Development of Predictive Equations for Optimizing the Whole Kernel Out-Turn of Pre-Treated Cashew Nuts Using Response Surface ....

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EFFECT OF DIFFERENT TILLAGE METHODS AND TEMPORAL FACTOR ON SOIL PHYSICAL PROPERTIES

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ABSTRACT

Field experiments were conducted to evaluate the effect of four different tillage methods and temporal factor on soil physical properties of a sandy loam soil. The soil physical properties analysed were moisture content, bulk density, porosity, shear strength and cone index. The tillage treatments in the study were conventional tillage (disc plough followed by one pass of disc harrow (PH)) and disc plough followed by two passes of disc harrow (PHH) and conservation tillage (No-till (NT) and disc plough alone (PA)). Results showed significant ($p<0.05$) changes in soil physical properties due to the imposed tillage treatments. Conventional tillage practices that invert the soil exhibited better soil moisture conservation and higher porosity than the no-tillage method. The conventional tillage methods also exhibited more favorable soil tilth having recorded lower soil strength properties in relation to the conservation tillage methods. However, disc plough followed by two passes of disc harrow may lead to waste of time and energy as the method had no significant impact on soil physical properties with time. Our study showed that soil physical properties varied temporally, irrespective of the tillage method imposed.

KEYWORDS: Conventional tillage, conservation tillage, temporal variation, soil physical properties.

1. INTRODUCTION

Soils physically support plants, and act as reservoirs for the water and nutrients needed by plants. The physical properties of soils determine to which extent soil can conserve moisture, roots can penetrate and extract nutrients and moisture migration. Optimum plant growth depends as much on a favorable physical environment as it does on soil fertility. Tillage is one among other management practices that are significant to the soil quality, and it has important effects on many soil characteristics. By modifying the soil structure, it changes water infiltration, and the air and water dynamics that control microbial activities and hence improve the soil structure and crop yield. Tillage affects the amount of residue on the soil surface which changes soil temperature and water content. The effect of tillage is determined by the shape of the implement, the number of passes, the speed and timing of tillage, and the water content and type of soil (Lewandowski et al., 1999). According to Ozgoz et al. (2012) soil management practices are input sources of temporal variability than soil type. They therefore concluded that temporal variability of soil physical properties can be even greater than spatial variability in agriculturally managed soil. As opined by Es et al. (1999), some soil physical properties especially the hydraulic properties significantly vary even in a short time period, such as during crop cycle, especially immediately after tillage. Similarly, other researchers (Strudley et al., 2008; Alletto and Coquet, 2009) related the dynamics of temporal and spatial variability in soil physical properties and processes to tillage management practices. Tillage is used to manipulate the soil to create conducive environment (soil loosening) for crop growth. In the process, the soil physical properties can be impacted either positively or negatively depending on the management technique.

Desirable tillage methods are those that positively impact on the soil physical properties and result in good tilth. As a consequence, soil aeration, infiltration rate and water holding capacity are enhanced, while the penetration resistance is reduced. Such a situation will engender root proliferation, nutrient uptake and vigorous growth of crops. It therefore becomes imperative to test the commonly practiced tillage methods in Nigeria in order to ascertain to efficacy of each method in relation to what is desirable.

The objective of this study was to determine the effect of four different tillage methods on soil physical properties with time.

2. MATERIALS AND METHODS

2.1 Site Description

The study was carried out at the National Centre for Agricultural Mechanization (NCAM), Ilorin Research farm, during the late crop cycle of 2012. Ilorin is 370 m above sea level and on Longitude 4^{o}40’47” E and Latitude 8^{o}22’56” N under the southern guinea savannah vegetation. The experiment was conducted during the second peak of rainy season in Ilorin to the early dry season (Fig. 1). The explored horizon (0-25cm) is made up of soil classified as sandy loam soil, having a composition of 79.7% sand, 5.1% silt and 15.2% clay, with a hydraulic conductivity of 1.47mm/day. The average annual rainfall of Ilorin is about 1186mm, while the annual average maximum and minimum temperatures of Ilorin are 32.3°C and 21.1°C, respectively (Fig.2).

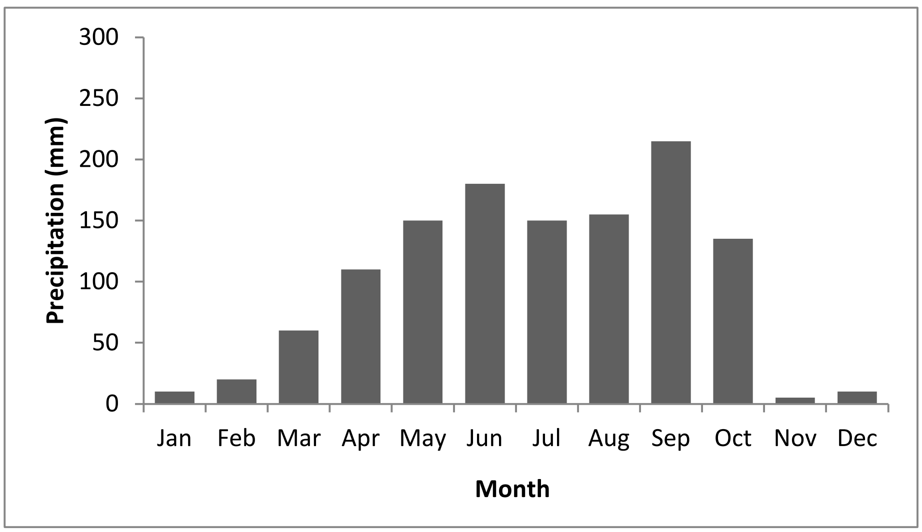

Fig. 1 Monthly rainfall for Ilorin in 2012

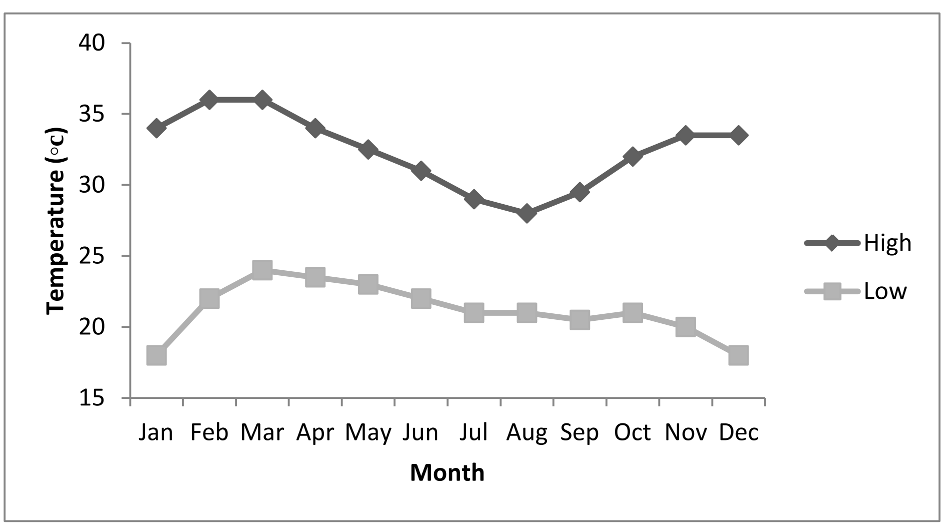

Fig. 2 Monthly average minimum and maximum temperature of Ilorin in 2012

2.2 Equipment Description

A 55 kW New Holland tractor (Model TC33D) was used to pull all the field equipment during the field operations. Disc plough and Disc harrow were used for the experiment; the plough consists of three (3) plane concave discs with a spacing of 680 mm, while the harrow consists of eighteen (18) gang plane concave and notched concave disc harrow spaced 225 mm apart.

