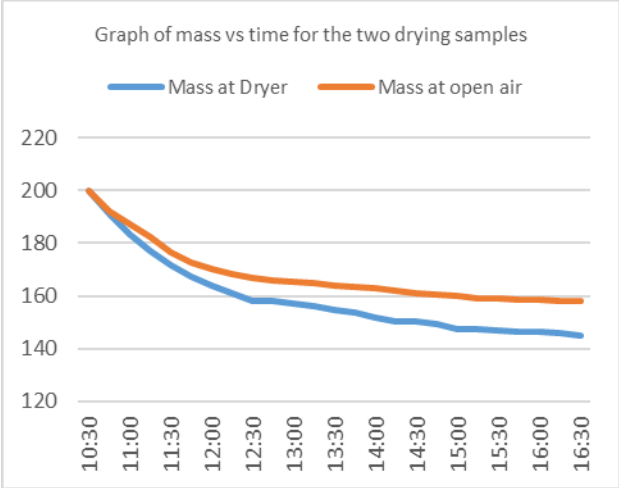

Figure 2. Graph of mass(g) versus time for the two drying samples.

The graph of figure 2 above clearly shows the difference in the rate at which the two samples are losing water simultaneously. From the graph, the dryer is observed to be 31.9 percent faster than the open air during the periods of manure drying. This is in line with the findings of Bhuyan *et al.*, 2019 whose active solar dryer was over 40 percent faster than open air when used for the drying of tomato samples. The drying rates for the two manure samples are 0.007kg/hr and 0.00916kg/hr for the manure samples in dryer and open air respectively and this is relatively proportional to the drying rates of 0.0272kg/hr and 0.03833kg/hr for the tomato samples in dryer and open air respectively as obtained by Bhuyan *et al.*, 2019.

Figure 1. Graphical representation of the relationship between drying rate and dryer temperature.

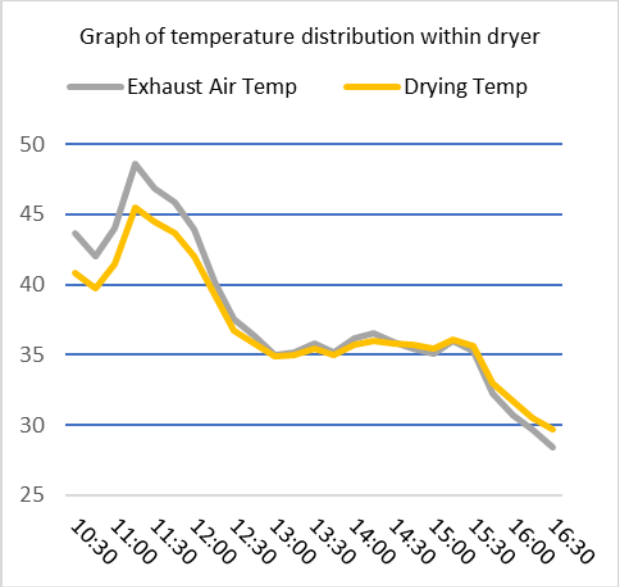

Figure 3. Graph of temperature distribution within dryer

From the figure 3 above, it shows that at dryer temperatures above 35^0C the air temperature at the chimney is higher than the temperature within the drying chamber, this is as a result of the heat from the metal components of the chimney. This means an increase in mean kinetic energy of the air in the chamber as it exits through the chimney and this translates to an increase in natural convectional movement thereby increasing the drift and in turn the rate of drying.

CONCLUSION

The average temperature of the dryer during the six hours drying period was 37.7^0c which is 22.8% higher than that of the ambient.

The Maximum and minimum temperatures attained by dryer during the test period are 45.5 and 29.7 respectively. with mean solar radiation of 420.24w/m, the average rate of drying for the period was 9.17 gram per hour which is 31.9% faster than that of the corresponding direct open air drying of same sample of 200 gram dried simultaneously at same time, location and spread density. The equilibrium moisture content of the sample was obtained to be 63.8kg of water per 100kg of dry poultry manure. The temperature of the exit air from the chimney is observed to be higher than that of the inside of the dryer because of the metal chimney and this helps to create the required air drift for natural convection to occur

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Surface and Ground Water Interactions in Africa: A Review of the Current State of Knowledge.

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Abstract

As pressures on water resources and uncertainties in water supply increase due to climate change and population growth, it is crucial to understand the interaction between surface water and groundwater (SW-GW). Africa's population is expected to double by 2050 and knowledge on the interaction between SW-GW is necessary for sustainable management of water resources. Therefore, this study reviews the current state of knowledge of the interactions between SW and GW in Africa. Twelve major river basins namely: Nile basin, Okavango basin, Niger basin, Volta basin, Lake Chad basin, Ganane basin, Zambezi basin, Limpopo basin, Orange basin Congo basin, Senegal basin and Rufiji basin were used for the classification. Generally, studies on SW-GW interactions have not been widely conducted across the continent, studies were recorded on some major river basins along the coastal region in southern part and very few on the northern part. It was observed that there is interaction between SW-GW in Nile basin, Okavango basin, Niger basin, Volta basin, Lake Chad basin, Ganane basin, Zambezi basin, Limpopo basin and Orange basin. The interactions were influenced by human activities in some of the basins. Unfortunately, no studies were recorded in the largest basin, Congo as well as in Senegal and Rufiji basin. These studies were done with some of the commonly used methods in quantifying SW-GW interaction which ranges from stable isotopes analysis, hydrochemical (cations and anions), chlorine mass-balance, MODFLOW model, PITMAN model, hydrograph separation approaches, piezometers, boreholes monitoring, Darcy's Law and geophysical approaches. It was noted that some of these approaches ignores spatial and temporal variability in SW-GW interaction. Therefore, there is need for more studies on the interaction between SW-GW across Africa more especially on the Congo basin and other techniques that have not been used should as well be explored.

Keywords: *Surface water, Groundwater, River basin and Africa.*

1. Introduction

Groundwater and surface water are not secluded components of the hydrologic system. They are hydraulically connected in many regions and knowledge of the hydrologic processes would help to understand the interaction between them for effective management of water resource (Owor et al., 2011). Understanding the hydrologic processes involves water balance analysis of major components of the hydrological cycle and interactions between them. Precipitation, the main source of freshwater in the hydrologic cycle and other components such as evapotranspiration are highly variable in distribution on earth's surface. Much of the precipitation that didn't return to the atmosphere will end up as surface water or subsurface/groundwater. Surface water infiltrates and eventually joins the groundwater. The groundwater system on the other hand is a three-dimensional flow and understanding how the vertical components interact with surface water is necessary (Winter et al., 1998). Groundwater discharges to rivers, wetlands, lakes, estuaries and the sea, and vice versa. It can sustain flow during dry periods (Saha et al., 2017) however, not all rivers are fed by groundwater (Parsons, 2004). Similarly, surface water (streams, rivers, lakes, wetlands, estuaries and sea) can recharge groundwater especially during flooding season and the interaction can take place in almost any landscape (Levy & Xu, 2012). The extent of interaction between SW-GW is a function of climatic and physiographic factors of the landscape. In a river for instance, Parsons (2004) noted that position of the water level in relation to water table can control the interaction. Basic interactions between the groundwater bodies and rivers are similar to that of streams and lakes

(Winter et al., 1998; Parsons, 2004) and it can happen in any of the three ways: 1) streams can gain water from groundwater via the streambed, 2) streams can lose water to groundwater via streambed and 3) streams and groundwater can gain or lose in some reaches (Winter et al., 1998). Similar to lakes, rivers and streams are wetlands which can either gain or lose water to groundwater.