2.3 Experimental Design

The experiments were laid out in a randomized complete block design (RCBD) with four treatments and three replications. Four tillage methods were compared. The tillage methods are conservation tillage and conventional tillage. The description of the tillage treatments are presented in Table 1. The size of each plot was 10.0 m long and 3.0 m wide. A buffer zone of 1.0m spacing was provided between plots. The plots were ploughed on the 14th September, 2012 and the treatments which required harrowing were carried out three days later (16th September, 2012). Prior to the treatments, the field has been under fallow for two years.

Table 1: Description of the different tillage treatments.

Treatments	Tillage type	Description
No-till (NT)	Conservation	No tillage
Plough alone(PA)	Conservation	Disc plough once
Plough and harrow once(PH)	Conventional	Disc plough + 1 pass of harrow
Plough and harrow twice(PHH)	Conservational	Disc plough + 2 passes of harrow

2.4 Measurements

Soil physical properties measurements were taken on each plot on the 14th September, 25th September and 4th October, 2012, respectively.

2.4.1 Soil Moisture Content

On each sampling occasion, nine (9) soil samples were taken randomly on each plot to a depth of 21cm at 7cm increments. Soil samples were weighed, oven-dried at 105^{o}C for 24 hours, and weighed again to determine the gravimetric moisture content.

2.4.2 Soil Bulk Density

Bulk density was measured with a Soil Bulk Density Sampling Apparatus developed at the National Centre for Agricultural Mechanization, Ilorin (Ogunjirin et al., 2000). Soil samples were collected on each plot at 7cm increments down to the depth of 21cm. The samples were weighed and the bulk density was calculated by dividing the sample weight by the sampler volume. Samples were taken randomly in 3 locations per plot.

2.4.3 Soil Porosity

Soil porosity was obtained from the relationship between bulk density and particle density (equation 1). The particle density of the soil was determined to be 2.52g/cm^3.

$$Soil\ Porosity = (1 - \frac{Bulk\ density}{Paticle\ density}) \quad (1)$$

2.4.4 Soil Cone Index

Soil cone index (CI) was measured to quantify the level of soil compaction. The Eijkelkamp Penetrologger (Art No: 0-6-15-01, 6987 ZG Giesbeek, the Netherlands) used comprised of an in-built data logger, an 80cm long shaft, a cone with a base area of 5.0cm^{2,} and an apex angle of 60^0. The penetrometer was pushed into the soil by hand at a speed of approximately 2cm/s according to ASABE (2006). On each plot, five measurements were taken randomly to a soil depth of 21cm at 7cm increment. Since cone index is strongly related to the water content (Materechera and Mloza-Banda, 1997), cone index measurements were performed after there were noticeable changes in the soil moisture level to maximize uniformity of soil moisture content through the depth profile.

2.4.5 Soil Shear Strength

Soil shear strength (SS) was measured to determine the level of soil compaction. The vane used was a Hand-Held Field Shear Vane Tester (Durham Geo Slope Indicator, model-no: S-162). It gives direct reading of shear strength to depths up to 3m, and the peak value is determined by a calibrated scale ring built unto the head assembly. The cross handle is used both to push the vane to the desired test depth and apply the shearing torque. The selected vane for the experiment is of dimension 25.4mm × 50.8mm. The vane was pushed into the soil by hand at 7cm depth increments, up to 21cm depth. Measurements of SS were taken randomly at 6 locations per plot, with three replications.

2.4.6 Tillage Depth

At the commencement of the experiment, immediately following the tillage operations, tillage depth was measured at 10 random locations on each plot. A steel rule was inserted down into the tilled soil until a characteristic hard pan was encountered. The tillage depth was measured from the corresponding reading on the steel rule.

2.4.7 Draft Force

A custom-made 20kN Dilon Dynamometer (Test 13.50 ± 4d, BV5550) connected to a data logger (Mess-und, Weigetechnik D30974 Wennigsen/Hannover, Germany) of range 0-20.00t, in the tractor cab was used to measure the draft force of the tillage implements. The force signal was recorded at 100 Hz for 40s. The dynamometer was attached to the front of the tractor on which the implement was mounted. Another auxiliary tractor was used to pull the implement mounted tractor through the dynamometer. The auxiliary tractor pulls the implement-mounted tractor with the latter in neutral gear but with the implement in the operating position. Draft was recorded in the measured distance (20 m) as well as the time taken to traverse the distance. On the same field, the implement was lifted out of the ground and the draft recorded. The difference between the two readings, gives the draft of the implement (Ahaneku et al., 2011). A constant tractor travel speed of 1.8ms^{-1} was maintained for the tillage operations for the soil of the area as recommended by Ahaneku and Ogunjirin, (2005).

2.5 Data Analysis

Analysis of variance (ANOVA) was performed on the data. Means between treatments were compared with Duncan's multiple range test. The statistical inferences were made at 0.05 (5%) level of significance.

3. RESULTS AND DISCUSSION

3.1 Effect of Tillage Methods on Soil Moisture Conservation

The effects of different tillage methods on soil moisture content is presented in Table 2. The results indicate that PHH treatment recorded the highest moisture content and the NT treatment recorded the lowest moisture content at every depth. This implies that at every depth the PHH has the tendency of conserving moisture more than PA, PH and NT. The significantly ($p < 0.05$) greater soil moisture content of the PHH treatment may be attributed to the fact that annual disturbance and pulverizing caused by conventional tillage produced a finer and loose soil structure which tend to conserve more moisture (Rashidi and Keshavarzpour, 2007). The low value of moisture content associated with the NT treatment is due to the decreased pore space, increased soil strength and stable aggregates (Mitchell et al., 2007) associated with conservation tillage. These results are in agreement with those of Khan et al. (1999) who reported that conventional tillage method increased tortuosity of the soil. The general trend of variation amongst the treatments was PHH > PH> PA > NT.

Table 2: Average soil moisture content (%) measured for the tillage methods at 0, 11 and 20 DAT at various soil depths.

Tillage Method	Soil depths (cm)		
	7	14	21
0 DAT at the various soil depths			
No tillage	9.81 ^{a}±0.81	7.38 ^{a}±0.75	8.52^{a}±0.84
Plough Alone	8.87^{a}±0.29	8.41^{a}±0.76	9.91^{ab}±0.06
Plough + harrow	10.29^{a}±0.83	9.87^{ab}±0.45	10.85^{b}±0.31
Plough + harrow twice	11.31^{a}±1.56	11.71^{b}±01.05	11.52^{b}±0.76
11 DAT at various soil depths			
No tillage	5.46^{a}±0.44	7.93 ^{a}±0.97	10.09^{ab}±0.58
Plough Alone	8.33^{b}±0.38	9.86 ^{a}±1.88	6.92^{a}±1.43
Plough + harrow	9.38^{b}±0.71	10.34^{a}±0.77	9.49^{ab}±0.23
Plough + harrow twice	9.35^{b}±0.49	10.38^{a}±0.96	10.80^{b}±1.07
20 DAT at various soil depth			
No tillage	4.16^{a}±0.18	5.31^{b}±0.53	6.89^{ab}±0.80
Plough Alone	4.43^{a}±0.13	4.36^{a}±0.02	5.52^{a}±0.05
Plough + harrow	6.25^{b}±0.31	6.93^{c}±0.01	7.24^{b}±0.32
Plough + harrow twice	6.14^{b}±0.00	8.47^{d}±0.05	7.96^{b}±0.04

Values are means of three replicates (n = 3) in all Treatment; DAT – Days after tillage.

Results presented are mean values of each determination ± standard error mean (SEM).Values on the same column for each parameter with different superscript are significantly different ($P \leq 0.05$) while those with the same superscript are not significantly different ($P \geq 0.05$) as assessed by Duncan's Multiple Range Test.

3.2 Effect of Tillage Methods on Soil Porosity

Soil porosity was significantly ($p < 0.05$) affected by tillage methods as shown in Table 3. The conventional tillage practices consistently yielded higher values of porosity for the period of the study as compared to the conservational ones. This phenomenon is attributed to less pulverization of the soil provided by the later methods. Ahaneku and Onwualu (2007) reported that conventional tillage practices provided larger pores within the soil profile and this may be responsible for the relatively higher porosity obtained for the PHH and PH treatments in this study. However, for sandyloam soils similar to those used in this investigation, which may be prone to excessive evaporation and leaching, this feature may definitely be advantageous (Ahaneku and Onwualu, 2007). Porosity generally decreased with soil depth due to the natural increase in packing density with depth due to soil weight, and lower soil moisture as the dry season sets in.

Table 3: Average soil Porosity (%) measured for the tillage methods at 0, 11 and 20 DAT at various soil depths.

Tillage Method	Soil depth (cm)		
	7	14	21
0 DAT at the various soil depths			
No tillage	34^a±0.0 1	26^c±0.01 1	25^a±0.17 4
Plough Alone	36^a±0.06 2	28^b±0.033	30^a±0.21 3
Plough + harrow	34^a±0.16 4	31^{ab}±0.01 2	31^a±0.092
Plough + harrow twice	32^a±0.12 3	33^a±0.16 1	33^a±0.09 1
11 DAT at various soil depths			
No tillage	34^a±0.04 1	27^b±0.43 4	28^a±0.08 4
Plough Alone	29^a±0.124	28^b±0.09 3	34^a±0.05 2
Plough + harrow	33^a±0.15 2	31^{ab}±0.23 2	34^a±0.06 1
Plough + harrow twice	32^a±0.08 3	37^a±0.05 1	31^a±0.04 3
20 DAT at various soil depth			
No tillage	31^a±0.11 3	27^d±0.04 4	23^b±0.06 3
Plough Alone	31^a±0.03 4	30^c±0.02 3	20^b±0.01 4
Plough + harrow	38^a±0.16 2	32^b±0.01 2	31^a±0.09 2
Plough + harrow twice	40^a±0.01 1	36^a±0.02 1	34^a±0.01 1

Values are means of three replicates (n = 3) in all Treatment; DAT – Days after tillage.

Results presented are mean values of each determination ± standard error mean (SEM).Values on the same column for each parameter with different superscript are significantly different (P≤ 0.05) while those with the same superscript are not significantly different (P ≥ 0.05) as assessed by Duncan's Multiple Range Test

3.3 Effect of Tillage Methods on Soil Bulk Density

Bulk density was significantly ($p < 0.05$) affected by tillage treatments as shown in Table 4. However, this was not reflected in the surface layers (0-7cm) depth. This is consistent with similar studies (Ball-Coelho et al., 1998; Schønning and Rasmussen, 2000) and in contrast with other results (Dao, 1996).Contrasting effects of soil management experiments in agricultural studies are common. Contradictory results have been obtained when tillage systems effects on soil bulk density is reviewed. Some studies found that bulk density increased under no-till in relation to conventional tillage (Tebrügge and Düring, 1999) or reduced tillage (McVay et al., 2006). According to Rasmussen, (1999) different limited tillage managements may induce soil densification of the upper soil layers when compared to intense tillage methods. These phenomena are mostly related to management factors such as planting machinery (machine weight, tire width, inflation pressure), number of machine passes, as well as the soil water content at which the soil is tilled (Czyz, 2004; Botta et al., 2005). Bulk density generally increased with depth but did not follow any consistent trend wuth time among the tillage methods (Table 4). This could simply mean that the bulk density of sandy loam soil is relatively the same on the average regardless of whether these soils were harrowed or ploughed. Tillage depth may be responsible for the significant difference at depth 7cm-14cm (Table 4) as the depth of cut of the harrow averages between 12cm-13cm. Also considering the undulating nature of the field surface there is a great tendency that the soil at this depth experienced minimal disturbance after being compacted due to the machinery weight and increased number of passes due to harrowing operation (Botta et al., 2005).

Table 4: Average bulk density (g/cm^3) measured for the tillage methods at 0, 11 and 20 DAT at various soil depths

Tillage Method	Soil depth (cm)		
	7	14	21
0 DAT at the various soil depths			
No tillage	1.64^{a}±0.04	2.00^{c}±0.06	1.89^{a}±0.17
Plough Alone	1.61^{a}±0.06	1.80^{b}±0.01	1.75^{a}±0.16
Plough + harrow	1.66^{a}±0.16	1.72^{ab}±0.01	1.73^{a}±0.09
Plough + harrow twice	1.69^{a}±0.04	1.67^{a}±0.05	1.68^{a}±0.09
11 DAT at various soil depths			
No tillage	1.65^{a}±0.00	1.82^{b}±0.04	1.79^{a}±0.12
Plough Alone	1.78^{a}±0.12	1.81^{b}±0.09	1.65^{a}±0.08
Plough + harrow	1.67^{a}±0.15	1.74^{ab}±0.23	1.67^{a}±0.06
Plough + harrow twice	1.71^{a}±0.08	1.58^{a}±0.05	1.72^{a}±0.09
20 DAT at various soil depth			
No tillage	1.75^{a}±0.11	1.85^{d}±0.01	1.94^{b}±0.01
Plough Alone	1.73^{a}±0.03	1.78^{c}±0.02	2.01^{b}±0.03
Plough + harrow	1.56^{a}±0.16	1.72^{b}±0.01	1.73^{a}±0.09
Plough + harrow twice	1.52^{a}±0.01	1.62^{a}±0.02	1.66^{a}±0.01

Values are means of three replicates (n = 3) in all Treatment; DAT – Days after tillage.

Results presented are mean values of each determination ± standard error mean (SEM).Values on the same column for each parameter with different superscript are significantly different (P≤ 0.05) while those with the same superscript are not significantly different (P ≥ 0.05) as assessed by Duncan's Multiple Range Test

3.4 Effect of Tillage Methods on Soil Strength (Shear Strength and Cone Index)

Soil shear strength increased both temporally and with soil depth. At any temporal regime, soil shear strength was not significantly different (p <0.05) among the tillage methods except the no-till method. The high shear strength values observed in the no-till treatments may be ascribed to the lower moisture retention in these treatments with time (Table 2). This is also associated with lower rainfall amounts (Fig.1) and higher temperature air temperatures (Fig.2) with time (September to October). PHH, PH and PA, respectively had reduced soil strength and compaction in the tilled layers when compared to the NT (Tables 5 and 6). Wilkins et al. (2002) also reported that a short-term no-till soil had higher soil strengths than a tilled soil. The low cone index and shear strength exhibited by PHH, PH and PA may be attributed to the effect of aggregate stability over time induced by different tillage treatments (Blevins and Frye, 1993).It was observed that the soil moisture content was a major determinant of soil cone index and shear strength as the values were higher on the second and third day of experiment when low soil moisture content was recorded. The statistically significant difference (p < 0.05) in this regard was observed at one depth (0 cm-14 cm). This is in agreement with the results reported by Ghuman and Lal (1984) that penetration resistance decreased with increase in soil moisture content and vice versa.

Table 5: Average soil shear strength (MPa) measured for the tillage methods at 0, 11 and 20 DAT at various soil depths.