The SW-GW interactions have some implications on water quality, water quantity, and ecological health (McLachlan et al., 2017). Movement of water between SW-GW gives a path for chemical transfer across the water bodies. For instance, contaminated aquifer can discharge groundwater into streams as a baseflow and this in turn can cause long-term contamination; contrarily streams can as well contaminate the aquifers (Abiye et al., 2015). These contaminations come mostly from underlying geologic materials and human activities. Human activities such as agricultural operations/activities, urban and industrial development, drainage of the land surface etc affect the interaction of SW-GW. Agricultural activities like some tillage operations changes the runoff and infiltration characteristics thereby affecting the interaction of SW-GW. The contamination, development and exploitation of either surface water or groundwater can affect the other component and as such have an impact on interactions between the two. Therefore, quantify the interaction between SW-GW is important for sustainable management of water resources (Rau et al., 2010; Saha et al., 2017) more especially in Africa where the population is expected to double by 2050. According to UN Report (2016), Africa has 9% of the world's fresh water resources and 11% of the world's population. As pressures on water resources and uncertainties in water supply increase in Africa due to climate change and population growth, it is crucial to understand the interaction between SW-GW across the continent.

Quite numbers of hydrological studies have been conducted in many parts of Africa to understand the hydrologic behaviour of the ecosystem. These studies include: water balance analysis (Bugan et al., 2012; Mbanguka et al., 2016; Smithers et al., 2017); hydrologic components modelling (Benito et al., 2011; Trambauer et al., 2013); hydro-climatic studies (Badou et al., 2017); isotope signatures of meteoric water (Wanke et al., 2018); groundwater studies (El Idrysy & De Smedt, 2006; Gokool et al., 2018; Leblanc et al., 2007); uncertainty modelling (Hughes, 2016). Hughes et al. (2015) reviewed hydrological studies in Africa for the past decade however; none of these studies assessed the interaction between SW-GW. Therefore, this study tries to review the current state of knowledge of the interactions between SW-GW in Africa.

2. Major River basins/Aquifer in Africa

There are numerous river basins in Africa however; this study adopted the major river basins classified by (Wit and Stankiewicz, 2006; *Lehner and Grill, 2013).* They include: Nile, Senegal, Niger, Volta, Lake Chad, Congo, Rufiji, Ganane, Zambezi, Okavango, Limpopo and Orange. The area covered by these basins together with their river length, countries and region are shown in Table 1. More information on these major river basins and the interaction between SW-GW are discussed below.

Groundwater on the other hand seems to be a more reliable source of water in many parts of Africa and approximately 75% of the population uses groundwater as the main source of drinking water (Nijsten et al., 2018). Groundwater is largely stored in aquifers. Twelve major sedimentary aquifer basins and seventy-two transboundary aquifers were mapped in Africa (Nijsten et al., 2018; Bonsor et al., 2018). They are located in different climatic zones across

Africa and differences in their storages among the wet and dry (arid) areas were examined by Bonsor et al. (2018). Groundwater resources are unevenly distributed across Africa, it is a bit shallow (approximately 0 - 25 mbgl) in many parts of central, eastern and western Africa where the climate is relatively wet (Bonsor & MacDonald, 2011). MacDonald et al. (2012) estimated the total groundwater storage in Africa to be approximately 0.66 million km^3. The biggest groundwater volumes were found in the Northern African countries with large sedimentary aquifers of hundreds of metres thick (MacDonald et al., 2012; Bonsor & MacDonald, 2011).

Table 1: Area of the major river basins in Africa and countries within the basin (Wit and Stankiewicz, 2006; Source book, 2007)

S/ No	Name of the Basin	Countries within the Basin	Basin area (km^2)	River length (km)	Region
1	Nile	Ethiopia, Egypt, Uganda, Sudan, Tanzania, Democratic Republic of Congo, Burundi, Eritrea Kenya and Rwanda	3,038,100	6,700	East and North Africa
2	Senegal	Senegal, Mauritania, Mali and Guinea	490,000	1,800	West Africa
3	Niger	Algeria, Nigeria, Benin, Mali, Cameroon, Guinea, Chad, Sierra Leone, Burkina Faso and Niger	2,113,350	4,200	West and Central Africa
4	Volta	Ghana, Togo, Burkina Faso, Benin, Côte d'lvoire and Mail	414,000	1,610	West Africa
5	Lake Chad	Chad, Nigeria, Central African Republic, Niger, Sudan and Cameroon	2,388,700	1,400	Western Africa
6	Congo	Democratic Republic of Congo, Angola, Zambia, Cameroon, Rwanda, Gabon, Malawi, Central African Republic, Congo Rep., Tanzania and Burundi	3,699,100	4,667	Central Africa
7	Rufiji	Tanzania	-	-	Eastern Africa
8	Ganane	Somalia, Kenya and Ethiopia	803,600	1,658	Eastern Africa
9	Zambezi	Mozambique, Angola, Congo Democratic Rep., Namibia, Malawi, Tanzania, Zimbabwe, Botswana and Zambia	1,400,000	2,650	Central and Southern Africa
10	Okavango	Angola, Botswana, Namibia and Zimbabwe	725,000	1,100	Southern Africa
11	Limpopo	South Africa, Mozambique, Zimbabwe, and Botswana	414,800	1,750	Southern Africa
12	Orange	South Africa, Lesotho, Botswana and Namibia	850,000	2,300	Southern Africa

3.0 Studies on interaction between SW-GW in Africa

Table 2 shows the summary of the investigations on the interaction between SW-GW in Africa. Locations where studies on SW-GW interaction have been conducted are shown in Figure 1.

Table 2: Summary of the investigations on interaction between SW-GW in Africa

S/N	Purpose	Method/model	Size (km^2)	Latitude/ Longitude	Location/ Country	Major River basin	References
1	Study lake and groundwater interactions	Numerical model (MODFLOW)	1455	6°48′ to 7°14′N and 38°16′ to 38°44′E	Rift lake catchment, Ethiopia	Ganane	Ayenew & Tilahun, 2008
2	Identification of groundwater flow systems	Hydrochemical analysis and geological mapping	300	4°14'56.3"S and 37°51'59.4"E	South Pare Mountains in Pangani river basin, Tanzania	-	Mul et al., 2007
3	Determination of the origin of recharge of the aquifer	Hydrochemical and isotopic analysis	-	30°24'46"N and 9°22'10.4"W	Souss wadi, Morocco	-	Boutaleb et al., 2008
4	Characterization of Ifni lake and the spring waters	Hydrochemical	-	30°59′ to 31°5′ N and 7°56 to 7°48’ W	High Atlas Mountains, Morocco	-	Kacem et al., 2016
5	Interaction between SW-GW from the headwater to the Nile Delta	Isotopic analysis and piezometric method	-	-2° to 32°N and 21° to 45°E	River Nile basin, Sudan and Egypt	Nile	Kebede et al., 2017
6	Interaction between the Nile and groundwater	Hydrochemical analysis	-	31°N and 31.10°E	Western Nile Delta, Egypt	Nile	Sharaky et al., 2017
7	Interactions between SW-GW	Piezometers, stable isotope hydrochemistry and Darcy calculation	-	2°S to 4°N and 30°E to 34°E	Lakes Victoria and Kyoga region, Uganda	Nile	Owor et al., 2011
8	The hydrology of the Okavango Delta	Regional review	-	-18°S to 20°5'S and 22°E to 24°E	Okavango Delta, Botswana	Okavango	Milzow et al., 2009
9	Understanding the groundwater flow	Hydrochemical, isotopic and hydrogeological method	4600	6°45 N to 7°40′N and 1°55′E to 2°50′E	Southern Benin	-	Kpegli et al., 2018
10	SW-GW interactions	Hydrograph separation	101,600	12°N and 6.45°W	Bani rivers, Mali	Niger	Mahe, 2009
11	SW-GW interactions	Hydrograph separation	20,800	13°N and 2.5°W	Nakambe rivers, Burkina Faso	Volta	Mahe, 2009
12	Inundation mechanisms and interaction between SW-GW	Borehole monitoring and isotope analysis	2,720	10°27'N and 16°08'E	Logone wetland, Chad and Cameroon	Lake Chad	Vassolo et al. 2015
13	SW-GW interactions	Water levels	-	10°00’0’’N to	Logone	Lake Chad	Vassolo et

		monitoring and isotopic analysis		12°50'0''N and 14°20'0''E to 15°50'0''E	floodplain, Chad and Cameroon		al., 2016
14	Interaction between SW-GW at the Zambezi Wetlands	Conceptual model (CHI)	-	22°E to 28°E and 16°S to 21°S	Zambezi Wetlands, Zambia	Zambezi	Chongo et al., 2015
15	Hydrogeological characterization of the Kosi bay lakes system	Hydro-geochemical, water balance analysis and isotopic method	659	-26°50'S to -27°30'S and 32°2'E to 32°9'E	Kosi bay, South Africa	-	Ndlovu and Demlie, 2016
16	Determine the mining impact on the interaction between SW-GW	Isotopic analysis	-	-25°S to - 26°S and 27°E to 28°E	Upper Crocodile river basin, South Africa	Limpopo	Abiye et al., 2015
17	Assessment of groundwater recharge and flow conditions	Isotopic analysis, baseflow separation, water table monitoring and chloride mass balance	4107	-25.85°S to –26.58°S and 27.29°E to 28.34°E	Upper Crocodile river basin, South Africa	Limpopo	Leketa et al., 2019
18	Conceptual modelling of SW-GW interactions	Chloride mass balance, isotopic, hydrochemical analysis	450	27°S to 28°S and 32°E to 33°E	Sibayi catchment, Eastern South Africa	-	Weitz and Demlie, 2014
19	Uncertainties in interactions between SW-GW	Pitman model	657	33.21°S, 26.68°E; 33.38°S, 19.03°E; 27.84°S, 22.98°E; 25.08°S, 30.78°E; 25.64°S, 27.03°E	Ecca river, Breede river, Gamagara river, Sabie river and Crocodile river; South Africa	Orange and Limpopo	Tanner & Hughes, 2015
20	Exchange of water at the groundwater and stream interface	Data-logger controlled probes	815	26.3°S to 27°S; 26.7°E to 27°E	Koekemoerspruit, North West Province, South Africa	Orange	Winde et al., 2004a
21	Coastal lakes and the surrounding aquifer interaction	Numerical model (MODFLOW)	-	-28.01°S and 32.13°E	Richards Bay, South Africa	-	Kelbe & Germishuyse, 2000
22	Interaction between coastal wetlands and groundwater	Piezometers and water quality assessment	0.5; 2.5	34°0′71″S and 22°54′22″E	Van Kervelsvlei Groenvlei, South Africa	-	Roets et al., 2008

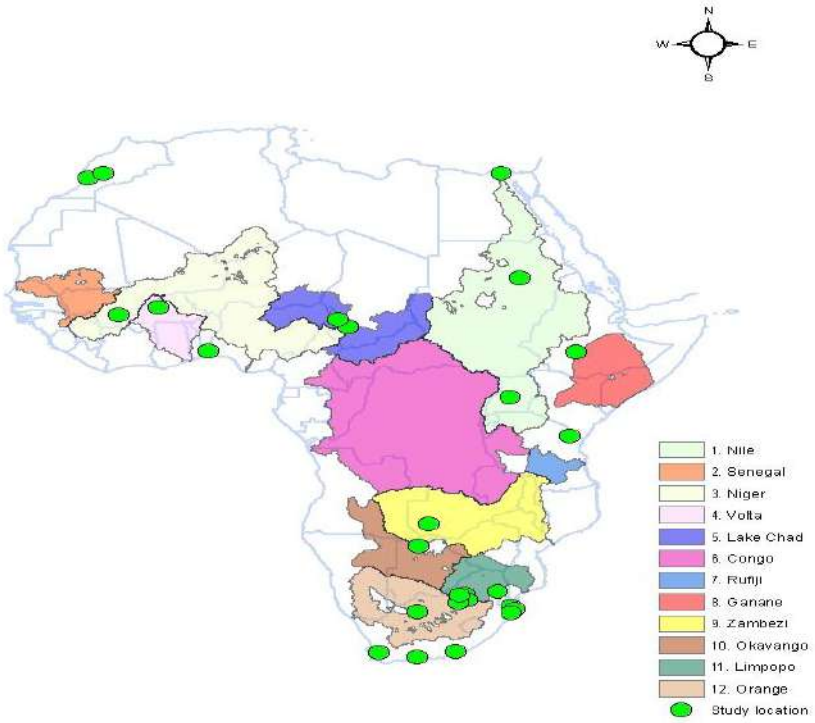

Figure 1: Map of Africa showing major river basins and locations where SW-GW interaction studies have been conducted.