Tillage Method	Soil depth (cm)		
	7	14	21
0 DAT at the various soil depths			
No tillage	51.81^{b}±1.27	88.04^{c}±9.13	157.59^{c}±1.36

Plough Alone	9.06^{a}±0.61	26.53^{ab}±3.11	78.95^{a}±4.91
Plough + harrow	9.56 ^{a}±1.44	14.36 ^{a}±2.43	107.29^{ab}±21.12
Plough + harrow twice	7.47 ^{a}±0.31	39.02^{b}±10.38	133.78^{bc}±14.49
11 DAT at various soil depths			
No tillage	71.81^{b}±1.27	111.38^{a}±12.47	184.25^{ab}±6.22
Plough Alone	43.44^{a}±10.61	113.89^{a}±19.45	190.96^{b}±6.60
Plough + harrow	39.74^{a}±16.26	87.63^{a}±15.85	194.46^{b}±3.82
Plough + harrow twice	46.35^{a}±14.61	113.19^{a}±13.34	159.94^{a}±11.27
20 DAT at various soil depth			
No tillage	129.35^{a}±2.64	190.55^{b}±2.25	265.62^{c}±4.49
Plough Alone	139.04^{a}±38.11	175.13^{a}±2.59	190.96^{b}±6.60
Plough + harrow	161.01^{a}±20.29	180.49^{ab}±0.14	194.46^{b}±3.82
Plough + harrow twice	121.24^{a}±29.47	172.02^{a}±5.16	159.94^{a}±11.27

Values are means of three replicates (n = 3) in all Treatment; DAT – Days after tillage.

Results presented are mean values of each determination ± standard error mean (SEM).Values on the same column for each parameter with different superscript are significantly different (P≤ 0.05) while those with the same superscript are not significantly different (P ≥ 0.05) as assessed by Duncan's Multiple Range Test

Table 6: Average Soil cone index (N/cm^2) measured for the tillage methods at 0, 11 and 20 DAT at various soil depths.

Tillage Method	Soil depth (cm)		
	7	14	21
0 DAT at the various soil depths			
No tillage	0.01^{a}±0.00	0.47^{b}±0.08	1.11^{c}±0.05
Plough Alone	0.01^{a}±0.00	0.01^{a}±0.00	0.16^{a}±0.02
Plough + harrow	0.02^{ab}±0.00	0.01^{a}±0.00	0.36^{b}±0.03
Plough + harrow twice	0.02^{b}±0.00	0.05^{a}±0.01	0.05^{a}±0.01
11 DAT at various soil depths			
No tillage	0.66^{c}±0.33	1.47^{a}±0.08	2.24^{a}±0.18
Plough Alone	0.42^{b}±0.40	1.41^{a}±0.29	2.00^{a}±0.17
Plough + harrow	0.10^{b}±0.06	1.33^{a}±0.26	1.62^{a}±0.29
Plough + harrow twice	0.29^{b}±0.25	1.15^{a}±0.32	1.52^{a}±0.27
20 DAT at various soil depth			
No tillage	1.23^{b}±0.21	1.77^{a}±0.09	2.17^{c}±0.14
Plough Alone	0.61^{a}±0.02	1.28^{ab}±0.09	1.93^{b}±0.05
Plough + harrow	0.80^{a}±0.41	1.35^{ab}±0.07	1.81^{b}±0.06
Plough + harrow twice	0.71^{a}±0.08	0.92^{a}±0.37	0.94^{a}±0.07

Values are means of three replicates (n = 3) in all Treatment; DAT – Days after tillage.

Results presented are mean values of each determination ± standard error mean (SEM).Values on the same column for each parameter with different superscript are significantly different (P≤ 0.05) while those with the same superscript are not significantly different (P ≥ 0.05) as assessed by Duncan's Multiple Range Test

There was no significant difference ($p < 0.05$) among the treatments at 7cm depth due to the depth of cut of the tillage operations (12cm-13cm), and this explains the high value obtained for NT at depth 14cm. The general trend of variation amongst the treatments during the study was NT > PA > PH > PHH.

3.5 Draft of Implements

The results of the draft force test required for the tillage operations (i.e. plough and harrow) showed that the draft force required for ploughing operation is greater than that required for harrowing operation. The result is in agreement with that reported by Ahaneku et. al (2011). This is attributable to the fact that ploughing is a primary tillage operation while harrowing is a secondary tillage operation. The draft force required for ploughing and harrowing operation were 4.95kN and 3.77kN, respectively.

4. CONCLUSIONS

This study established a data base that can aid the prediction of the effect of various tillage methods on soil physical properties. Results from the study indicate that:

- Conventional tillage practices that invert the soil exhibited better soil moisture conservation and relatively higher soil porosity.
- The more intensive the tillage operation, the lower the soil strength properties but the more the farm power (draft) required.
- Resistance to penetration and shear strength are more reliable indices for assessing soil tilth than the bulk density under different tillage methods.
- The draft force required for ploughing and harrowing operations were found to be 4.95kN and 3.77kN, respectively.

REFERENCES

Ahaneku, I. E., Oyelade, O. A., Faleye, T. 2011. Comparative Field Evaluation of Three Models of a Tractor. *Proceedings of Nigerian Branch of the International Soil Tillage Research Organization (ISTRO)*, (p. 93). University of Ilorin, Ilorin, Nigeria.

Ahaneku, I.E.,Ogunjirin, O.A. 2005. Effect of Tractor Forward Speed on Sandy Loam Soil Physical Conditions During Tillage. *Nigerian Jornal of Technology 24: 1*, 51-57.

BIBLIOGRAPHY Ahaneku, I.E., Onwualu, A.P. 2007. Tillage Effects on Maize Performance and Physical Properties of a Sandy Soil. *Journal of Applied Science, Engineering and Technology* , 3.

Alletto, L., Coquet 2009. Temporal and Spatial Variabilty of Soil bulk Density and Near-Saturated Hydraulic Conductivity Under Two Contrasted Tillage Management Systems. Geoderma 152: 85-94.

ASABE. 2006. EP542Feb 99. Procedures for Using and Reporting Data Obtained with the Soil Cone Penetrometer. ASABE, St. Joseph: Michigan.

Ball-Coelho, B.R., Roy, R.C., Swanton, C.J. 1998. Tillage alter corn root distribution in coarse-textured soil. *Soil and Tillage Research*, 249-273.

Blevins, R.L., Frye, W.W. 1993. Conservation tillage: an ecological approach to soil management and Advances in Agronomy. *International Journal of Agronomy*, 51, 33–78.

Botta, G.F., Jorajuria, D., Rosatto, H., Ferrero, C. 2005. Light tractor traffic frequency on soil compaction in the Rolling Pampa region. *Soil and Tillage Research 86*, 9-14.

Czyz, E. 2004. Effects of traffic on soil aeration, bulk density and growth of spring barley. *Soil and Tillage Research*, 153–166.

Dao, T. 1996. Tillage system crop residue effect on surface compaction of a paleustoll. *Agronomy Journal*, 141-148.

Ghuman, B.S., Lal, R. 1984. Water percolation in tropical Alfisol under conventional ploughing and no-tillage systems of management. *Soil and Tillage Research*, 263-276.

Khan, F, Tahirn, A.R., Yule, I.J. 1999. Impact of different tillage practices and temporal factor on soil moisture content and soil bulk density. *International Journal of Agriculture*, 163-166.

Lewandowski, A. Zumwinkle, M. Fish, A. 1999. Assessing the Soil System: A Review of Soil Quality Literature. *Energy and Sustainable Agriculture Program Minnesota Department of Agriculture,* (pp. 30 - 45). Minnesota.

Materechera, S.A., Mloza-Banda, H.R.,. 1997. Soil cone index, root growth and yield of maize as influenced by tillage system on ridges in Malawi. . *Soil and Tillage Research. 41*, 13-24.

Mc Vay, K.A., Budde, J.A., Fabrizzi, K.,Mikha, M.M., Rice, C.W., Schlegel, A.J., Peterson,D.E., Sweeney, D.W., Thompson, C. 2006. Management effects on soil physical properties in long-term tillage studies in Kansas. *Soil Science Society of America Journal,* 434-438.

Mitchell, J.P., Klonsky, K., Shrestha, A., Fry, R., DuSault, A. 2007. Adoption of conservation tillage in California:. *Australian Journal of Experimental Agriculture*, 2.

Ogunjirin, O.A., Ahaneku, I.E,. Kamla, A.R. 2000. Design, Construction and Evaluation of Soil Bulk Density Sampling Apparatus. *Proceedings of the 1st International Conference of Nigerian Institution of Agricultual Engineers Vol.22*, (pp. 129-134).