3.1 Southern Africa: coastal region

Studies on SW-GW interaction conducted on the coastal region include: Kosi bay lakes (Ndlovu & Demlie, 2016); lake Sibayi catchment (Weitz & Demlie, 2014); lake Mzingazi (Kelbe & Germishuyse, 2000); Groenvlei and Van Kervelsvlei (Roets et al., 2008). Ndlovu & Demlie (2016) conducted a hydrogeological characterization of the Kosi bay lakes system. The Bay consists of four interconnected lakes, two isolated lakes and an estuary. Ndlovu & Demlie (2016) noted that groundwater recharge to the topmost aquifer, which is connected to the lakes, is 12 % of the mean annual precipitation and this was estimated using the chloride mass balance method. Groundwater passing through the lakes flows from west to the Indian Ocean. Hydrochemical water types identified in the catchment are: shallow aquifers (Na–HCO3–Cl water facies), deep aquifers (Na–Ca–Cl water facies) and the lakes (dominated by Na–Cl water facies). The hydrochemical characteristics of the lakes indicate termination of the local flow and interaction with the Indian Ocean through the Kosi estuary. The EC for Kosi bay lakes range from 1024µS/cm to 24,600µS/cm for Amanzamnyama and Makhawulani respectively. This high EC values indicate high evaporation, termination of the local flow system and connection to the sea through the estuary. Generally, groundwater here has similar hydrochemical and isotopic signature which indicates strong interaction. The water type that dominates in the groundwater and streams is Na–Cl–HCO3 which is very low in salinity ranges from 88 to 400µS/cm and a negative isotopic signature. The overall water quality of the catchment is within the acceptable limit for domestic and irrigation purposes except for the brackish and saline lakes.

Conceptual modelling of SW-GW interactions in the lake Sibayi catchment was done by (Weitz & Demlie, 2014). Hydrochemical and stable isotope results show direct hydraulic link between the lake and groundwater. In the western section of the catchment, groundwater recharges the lake whereas along the eastern section, the lake recharges the aquifer. Similarly,

interaction between coastal lakes, Mzingazi and aquifer was modelled by Kelbe & Germishuyse (2000) using numerical model (MODFLOW). Lake Mzingazi located in the Richards Bay area of South Africa is a freshwater coastal lake. Kelbe & Germishuyse (2000) noted that the lake is unlikely to be completely isolated from the primary aquifer. Using MODFLOW, simulation for maximum rates of interaction between the lake and aquifer were done by making assumption that no sedimentary restriction through a constant head boundary where flow dynamics was controlled by the hydraulic characteristics of the aquifer. Also on the coastal region, Roets et al. (2008) used water quality study in Groenvlei and Van Kervelsvlei and validated the prediction that groundwater discharges from the deep circulating Table Mountain Group aquifers to lowland wetlands. Earlier reports had it that the wetlands were recharged from the fixed dunes around them. By measuring water level and quality of SW-GW, Roets et al. (2008) established that there is an interaction between the Table Mountain Group aquifers and wetlands. It was found that groundwater directly discharges from the Table Mountain Group aquifers to Van Kervelsvlei while Groenvlei receives secondary discharges from the Table Mountain Group aquifers via Van Kervelslvlei. This assertion was disputed by Parsons (2009) who reviewed the information and noted that no information is available that supports a link between Vankervelsvlei and the Table Mountain Group aquifers. It was argued that limited hydrochemical data on which the hypothesis was based did not explore other possible water sources. Therefore, according to Parsons (2009) the wetland is sustained by direct rainfall and there is no hydraulic link between Vankervelsvlei and Groenvlei.

3.2 Northern Africa

Quite a few studies on SW-GW interaction have been conducted in Northern Africa possible because greater percentage of the area is not covered under major river basins in Africa. Boutaleb et al. (2008) conducted a study on determination of recharge modes of aquifers of the contact zone between the Western High-Atlas Chain and Souss Plain, South West, Morocco using chemical and isotopic tracers. They noted that Souss aquifer is recharged from composite of direct infiltration from tributaries of High-Atlas and remote recharge from the High Atlas aquifers borders. Similarly, Kacem et al. (2016) carried out a research on features of interaction between Ifni Lake water and springs in High Atlas Mountains, Morocco using hydrochemical parameters. They found that there is a relationship between Ifni Lake and spring waters in High Moroccan Atlas Mountains, North Africa. Edmunds (2009) compared the groundwater evolution of three areas (northeast Africa, northwest Africa and the Sahel region of Nigeria, Niger and Cameroun) in northern Africa using three broad time scales (Holocene, Modern and Late Pleistocene) using isotopic analysis. Isotopic compositions (–6 ± 1‰ δ18O) for northwest Africa region (Senegal, Morocco and Mali) were similar across the three broad time scales indicating steady recharge over the time span. Similarly, groundwater isotopic compositions are close to that of recent rainfall which indicates steady rainfall over the time. Depleted isotopic compositions (approximately 2‰) were recorded in the Central Sahelian region for Late Pleistocene time scale relative to present rainfall. This indicates abundant rainfall recharge derived from Atlantic area with some modification as it moves inland coupled with losses. Also, significant depleted isotopic compositions were recorded in the northeastern Africa (Libya, Egypt and Sudan) which indicate recharge from Atlantic rainfall that got modified as it moves across Sahara region.

4. Commonly used methods in quantifying interactions between SW-GW

The SW-GW interaction process is difficult to observe and measure, because of the heterogeneity and anisotropic fractured-rock settings in many parts of Africa (Levy & Xu, 2012). There are many established methods/tools for investigating, characterizing and quantify SW-GW interactions. These methods can be classified as direct and indirect; small-scale (e.g. mini piezometers, seepage meters) and large scale (Levy & Xu, 2012). Large scale methods are usually used for meeting policy needs and they include stable isotope analyses, groundwater modeling, baseflow separation, hydrogeologic mapping and hydrochemical analyses (Levy & Xu, 2012). However, commonly used methods in quantifying SW-GW interaction include: multi environmental tracers, conceptual models, hydrograph separation approaches, measurement and monitoring, Darcy's law and Geophysical approaches.

5. Summary and Conclusion

Studies on the interaction between SW-GW in Africa are still scanty. Across the continent, studies were recorded on some major river basins, along the coastal region in southern part and very few on the northern part. Considering the 12 major river basins, studies were recorded on the Nile basin, Okavango basin, Niger basin, Volta basin, Lake Chad basin, Ganane basin, Zambezi basin, Limpopo basin and Orange basin. Unfortunately no studies were recorded in the largest basin, Congo as well as in Senegal and Rufiji basin in Africa. From the studies done so far, it was observed that there is interaction between SW-GW along the Nile basin, Okavango basin, Niger basin, Volta basin, Lake Chad basin, Ganane basin, Zambezi basin, Limpopo basin and Orange basin. It was noted that the interactions are influenced by human activities in Nile River basin. Similarly, water pollution was observed in Orange river basin due to artificial flow regime caused by pumping of groundwater from underground mine activities to the stream.

In addition, these studies were done with some of the commonly used methods in quantifying SW-GW interaction which ranges from multi environmental tracers, conceptual models, Darcy's law, hydrograph separation approaches, geophysical approaches, measurement and monitoring etc. Among the multi environmental tracers, hydrochemical (cations and anions) and stable isotopes analysis and chlorine mass-balance have been used in many river basins in Africa while radioactive isotopes such as (tritium and radon), water temperature and heat methods have not been used to the best of our knowledge. Similarly, among conceptual models, only MODFLOW and PITMAN models have been applied whereas FEFLOW and WaSiM/MIKE 11, SWAT, MIKE SHE, GSSHA etc. have not been used. Hydrograph separation approaches and some measurement and monitoring methods (e.g., Piezometers and boreholes) have equally been applied. Darcy's Law and geophysical approaches on the other hand have been sparingly used possibly because of difficulty in measuring the components of the equation and cost associated with the equipment respectively. Generally, there is need for more studies on the interaction between SW-GW across Africa more especially on the Congo basin for sustainable management of water resources and other techniques that have not been used should as well be explored.

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REVIEW OF SHEA FRUITS EXTRACTION TECHNOLOGIES AND FUTURE PROSPECTS

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Abstract

Shea nut is a high–value fruit containing fat used as an edible oil, antimicrobial and moisturiser in the food, pharmaceutical and cosmetic industries, respectively. The annual worldwide export of shea nut from Africa is 360,000 MT of kernels with a market value of approximately $130 million to producing countries. The multifunctional properties of the shea butter depend exactingly on its compositional properties: the peroxide value, moisture content, free fatty acid level and the insoluble impurities. Standard extraction technologies: the traditional, mechanized, enzymatic and chemical methods were used for shea butter extraction. Current extraction technologies which rely on different extraction parameters for shea butter extraction are yet to yield the desired qualities and efficiencies of butter. Application of hydrolysing enzymes during enzyme extraction however eliminates the laborious, tedious and labour–intensive extraction processes creating alternative, selective and mild extraction conditions. The current review gives an overview of shea butter extraction technologies, the efficiencies, qualities and a perspective into the shea butter industry.

INTRODUCTION

Shea butter is the oleaginous material obtained from the kernel of the shea nut tree *Vitellaria paradoxa*. Research has consistently described the shea butter as a vegetable fat extracted from the kernels of the fruit of *V. paradoxa*, Sapotaceae (Abdul-Mumeen *et al.*, 2019). Others described the shea butter as a yellowish– grey solid material (Mégnanou and Niamké, 2012) or yellowish white in colour with a strong smell extracted as fat from the kernels of the shea nut fruit. Shea butter extracted from shea kernels is raw and can be refined. Shea butter is as good as table oil because of its high nutritive value and low cholesterol levels; widely used locally for curing leprosy and other ailments and has various industrial uses that include soap making, cosmetics, lubricants and paints (Goumbri et al., 2021). Shea butter is ideal for use as raw materials for.

Raw shea butter is obtained primarily by the traditional method of extraction (Mégnanou and Niamké, 2012), from the shea fruit kernel, but can also be obtained by mechanical (Olaniyan and Oje, 2007a), enzymatic (Didia et al., 2018) and chemical methods (Apea and Larbi, 2013). It can be consumed raw without any further physical or chemical treatments or refinement.

Africa produces about 1,760,000 tons of raw shea nuts annually from its wild trees (Aneni et al., 2020). In Ghana, there are estimated 94 million shea nut trees which were projected to produce at least 60,000 metric tonnes of shea nuts per annum for the production of all shea butter processed locally. This yields about 150 tonnes of shea butter, 60% of which is used locally with 25% exported. Over 80% of the woody vegetation in Northern Ghana is *Vitellaria*. (Choungo Nguekeng et al., 2021)

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include soap making, cosmetics, lubricants and paints (Agbetuyi et al., 2020). Shea butter is ideal for use as raw materials for cooking oil, margarine, cosmetics, soap, detergents and candles due to the presence of solid fat (stearin) and liquid oil (olein). Shea butter is used extensively in the food, pharmaceutical, cosmetic industries and often as cocoa butter substitute by chocolate manufacturers and for margarine and baking purposes (Owoicho 2021; Ogunsola et al., 2022).

Choungo Nguekeng et al. (2021) The American Shea Butter Institute reports that 100% pure natural shea butter is an all– natural vitamin A cream which has shown to be a superb moisturizer, with exceptional skin healing properties. has also asserted that shea butter has proved to be effective against skin and other skin related conditions such as dry skin, skin rash, skin peeling after tanning, blemishes and wrinkles, itching skin, sunburn, shaving cream for a smooth silky shave, small skin wounds, skin cracks and tough or rough skin, cold weather, frost bites, stretch mark prevention during pregnancy, insect bites, health skin, muscle fatigue, aches and tension, skin allergies such as poison ivy or poison oaks, eczema, dermatitis and skin damage from heat.

Raw shea butter is obtained primarily by the traditional method of extraction (Abdul–Mumeen et al., 2013), from the shea fruit kernel, but can also be obtained by mechanical (Abdul-Mumeen *et al*., 2019), enzymatic (Iddrisu *et al.*, 2020) and chemical methods (Didia and Idrisu, 2018). It can be consumed raw without any further physical or chemical treatments or refinement. However, much uncertainty still exists about the standard method of extraction of shea butter which will meet the standards declared by the various certification and standard organizations for shea butter quality. Thus, there still remains huge information regarding the reasons for differing approach to the extraction of shea butter and their efficiencies that are yet to be collected. This sort of information would extremely benefit not only the communities and industries within Ghana but all the countries within the West African sub–region. Additionally, once the shea nuts have been harvested, a huge amount of time and effort is spent on the processing and extraction methods currently employed.

Africa produces about 1,760,000 tons of raw shea nuts annually from its wild trees (Mohammed et al., 2013). In Ghana, there are estimated 94 million shea nut trees which were projected to produce at least 60,000 metric tonnes of shea nuts per annum for the production of all shea butter processed locally. This yields about 150 tonnes of shea butter, 60% of which is used locally with 25% exported. Over 80% of the woody vegetation in Northern Ghana is *Vitellaria*. The shea nut market in Ghana is well established, being sold both locally and internationally (Ogunsola *et al.*, 2022).

Fig1: Shea Fruits

The processing of shea butter is seasonal. The fruiting and gathering of the nuts occur between the months of May to August every year. during which the shea nuts are processed into kernel. The raw and ripe fruits are green but the ripe fruit is occasionally yellowish and soft when felt.