Ozgoz, E.H., Gunnal, H., Onen, H., Bayram, M., Acir, N. 2012. Effect of Management on Spatial and Temporal Distribution of Soil Physical Properties. Journal of Agricultural Sciences 18: 77-91.

Rashidi, M., Keshavarzpour, F. 2007. Effect of different tillage methods on grain yield and yield components of maize (Zea mays L.). *International Journal of Agriculture and Biology*, 274-277.

Rasmussen, K. 1999. Impact of ploughless soil tillage on yield and soil quality. *Soil and Tillage Research 53*, 3-14.

Schønning, P., Rasmussen, K.J. 2000. Soil strength and soil pore characteristics for direct drilled and ploughed soils. *Soil and Tillage Research*, 69-82.

Struddley, M.W., Green, T.R., Ascough, J.C. 2008. Tillage effects on Soil Hydraulic Properties in Space and Time: State of Science. Soil and Tillage Research. 99: 4-48.

Tebrugge, F., During, R.A. 1999. Reducing tillage intensity—A review of results from a long-term study in Germany. *Soil and Tillage Research,* 15-28.

Wilkins, D.E., Siements, M.C., Albrecht, S.L. 2002. Changes in soil physical characteristics during transition from intensive tillage to direct seeding. *Trans ASAE 45*, 877-880.

Van Es, H.M., Ogden, C.B., Hill, R.L., Schindllbeck, R.R., Tsegaye, T. 1999. Integrated Assessment of Space, Time, and Management-Related Variability of Soil Hydraulic Properties. Soil Science Society of America Journal 63: 1599-1608.

SOIL MOISTURE CONTENT VARIATION AND MECHANICAL RESISTANCE OF NIGERIAN ALFISOL UNDER DIFFERENT TILLAGE SYSTEMS

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ABSTRACT

The spatial variability of moisture content and mechanical resistance and their effects on soil properties such as bulk density, micro and macro porosities and soil organic matter was studied, in an Alfisol cropped with okra, and under no-till, primary and secondary tillage systems. The experiment was conducted at the Research and Training Farm of the Federal University of Technology, Akure, Ondo State, Nigeria, located on latitude 7^0 $10^'$ N and longitude 5^0 $05^'$ E. The three tillage treatments were replicated three times following a split plot design to give a total of nine plots and the area of each plot was 10 x 10 m^2. Soil samples were randomly collected at 3 points from each plot at an interval of 10 cm up to the 40 cm depth i.e. 0 - 10, 10 - 20, 20 - 30 and 30 - 40 cm. Total mean volumetric moisture content were in the order no-till > primary tillage > secondary tillage. The bulk density of the no-till plot (1.54±0.08 g cm^{-3}) was highest among the three tillage systems at the 20 – 30 cm soil depth and consequently a higher mean degree of compaction of 93.86 %. The lowest degree of compaction was observed in treatment plots under secondary tillage with a value of 89.45 %. There was no significant difference ($p = 0.05$) in the degree of compaction of soil within the 20 - 30 cm soil depth for the three different soil tillage treatments. The highest unconfined compressive strength (74.87 kPa) was recorded in the 20 – 30 cm soil depth in plot under the no-till treatment, which resulted in high shear strength of 37.42 kPa, while the lowest compressive strength (55.48 kPa) and corresponding shear strength of 27.74 kPa were recorded in the 0 - 10 cm soil layer of plot under secondary tillage. The research finding is useful in conservation agriculture for optimum crop production and ecosystem preservation.

KEYWORDS: Spatial variability, mechanical resistance, moisture content, bulk density, total porosity.

1. INTRODUCTION

Soil moisture is an influential store of water in the hydrologic cycle (Western et al., 2002) even though it is a small proportion (only 0.15%) of the liquid freshwater on Earth (Dingman, 1994). Soil moisture is critical for addressing environmental issues related to soil erosion, flooding and solute transport (Kitanidis and Bras, 1999). According to Entekhabi (1995), soil moisture acts as a modulator between the land surface and the atmosphere, thereby influencing climate and weather. Soil moisture also influences various processes related to plant growth and hence ecological patterns (Rodrıguez- Iturbe, 2000) and agricultural production (Western et al., 2002), as well as a range of soil processes (Brady 1990, White 1997).

However, soil moisture is spatially and temporally highly variable and it influences a range of environmental processes in a nonlinear manner (Western et al., 2002). This variability results from many processes operating at a wide range of scales influenced by soil types, textures, and structure. Similarly, many other spatial and temporal fields (e.g., soil, vegetation, topography, meteorology) that influence soil moisture and other hydrologic responses are variable (Western et al., 2002). Land use also plays an important role in controlling spatial patterns of soil moisture by influencing the infiltration, runoff and evapotransipiration, particularly during the growth season (Reynolds, 1970c; Hawley et al., 1983; Francis et al., 1986; Fu et al., 1994; Fu and Gulinck, 1994; Fu and Chen, 2000; Qiu et al., 2001). Soil moisture and processes also vary dynamically in space and time due to tillage practices. In order to achieve a better understanding of these issues, it is necessary to understand the spatio-temporal variability of soil moisture under different climatic and geological conditions and at different hierarchical space scales and time scales (Mohanty et al., 2000).

The spatio-temporal variability of soil moisture directly influences tillage and consequently the mechanical resistance of soil. The high mechanical resistance of a soil can be of advantage if the intended use of the soil has an engineering inclination. Soil compaction is an indicator of high mechanical resistance (Hakansson et al., 1988). Soil compaction is the main form of soil degradation which affects 11% of the land area in the surveyed countries of the world (Connolly et al., 1997). Compaction is caused by the use of heavy machinery, pressure from wheels, tillage equipments, reduced use of organic matter, (Wolkowski and lowery, 2008), trampling by animals((Warren et al., 1986, Mulholland and Fullen, 1991, Horn, 1986), frequent use of chemical fertilizers and ploughing at the same depth for many years. Miller et al. (2001) reported that physical properties such as the bulk density and the moisture content of the soil are related to its resistance. The mechanical resistance of an agricultural soil affects the depth of penetration of plant roots, which in turn affects the nutrient uptake of the roots (Catriona et al., 1999). This research was aimed at investigating the variation in moisture content and mechanical resistance of a Nigerian Alfisol under different tillage systems.

2. MATERIALS AND METHODS

2.1 Site Description

The research was conducted between June and September, 2012 at the Research and Training Farm of the Federal University of Technology, Akure, Ondo State, Nigeria. The site lies within the latitude 7^0 $10'$ North and longitude 5^0 $05'$ East. Akure lies in the rain forest zone of Nigeria with a mean annual rainfall of between 1300 – 1600 mm and with an average temperature of 27 ^{0}C. The relative humidity ranges betwee n 85 and 100% during the rainy season and less than 60% during the dry season period. Akure is about 351 m above the sea level. Akure has a land area of about 2,303 sq km and is situated in the western upland area within the humid region of Nigeria (Fasinmirin and Adesigbin, 2012). Other hill-like structures which are less prominent rise only a few hundred meters above the general elevation (Fasinminrin and Konyeha, 2009). The pattern of rainfall is bimodal, the first peak occurring in June-July, and the second in September with a little dry spell in August. The soil of the site is predominantly sandy clay loam and belongs to the Alfisol (Soil Survey Staff, 1999) or Ferric Luvisol (FAO, 2006). The soil is well drained, coarse textured, overlying weathered rock materials and moderately supplied with organic matter and nutrients. Moisture holding capacity is moderately good.