The fruit is composed of four layers: the epicarp, mesocarp, shell and the kernel. The fruit primarily undergoes several processes for example, de-pulping, boiling, drying, deshelling, winnowing and sorting to obtain the kernel from which the shea butter is extracted.

Attempts have been made to introduce new technologies into the gathering, storage and processing of Shea butter (Abdul-Mumeen et al., 2019). The semi-mechanized system of extraction utilizes appropriate technology to mechanize some of the unit operations of the manual traditional system although with the same number of stage when compared with traditional method. A nut crusher, roaster, a kneader or a hydraulic/screw press oftentimes complements the manual process and reduces drudgery of the traditional system. In opinion of Zinash (2021), mechanized processing in West Africa yields 30-40% of Shea butter from raw nuts, but more efficient, fully mechanized systems achieve extraction rates of between 42% and 50% This is relatively higher, compared with 25%- 60% of extraction rates of the traditional and semi-mechanized systems.

Zinash (2021) again stated that, most of the West African plants produce less than 25% of their installed capacity and operates only six months in a year in order to offset the high cost of storing Shea nuts throughout the year. Shea butter production in Nigeria is dominated by women. Although there are men who trade in nuts and work in processing, but women are the primary pickers, processor~ and sellers of Shea butter in the local market place. Many works has been done on Shea butter so as to fully maximize its numerous medicinal benefits. Lots of values have been added to the raw form of Shea butter gotten from processor to give different herbal products which include: Shea butter balm, Shea butter baby cream, herbal hair care, Shea butter body care 'plus' and Shea butter body lotion.

De–pulping

The fresh mature fruit of the shea tree is covered externally by the pulp consisting of an epicarp (greenish) and a mesocarp (yellowish). De–pulping is the removal of the pulp (the epicarp and the mesocarp) when the shea fruit is ripe. The pulp which is mostly green becomes soft when the fruit ripens. It has been well documented that the fruits are collected by African women from the ground and the pulp is removed by fermentation or manual peeling. Fruit storage before de pulping, especially after three days, negatively affected the quality (Aculey *et al*, 2012) and quantity of the resulting butter because of the sugar rich pulp which assists fungal growth and thereby reduces oil content of the kernel. Ojo and Adebayo (2013) confirmed this when, during the bio–deterioration of the shea nut fruit pulp, they isolated eight fungi species (*Aspergillus flavus, Aspergillus niger, Botrydiplodia theombromae, Botryosphaeria* spp.*, Colletotrichum gleosphoriedes, Lisidiplodia* spp.*, Pseudofasicocum* spp*. and Trichoderma viridae*) from the fruit natural environment and from parboiled kernels (Aculey *et al.*, 2012).

De–shelling or de–husking

Removal of shells from the nut after cracking and winnowing is a process described as de–husking or de– shelling (Abdul-Mumeen et al., 2019). During the drying period, the kernels become detached from the shell wall. De-shelling is carried out using stone, hammers and pistles. Winnowing is achieved by holding basket filled with a mixture of the shells and kernel at arm's length and allowing a gradual pour–out. If there is a strong wind, the pieces of shell will be blown away, if not, then the process is repeated many times.

Sorting and further drying

Sorting is the removal of the remains of the shell pieces from the shea kernels after winnowing (Mohammed et al., 2019). At this stage, shea kernels that are broken, infected by mould or are black in colour are also removed to obtain clean unbroken shea kernels. The shea kernels can now be stored for several months without deterioration or processed into shea butter. The pre–treatment and storage of the shea kernels before the butter extraction process is a critical stage that affect the quality of shea butter produced. The first adverse effects are seen in the decrease in oil phenols and in the reduction of volatile compounds responsible for the various properties of shea butter (Pérez et al., 2021). notes that in several operative conditions involving long–term storage of seeds and high relative humidity, mould contamination increases the free acidity due to the production of fungal enzyme lipase, and simultaneously forms the characteristic sensory defect of "mould" (Jimenez-Lopez *et al.*, 2021).

Shea butter extraction technologies

Classified the processing technologies of shea butter into three methods: the traditional manual method, traditional semi–mechanized method and the fully mechanized method. However, recent studies have suggested that the traditional butter extraction encompass the traditional manual and the traditional semi–mechanized methods and that shea butter can be extracted by chemical and enzymatic processes (Didia et al., 2018). Whether the various extraction technologies have answered the numerous challenges bedevilling the shea butter industry is discussed below.

Kneading

A kneading process takes place to break up oil cells and ease oil extraction and women take an average time of 30 min to complete one kneading session. Abdul– Mumeen (2019) explains that a kneading session involves taking a reasonable quantity of shea paste, adding an initial amount of about 3 litres of cold water, stirring slowly and then vigorously later, with the hand until the butter begins to rise in crude milky–white form. Some researchers suggest that traditional extractors boil water and skim off the released oil from the kernel or by kneading and hand beating. At this stage 10– 20 kg of finely pulverized paste is mixed with three litres of water and kneaded until a white bloom appears which marks an important enzymatic step and followed addition of hot water. Kneading is successful depending on the individual's recognition of changes in temperature, consistency and appearance and this can only be assessed correctly with experience.

The mechanical processing technology

The mechanical processing technology is usually referred to as the Cold Press Extraction method, so called because it does not involve the various different heating stages of the traditional procedure. The mechanical press method of shea butter extraction is one of the earliest researches works on the use of the mechanical press. His research revealed that equipped with a jack that exerts 30 tonnes of force, a shea butter press could crush more than 3 kg of shea kernels within 20 min. The press could extract up to 85% of the fat contained in the kernel in a simplified process through a reduction in the various heating stages of the kernel and subsequently saves fuel wood. The emergence and proliferation of processing shea butter by this method in the shea producing zones of Ghana was mainly due to the collaborative work between women groups and some development partners and Non–Governmental Organizations. The United Nations Fund for Women‟s Development, Technoserve Ghana and the Netherlands Development Organisation (SNV) introduced these innovations in the form of mechanized technologies such as hydraulics and mechanical presses, which were locally designed and

manufactured. The CRIG (2002) however notes that the Dagomba women of Ghana were the first to initiate the mechanization of the butter extraction process. These have reduced processing times and enhance water use. The processing of shea butter by this technique is carried out in a plant comprising of a boiler, mechanical press system and a filter press system. The mechanical press applies a great deal of pressure to the pulverized.

The chemical extraction processes

With this method, the dried kernels are first crushed into paste and fed into the Soxhlet extractor. Afterward an organic solvent such as n–hexane or ether is added. The mixture is allowed to stand for some number of h for the oil to be separated which is decanted and allowed to solidify. The types of the solvents used in the extraction have some influence on the quality characteristics of shea butter especially the peroxide value of the butter. The best solvent for shea butter extraction, petroleum ether, n–hexane, chloroform, benzene, and water were employed. Hexane extraction gave the highest amount of fat from the kernel. The principle with hexane extraction is that, the pulverized kernel is mixed with hexane which then unlocks the polymeric mass allowing all the oily and fatty constituents of the kernel to dissolve in it. The resulting oil–hexane mixture is later separated from the seed residue by filtration. The oil–hexane mixture is then heated to 68ºC to vaporise and recover the hexane to obtain the crude Shea Butter (Abdul–Mumeen, 2019).