2.2 Field Experimentation

Field experiment was conducted bare soil to determine the effects of different tillage practices on the moisture content and mechanical properties of the soil. There were three tillage treatments i.e. no-till, primary tillage and secondary tillage. The treatments were replicated three times to make a total of nine plots. Primary tillage was done using disc plough, while the secondary tillage involves harrowing of the soil after ploughing operation. Ploughing and harrowing operations were carried out on the 10th and 11th of July, 2012, respectively. The area of each plot was 10 x 10 m^2. The soil parameters determined include the moisture content, the bulk density, total porosity, micro-porosity and macro-porosity, organic carbon content, degree of compaction and the unconfined compressive strength.

2.3 Measurements

2.3.1 Moisture Content, Bulk Density and Degree of Compaction

Soil samples were taken from soil core at depths 0 - 10 cm, 10 - 20 cm, 20 - 30 cm and 30 - 40 cm using ring cylinders with height 10 cm and diameter 4.8 cm. The sampler was driven vertically into the soil enough to fill the sampler after which the sampler and its content was carefully removed to preserve the natural structure and packing of the soil as good as possible. The soil extending beyond each end of the sample holder was trimmed to ensure soil is contained in exactly the volume of the cylinder. Thus the soil sample volume was established to be the same as the volume of the sampler holder. The soil cores were wrapped in polyethylene, placed in wooden box and transported to the laboratory for analysis. The soil samples were then removed from the box, transferred to a metal container and placed in an oven at a temperature of 105 ^{0}C and allowed to dry for 24 hours. The weight of the wet soil sample, dry sample and core samplers were recorded and the moisture content was determined using gravimetric method (equation 1) as described by Reeb (1999). Separate soil cores samples were collected from the 0 – 10, 10 – 20 and 20 – 30 cm soil depths for bulk density determination. The bulk density was calculated using the method described by Blake and Hartge (1986). To determine the reference bulk density, soil core samples were equilibrated at a tension of 33 kPa (moisture content at field capacity) and subjected to the uniaxial compression test. The compression test was conducted by the application of loads 200, 400, 800, 1600 and 3200 kPa to separate samples using the Consolidometer Boart Longyear (Reichert et al., 2009). The “degree of compaction” or “relative compaction” of the soil, DC was defined by Suzuki et.al (1994) as shown in equation (1):

$$\text{DC} = \frac{100BD}{BD_{ref}} \qquad 1$$

where; BD= Current Bulk Density; BD_{ref} = Bulk Density of the same soil in a reference state obtained in the laboratory

2.3.2 Total, Micro and Macro-porosity

Total porosity (% pore space) was calculated using the same soil samples that were collected for soil bulk density determination. According to Suzuki et al. (1994), total porosity of the soil was calculated from the ratio of bulk density to particle density and assuming a particle density value of 2.65 Mg/m^3 (Fasinmirin and Adesigbin, 2012). The value of 2.65 Mg/m^3 was assumed based on the research conducted in similar soil by Osunbitan et al. (2005). The percentage organic carbon and organic matter was calculated using the procedures described by Bouyoucos (1962). 1g of 2 mm sieved soil sample was grinded using mortar and pestle and was transferred into a 250 ml conical flask. 10 ml of 0.167M $K_2Cr_2O_2$ and 20 ml of concentrated H_2SO_4 was added rapidly and stirred gently until soil and reagents were mixed. The flask was rotated again and was allowed to stand on a sheet of asbestos for 30 minutes. 100 ml of distilled water was added after 30 minutes and then 3 drops of Ferroin indicator were added and titrated with 0.5M iron (II) ammonium sulphate with a green cast, which later changed to dark green and finally changed to a brownish red colour (maroon colour in reflected light against a white background). A blank titration was also made with the same process but without the soil to standardize the Iron (II) solution. The percentage organic carbon and organic matter was then calculated using the formula:

$$\%\ organic\ carbon = (B - T) \times M\ \times 0.003\ \times\ \frac{100}{M} \qquad 2$$

$$\%\ organic\ matter\ =\ \%\ organic\ carbon\ \times 1.724 \qquad 3$$

where: B = Blank titre value; T = Sample titre value; M = Molarity of $(NH_4)_2Fe\ (SO_4)_2.6H_2O$

2.3.4 Unconfined Compressive Strength

According to the ASTM standard, the unconfined compressive strength is defined as the compressive stress at which an unconfined cylindrical specimen of soil will fail in a simple compression test. In this test method, the unconfined compressive strength was taken as the maximum load attained per unit area during the performance of a test.

The unconfined compressive strength (UCS) of the soil on each plot at depths 0 - 10, 10 - 20 and 20 - 30 cm was determined by Uniaxial compression test at the Geology laboratory of the Department of Applied Geology, Federal University of Technology, Akure. The results obtained were used to calculate the shear strength of the soil samples under unconfined condition. Soil samples were taken in each plot using cylinders with height of 8 cm and diameter of 3.7 cm. The samplers were driven vertically into the soil surface enough to fill the sampler; the sampler and its content were carefully removed to preserve the natural structure and packing of the soil as much as possible. The samples were taken to the Geology laboratory and carefully extruded to determine its volume.

The soil samples were extruded from the sampler and soil specimen cut so that the ratio of length to diameter (L/d) is approximately between 2 and 2.5. The exact diameter of the top of the specimen was measured at three locations 120^0 apart and the same measurement on the bottom of the specimen. The average measurement was recorded as the average diameter on the data sheet. The exact length of the specimen was measured at three locations 120^0 apart and the average measurement was recorded on the data sheet as the average length. The weight of each sample was on the data sheet. The deformation (ΔL) corresponding to 15 % strain (Ɛ) was calculated using the formula described in Reichert et al. (2009):

$$\text{Strain } (\varepsilon) = \frac{\Delta L}{L_0} \qquad 4$$

The specimen was placed carefully in the compression device and was centred on the bottom plate. The device was adjusted so that the upper plate just makes contact with the specimen before the set of the load and deformation dials to zero. Load was applied so that the device produced an axial strain at a rate of 0.5% - 2.0% per minute. The load and deformation dial readings was recorded on the data sheet at every 20 - 50 division deformation on the dial. The load was applied until the load dial decreased on the specimen significantly and the load held constant for a least four deformation dial readings. The sketch of the sample failure was drawn. The sample was then removed from the compression device.

The unconfined compressive strength (UCS) was determined and shear strength of samples was estimated using the relationship given by the American Society for Testing and Materials (ASTM) Standard

$$\text{Shear Strength} = \frac{UCS}{2} \qquad 5$$

where UCS = Unconfined Compressive strength.

3. RESULTS AND DISCUSSIONS

3.1 Moisture Content

The volumetric moisture content of soils under different tillage treatments for seven weeks is presented in Tables 1 - 4. The highest and lowest mean soil moisture content (SMC) of the no-till plot were observed in the 30 - 40 cm and 0 – 10 cm soil depths with values 0.39 cm^3cm^{-3} and 0.18 cm^3cm^{-3}, respectively. The increased soil moisture retention capacity under the no-till as a result of higher organic matter content may be responsible for the highest SMC value observed in the no-till plot. Lowest mean soil moisture content (0.08 cm^3cm^{-3}) was observed in the 10 - 20 cm soil depth of the plot under secondary tillage. This must have resulted from the increased soil porosity at the superficial soil layer due to intense breakage of soil clods, which ultimately resulted to fast infiltration of moisture deep down the soil and beyond the surface horizon. The highest soil moisture content in plot under secondary tillage was 0.26 cm^3cm^{-3} at the 20 – 30 cm and 30 - 40 cm soil layers. The sharp rise in moisture content from 0.09 cm^3cm^{-3} at depth 20 – 30 cm to 0.20 cm^3cm^{-3} at depth 30 – 40 cm must have resulted from rainfall occurrence and moisture accumulation in soil layers extending beyond the working depth of disc plough and harrow. Similar observation was made by Welling and Bell (1982), Halfmann (2005), and Fasinmirin and Olorunfemi, (2012). These researchers reported volumetric moisture content increases with increased soil depth**.** Moisture content mainly affects the penetration resistance and compaction of the soil (Bengough and Mullins, 1990), hence, lower moisture content at the superficial soil layer (0 – 10 and 10 – 20 cm layers) resulted to higher degree of compaction.