Enzyme assisted extraction technology

Enzymatic extraction of vegetable oil with water–soluble enzymes involves the degradation of the cell wall and then the release of the oil (Perez et al., 2013). Aqueous enzymatic extractions are potentially used in the oil industries due to their high specificity and low operating temperatures. Several enzymes such as: amylase, glucanase, protease, pectinase, cellulase and hemicellulase have been used for the extraction of various vegetable oils from their kernels. Cellulase and hemicellulase have been reported to be the most suitable enzymes for cell wall degradation while pectinase has been identified as an effective enzyme for vegetable oils extraction. Lipases can be produced by animals, plants, and microorganisms. Microbial lipases however primarily catalyze the hydrolysis of triacylglycerols and have been extensively studied due to their interesting characteristics of stability in organic solvents, action under mild conditions, and high substrate specificity (Goumbri et al., 2021)

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IMPACTS OF FRYING METHODS ON GROUNDNUT CAKE: A REVIEW OF LITERATURE

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Abstract

This systematic review studies the influence of different frying methods (deep fry, air fry and vacuum fry) on the fatty acid, nutritional and sensory characteristics of groundnut cake. Deep frying affected the oxidation of lipids and degradation of proteins. Deep frying was found to reduce perfluorinated compounds, eliminate some toxins, lower the trypsin inhibitor (TI), and increase the sensory parameters of groundnut cake. while air frying increased the acceptance score with reduced product shelf and harbouring of toxins. Consequently, research is needed to modify the deep frying method as the common and acceptable frying approach and to also reveal the effectiveness of vacuum frying in maintaining the nutritional and sensory properties of fried ground nut products.

Key words: Groundnut cake, Deep Frying, Air frying, Vacuum frying, fatty acid, oxidation

INTRODUCTION

Frying is a widely used and industrially important food process. (Karayiannis and Tassou, 2013), it is processing (drying and cooking) of foods through contact with hot oil (Shaker, 2015). The oil not only serves as a heat transfer medium but also is absorbed by the food and contributes to flavour and texture of the product (Asokapandian *et al*., 2020). Frying is classified as one of the most complex food processing operations (Nurhan, 2018) due to the numerous interactions that take place within the food.

Frying as the process of cooking and dehydration of foods by immersing them in hot oil, typically, at 165–190◦C. During this time, various chemical and physical changes occur. Chemical structural changes occur in the form of starch gelatinization, protein denaturation, and flavour development. Physical changes are manifested as a decrease in moisture content, increase in product temperature, oil content, and crust formation (Ching *et al*., 2021).

Three methods can be used to fry groundnut cake: deep (Akinoso *et al*., 2021), vacuum (Adekunle *et al*., 2020), and air frying (Kperegbeyi and Ikperite, 2021). Deep frying is a simple and common method. Food is immersed in oil that has been heated to a temperature sufficiently high to brown the food's surface, partially or completely cooking it. This frying process ensures that the food is tender and juicy inside and crisp on the outside (Negara *et al*., 2021).

Furthermore, vacuum frying involves atmospheric pressure (<50 Torr), a reduced pressure, under these conditions, the reduced moisture of fried products is obtained without excessive darkening or scorching (Akinoso *et al*., 2021). This method has been used in several industries to fry and produce high-quality fried products. Vacuum frying maintains the nutrition of fried products with low oxidation (Asokapandian *et al*., 2020). Air frying is a method that circulates and utilizes hot air to fry food. Under these conditions, oil absorption in food can be minimized; thus, it is claimed to be a healthier frying method. The fried products will have low calories, fat, and good colour. A common schematic is depicted in Fig. 1, showing that simultaneous heat and mass transfer occurs during frying.

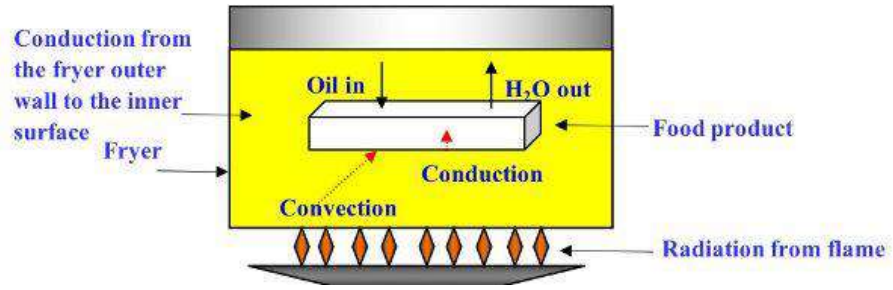

Fig1: heat and mass transfer

These frying methods can be used to produce high-quality groundnut products. Nonetheless, during the frying process, some reactions that affect nutritional quality may occur. Lipid, fat, and minerals in fish can be affected. Moreover, some water-soluble proteins can be lost during the process (Karayiannis and Tassou, 2013).

Several studies have been conducted on the effects of deep, vacuum, and air frying on groundnut cake, Furthermore, studies on the effect of frying on minced groundnut products. However, there are no review papers on this topic. Therefore, this article reviews studies conducted on the effects of different frying processes on groundnut and minced groundnut products.

This study focuses on reviewing the current scientific literature on the effects of frying methods. Thus, the changes in the composition that occur during the frying process are discussed. Special emphasis has been placed on the nutritional and sensory characteristics of fried groundnut and minced groundnut products, as influenced by the different frying processes.

3. Methodology

The study adopted an archival research methodology which focus on the review of empirical studies of conventional methods in the frying. Thus, the required data for the study were obtained from secondary sources (MEDLINE, Web of Science, PubMed, and Science Direct) (Liberati *et al.*, 2009). Studies with clear methodologies were selected. The process is presented

4. Results

A total of 51 articles were found based on the search criteria "groundnut cake frying" After filtering the articles with several criteria, including "Deep frying", "Air frying", "Vacuum frying", "nutritional," and "sensory," 21 articles were found to have examined the effect of deep frying, 16 articles examined effect of vacuum frying while 18 articles were on the effect of air frying; on the nutritional and sensory characteristics of groundnut cake.