Table 1: Mean volumetric moisture content for different soil tillage systems at depth 0 – 10 cm

Julian Days (DOY)	No-Till (cm^3cm^{-3})	Primary tillage (cm^3cm^{-3})	Secondary tillage (cm^3cm^{-3})
201	0.18(±0.02)	0.16(±0.01)	0.12(±0.05)
208	0.21(±0.04)	0.21(±0.04)	0.17(±0.03)
215	0.27(±0.10)	0.15(±0.01)	0.19(±0.07)
222	0.16(±0.05)	0.16(±0.03)	0.08(±0.03)
229	0.15(±0.03)	0.17(±0.01)	0.15(±0.06)
236	0.16(±0.01)	0.15(±0.02)	0.12(±0.02)
243	0.15(±0.06)	0.15(±0.01)	0.14(±0.01)

Table 2: Mean volumetric moisture content for different soil tillage systems at depth 10 - 20 cm

Julian Days (DOY)	No-Till (cm^3cm^{-3})	Primary tillage (cm^3cm^{-3})	Secondary tillage (cm^3cm^{-3})
201	0.20(±0.05)	0.16(±0.02)	0.13(±0.06)
208	0.24(±0.01)	0.19(±0.01)	0.19(±0.02)
215	0.29(±0.03)	0.21(±0.06)	0.22(±0.08)
222	0.12(±0.07)	0.20(±0.10)	0.08(±0.02)
229	0.17(±0.06)	0.16(±0.04)	0.15(±0.07)
236	0.19(±0.04)	0.20(±0.02)	0.12(±0.04)
243	0.20(±0.07)	0.17(±0.06)	0.15(±0.01)

Table 3: Mean volumetric moisture content for different soil tillage systems at depth 20 - 30 cm

Julian Days (DOY)	No-Till (cm^3cm^{-3})	Primary tillage (cm^3cm^{-3})	Secondary tillage (cm^3cm^{-3})
201	0.29(±0.12)	0.18(±0.04)	0.13(±0.02)
208	0.22(±0.08)	0.25(±0.07)	0.21(±0.06)
215	0.18(±0.04)	0.18(±0.03)	0.26(±0.11)
222	0.16(±0.10)	0.21(±0.06)	0.09(±0.02)
229	0.22(±0.06)	0.19(±0.08)	0.14(±0.04)
236	0.16(±0.02)	0.17(±0.06)	0.16(±0.08)
243	0.21(±0.07)	0.18(±0.02)	0.14(±0.05)

Table 4: Mean volumetric moisture content for different soil tillage systems at depth 30 - 40 cm

Julian Days (DOY)	No-Till (cm^3cm^{-3})	Primary tillage (cm^3cm^{-3})	Secondary tillage (cm^3cm^{-3})
201	0.39(±0.01)	0.25(±0.03)	0.20(±0.03)
208	0.38(±0.06)	0.28(±0.07)	0.25(±0.60)
215	0.38(±0.03)	0.29(±0.02)	0.26(±0.01)
222	0.35(±0.10)	0.25(±0.01)	0.20(±0.04)
229	0.35(±0.07)	0.23(±0.07)	0.18(±0.02)
236	0.35(±0.05)	0.26(±0.01)	0.22(±0.01)
243	0.35(±0.02)	0.23(±0.04)	0.19(±0.03)

3.2 Bulk Density

The bulk densities of soil under varying tillage management are presented in Table 5 while the reference bulk densities are shown in Table 6. There were variabilities in bulk densities amongst the different tillage practices. The bulk density of the 20 - 30 cm layer was the highest in all the different tillage systems. Bulk density was highest in No-till plot with an average value of 1.54 g cm^{-3} (±0.08) within the 20 – 30 cm soil layer and lowest in the ploughed and harrowed plot with an average value of 1.46 g cm^{-3} at the 0 – 10 cm soil layer. Similar observation was made by Jin et al., (2007) who reported that tillage practices affect the bulk densities of soils. The 0 – 20 cm is the most effective ploughing and harrowing depth, where thorough soil loosening of aggregates by tillage operation and consequently increased porosity must have occurred. This result agreed with the findings of Vereecken et.al. (1989) who reported that bulk density increased with depth.

Table 5: Mean bulk densities of soil at different depths

Depth (cm)	No-till (gcm^{-3})	Primary tillage (gcm^{-3})	Secondary tillage (gcm^{-3})
0 - 10	1.49 (±0.06)	1.48(±0.43)	1.46(±0.01)
10 - 20	1.51(±0.13)	1.49(±0.05)	1.48(±0.10
20 - 30	1.54(±0.08)	1.50(±0.22)	1.50(±0.03)

Table 6: Mean Reference Bulk density of soils under different tillage systems

Depth (cm)	No-till (gcm^{-3})	Primary tillage (gcm^{-3})	Secondary tillage (gcm^{-3})
0 - 10	1.60(±0.02)	1.62(±0.03)	1.60(±0.17)
10 - 20	1.62(±0.12)	1.59(±0.08)	1.63(±0.07)
20 - 30	1.68(±0.07)	1.67(±0.14)	1.63(±0.15)

3.3 Soil Organic Carbon

The organic carbon was highest in the no-till plots with mean value of 1.81%. The high value observed in the no till plots might have been caused by the presence of dead plant residues on the soil surface, this is in accordance with the findings of Edwards et al. (1999) who studied the effect of 10 years of conventional till and no-till on organic carbon. Organic carbon was lowest in the plots under primary tillage due to the inversion of the soil during tillage operation. The organic carbon in the plots under secondary tillage was higher than the value obtained in plots under primary tillage due to the further pulverization of the soil which helped to redistribute the organic carbon concentration throughout the soil profile. A spatial characteristic was also noticed in soil carbon due to the tillage systems. The high organic matter content also improved the water retention capacity of the soil (FAO, 2005; Olorunfemi and Fasinmirin, 2011) as shown in the high moisture content of the no till plots. The mean organic matter content of plots under primary tillage was 0.96 while that of secondary tillage (plot C) was 1.10 % as seen in Table 7. Similar results was reported by Carter (1996) who explained that soil organic carbon content is a function of the tillage practice used on the soil.

Table 7: Organic Carbon Content of Soil under different treatment systems

Replicates	No till (%)	Primary tillage (%)	Secondary tillage (%)
Rep 1	1.86	0.90	1.16
Rep 2	1.76	0.85	1.01
Rep 3	1.82	1.14	1.12
Mean	1.81	0.96	1.10
STD	±0.05	±0.15	±0.08

3.4 Degree of Compaction

The result of the degree of compaction of soil under different tillage systems is presented in Table 8**.** Highest degree of compaction was observed in the no-till plot with value of 93.86% within the 10 - 20 cm soil layer, while the plots under primary and secondary tillage had reduced degree of compaction with values 93.71 and 92.02%, respectively at the 20 - 30 cm soil layer. Similar observation was made by Fasinmirin and Adesigbin (2011) who reported that degree of compaction increased down the soil profile, most especially within depths 20 – 30 cm. There were no significant difference in the degree of compaction at p = 0.05 in the 20 - 30 cm depths probably due to the depth of operation of the tillage equipments. The lowest degree of compaction of tilled soil might have been caused by the relatively low strength and increased air permeability of the soil. However, soil parameters that are adversely affected by compaction of soil particles are those that control the content and transmission of water, air, heat and nutrient (Shafiq et.al., 1994). Water content and the degree of compaction had an inverse relationship (Soane et.al., 1981). Increase in volumetric soil moisture decreases the degree of compaction.