5. Discussion

Deep fat frying is one of the oldest methods of cooking that probably originated from the Mediterranean (Goswami *et al.*, 2015). Foods are fried primarily to cook and to make them more desirable, palatable, and digestible. Deep frying is a process that involves simultaneous heat and mass transfer, in which frying oil is the medium of heat transfer into the food, while moisture migrates out and oil is absorbed into the food (Kita *et al.*, 2017). Usually, foods to be fried are immersed in hot oil at a temperature range between 120 and 180°C (Wu *et al.*, 2015; Kita *et al.*, 2017)

Table1: frying methods on Fatty Acid of Fried groundnut cake

Cake shapes	Frying Methods	Optimum Condition	Filet Size	Results	Ref.
Rod/Cylindrical	Deep fry	180 ˚C for 7 min in canola oil	3 cm diameter	Maintaining fatty acid content Increasing protein and fat	Wu *et al*., 2015
	Deep fry	180 ˚C for 5 min in soybean oil	-		Kita *et al*., 2017
Chub shape *	Deep fry	165 ˚C for 3 min in sunflower oil	5 × 5 cm	Increasing the score of overall acceptance	Luo *et al*., 2019
Flat shape	Deep fry	160 ˚C for 3 min	-	Reducing perfluorinated compounds (PFCs)	
Chub Cake	Deep fry	180 ˚C for 90 s in soybean oil	-	Improving the taste of fried groundnut	Quadros *et al*., 2015
Chub Cake	Vacuum fry	95 ˚C for 7 min at 80 mmHg in sunflower oil	5 × 5 cm	Lowering the oxidation of lipids and proteins	
Rod/cylindrical shape	Air fry	160 ˚C for 15 min	5 × 5 cm	Increasing the score of overall acceptance	Luo *et al*., 2019

Influence of various frying methods on Fatty Acid of Fried groundnut cake

The frying process of groundnut affects its fatty acid profile. During the frying process, several factors are known to affect the fatty acid profile of groundnut, including the oxidative decomposition of unsaturated fatty acids, the migration of fatty acid compounds into the medium during the deep frying process, and the absorption of linoleic acid from oil. Moreover, the use of different oils as frying media is known to have some effects on the fatty acid profile (Okogeri *et al*., 2019; Kim *et al*., 2020; Ikegami, 1973; Ismail *et al*., 2004).

Oxidative decomposition of unsaturated fatty acids of groundnut cake is influenced by high temperature during the frying process. At high temperatures, and their levels tend to decrease as the temperature rises (Asokapandian, 2019). Furthermore, water loss during air frying increases the lipid content in fried

products. These conditions also affect the changes in fatty acids of groundnut cake, especially the overall score acceptability of the fried cake. (Okogeri *et al*., 2019).

Moreover, the migration of fatty acid compounds into the medium during the deep frying process of flat cakes might cause decreased fatty acid content in Atlantic groundnut. There is virtually absorption of linoleic acid from oil affects the leaching of lipids into the frying medium, resulting in a reduction of essential fatty acids in Atlantic groundnut of 88% (Zhang *et al*., 2020).
Oil absorption during the frying process occurs as a consequence of the loss of moisture. The size, shape, and surface of products influence oil absorption. The thinner the product, the more oil is absorbed. Moreover, the pre-treatment before frying also affects the oil absorption. Pre-drying decreases oil uptake in fried products (Quadros *et al.*, 2015)

Moreover, Zhang *et al*. found that oil absorption and the production of acrylamide as a result of the Maillard reaction are the primary changes in the nutrition of fried products caused by frying.

Influence of various Frying methods on Amino Acid Profile of groundnut cake

The frying process has also been known to influence the amino acids of fried deep fried groundnut cake. The Maillard reaction and the thermal decomposition of sensitive amino acids are two factors that affect the amino acid content in fried cake. This reaction forms between reducing sugars and amino acid groups and causes the brown colour in fried foods.

The presence of a free amino group at the ε-carbon unit, which is readily available for reaction with reducing sugars, makes lysine the most susceptible amino acid in intact proteins as observed in the case vacuum frying of groundnut cake. Two free amino groups give free lysine an even higher reactivity. The crash of disulfide bonds and the acquisition of sulfide ions and free sulfur are the two effects of the increasing temperature on serine and threonine due to the conversion of these amino acids. Technically resulting from a reduced temperature frying in vacuum frying of the groundnut cake.

Table 2: **frying methods on Amino Acid Sensory Properties on Fried groundnut cake**

Frying Methods	Marinating/Spicing	Optimum Condition	Filet Size	Results	Ref.
Deep Fry	Groundnut marinated with 6% of sodium Chloride	180 ˚C for 10 min in soybean oil	-	Lowering trypsin inhibitor level	(Wang *et al*., 2019)
Vacuum fry	Groundnut marinated with polyethylene glycol (PEG) 200, sorbic acid, and butylated hydroxyl anisole (BHA) and seasoned with turmeric powder, garlic, shallot, red chilies, ginger, wheat flour, table salt (NaCl), and monosodium glutamate (MSG)	90˚C for 4 min in corn oil	4 × 0.75 × 3 cm	Affecting the color of fried groundnut	
Deep fry	Groundnut spiced with shallot, red chilies, turmeric powder, ginger, garlic, salt, and MSG	191 ˚C for 3 min in palm olein	4 × 0.75 × 3 cm	Increasing proximate composition	Ozogul *et al*., 2013

Moreover, the frying time would affect the taste of fried cake. The longer frying time resulted in less oily tasting groundnut this is a case peculiar to deep fry groundnut cakes (Wang *et al.*, 2019). The alteration of fat might cause a change in the taste of fried groundnut cake which is likely consequence of vacuum fry, under these conditions; the exchange of fatty acids between the cake and the oil might have occurred and impacted the test. During this process, gadoleic acid were taken up by frying oil, while linoleic and oleic acids from the frying oil were absorbed by the groundnut. Additionally, the texture of fried groundnut also changed after frying due to the dehydration or transformation of the tissue.

Furthermore, fried chub groundnut in vacuum frying produced higher protein, lipid, DHA, and EPA levels, as well as better sensory properties than deep frying. Lipid atherogenic (AI), thrombogenic (TI), an hypocholesterolemic/hypercholesterolemic (h/H) indices of the vacuum-fried product showed better values suitable for human health. Moreover, lower AI and TI values are considered to be healthy conditions for preventing cardiovascular disease

For sensory analysis, the scores for taste, flavor, texture, and colors of fried chub groundnut with batter that contain wheat flour, water, NaCl, potassium sorbate, and red pepper were 4.5–5, based on five hedonic scales. These sensory parameters were categorized from “good” to “very good” products.

Notably, the sensory property scores of the fried mackerel with batter in vacuum fry samples were higher than those of the deep fry samples, although all the samples were scored above the "like very much" category.

Conclusions

The study reveals frying of groundnut cake with different frying methods which influences the nutritional, physicochemical, and sensory properties of the food. Frying can reduce perfluorinated compounds (PFCs), eliminate some toxins, lower the trypsin inhibitor (TI), and increase the sensory parameters of groundnut cake. Consequently, research is needed to reveal the effectiveness of vacuum frying in maintaining the nutritional and sensory properties of fried and groundnut products.

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