Table 8: Degree of compaction of soils under different tillage systems

Depth	No-till	Primary tillage	Secondary tillage
0 - 10	93.13	91.36	87.42
10 - 20	93.21	89.22	88.09
20 - 30	93.86	93.71	92.02
Mean	93.28	91.42	89.45
STD	± 0.20	± 0.52	± 0.11

3.5 Porosity

The impact of tillage on the physical properties of the soil such as total porosity, micro-porosity and macro-porosity is evident as shown in Table 9**.** The plots under secondary tillage on the average had the highest total porosity of 43.23 %, which definitely will encouraged the easy penetration of air and water into the soil and consequently improved plant growth. Total porosity decreased in the ploughed plot and no-till plot with values of 42.92 % and 41.83 %, respectively. Average micro-porosity was the highest in the plots under primary tillage with a value of 21.82 % and decreased in the plots under secondary tillage and the no till plots with mean values of 21.27 % and 20.85 %, respectively. Mean macro-porosity decreased in the order secondary tillage > primary tillage > no till with values of 21.96 %, 21.09 % and 20.97 %, respectively. This agrees with the findings of Ann et.al, (2005) who reported that total porosity, micro-porosity and macro- porosity vary with different tillage practices.

Table 9: Mean Total Porosity, Micro-Porosity and Macro-Porosity of Soil under different Tillage systems

	Depth (cm)	No-till	Primary tillage	Secondary tillage
Total-Porosity (%)	0 - 10	43.9	44.3	44.9
	10 - 20	42.5	43.9	44.3
	20 - 30	42.9	43.7	43.5
	30 - 40	38.1	39.7	40.2
Micro-Porosity (%)	0 - 10	14.9	13.8	13.3
	10 - 20	23.2	25.9	24.9
	20 - 30	24.9	24.3	23.2
	30 - 40	20.4	23.2	23.8
Macro-Porosity (%)	0 - 10	29.0	30.5	31.7
	10 - 20	19.2	17.9	19.5
	20 - 30	18.0	19.4	20.3
	30 - 40	17.6	16.5	16.4

3.6 Unconfined Compressive Strength

The result of unconfined compressive strength and shear strength of soils under different tillage systems is presented in Tables 10 and 11. Plots under secondary tillage had the lowest unconfined compressive strength (UCS) of 55.48 kPa at the 0 - 10 cm depth, while the highest UCS was observed in the no-till plot with a value of 74.87 kPa at the 20 - 30 cm depth. Similar observation was made by Christopher et.al (2006), who affirms spatial variability of UCS due to different soil treatments. The observed values indicated that the no till plot had about 20% increase in the compression strength of soil over the soil under secondary tillage at the 0 - 10 cm depth, while the plots under primary tillage had an increase of about 16%. Christopher et.al (2006) reported that soils with high unconfined compressive strength offer the most resistance to penetration. The shear strength was highest at the 20 - 30 cm depth with values of 37.43 kPa, 32.33 kPa and 30.46 kPa in the no-till, primary and secondary tillage plots, respectively. This agrees with the findings of Fasinmirin and Adesigbin (2011), who reported that shear strength increased down the soil profile, especially in the sub-soil layer.

Table 10: Unconfined compressive strength for soils under different tillage systems

Sample code	Depth (cm)	Unconfined Compressive Strength (kPa)
No till	0 - 10	69.06
	10 - 20	71.59
	20 - 30	74.87
Primary tillage	0 - 10	58.00
	10 - 20	61.58
	20 - 30	64.66
Secondary tillage	0 - 10	55.48
	10 - 20	58.20
	20 - 30	60.91

Table 11: Shear Strength of soils under different tillage systems

Sample code	Depth (cm)	Shear Strength (kPa)
No till	0 - 10	34.53
	10 - 20	35.80
	20 - 30	37.43
Primary tillage	0 - 10	29.00
	10 - 20	30.79
	20 - 30	32.33
Secondary tillage	0 - 10	27.74
	10 - 20	29.10
	20 - 30	30.46

4. CONCLUSION

The effect of different tillage practices (no till, primary and secondary) on the physical and mechanical properties of a typical Nigerian Alfisol was studied. Bulk density was highest in the no-till plot. This resulted in high unconfined compressive strength and consequently high shear strength in the no-till plot. The bulk density of the ploughed and harrowed plot was reduced due to the loosening action of tillage implements. Organic carbon of the ploughed and harrowed plot was higher than the ploughed plot due to further pulverization of the soil which re-distributed the carbon. Organic carbon content on the no-till plot was higher by about 50 % increase when compared with plots under primary tillage. The tillage operation resulted in improved aeration in the plots under primary and secondary tillage systems with increased total porosity, micro and macro porosity comparatively with the no-till plots.

REFERENCES

Ann, M. Clain, J. and Jeff, J. 2005. Basic Soil Properties, Soil and Water Management Module I

Bengough AG, Mullins CE, 1990. Mechanical impedance to root growth: a review of experimental techniques and root growth responses. Journal of Soil Sciences 41. 341-358.

Blake, G.R., Hartge, K.H., 1986. Bulk density. In: A. Klute (Ed.). Methods of Soil Analysis. Part I. Physical and Mineralogical Methods. 2nd. Ed., Agronomy No. 9 (part I). ASA-SSSA. Madison, Wisconsin, USA, 363-375.

Bouyoucos, G. J., 1962. Hydrometer methods improved for making particle size analysis of soils. Soil Science Society of America Proceeding 26: 464-465.

Brady, N.C. 1990. The Nature and Properties of Soils. New York: Macmillian. 621 pp.

Carter, M.R. 1996. Characterization of soil physical properties and organic matter under long term primary tillage in a humid climate. Soil and Tillage 38, pp 251 – 263

Catriona, M.K. Gardner, K.B. Laryea and P.W. Unger, 1999. Soil physical constraints to plant growth and crop production. Land And Water Development Division Food And Agriculture Organization Of The United Nations Rome, pp 58

Connolly, R.D., Freebairn, D.M., Bridge, B.J., 1997. Change in infiltration characteristics associated with cultivation history of soils in south-eastern Queensland. Aust. J. Soil Res. 35, 1341–1358.

Dingman SL. 1994. Physical Hydrology. New York: Macmillan. 575 pp.

Edwards J H., Wood, C.W., Thurlow, D.L. and Ruf, M.E. 1999. Tillage and crop rotation effects on fertility status of a Hapludalf soil. Soil Sci. Soc. Am. J. 56:1577-1582

Entekhabi, D. and K. L. Brubaker, 1995: An analytic approach to modeling land-atmosphere interaction: 2. Stochastic extension, Water Resources Research, 31(3), 633-644

FAO. 2005. The importance of soil organic matter. FAO soils bulletin No. 80. Rome

Food and Agricultural Organization/World Reference Base for Soil Resources. 2006. Aframework for international classification, correlation and communication.

Fasinmirin J.T. and S. Konyeha 2009. Evaluation of some hydraulic characteristics of furrow irrigation system in a cassava Manihot esculenta crantz field. Journal of Applied Irrigation Science. Zeitschrift für Bewässerungswirtschaft, 44. Jahrg., Heft, 1 /2009, ISSN 0049-8602 Vol 44, No 1, pp71 – 84.

Fasinmirin, J.T., Adesigbin, A.J. 2012. Degree of Compaction and Compression Strength of Nigerian Alfisol Under Tilled Condition and Different Machinery Traffic Passes. Int. J. Agric and Biol. Eng. Vol. 5 No 2. pp 34-41.

Fasinmirin, J.T and Olorunfemi, I.E. 2012 Copmarison of Hydraulic Conductivity of Soils of the forest Vegetative Zone of Nigeria. App. Trop. Agric., Vol. 17, Nos. 1, PP 64 – 77. ISSN: 1118 - 6712

Francis, C.F., Thomes, J. B., Romero Diaz, A., Lopez Bermudez, F. & Fisher, G. C. 1986. Topographic control of soil moisture, vegetation cover and land degradation in moisture stressed Mediterranean environment. Catena, 13: 211–225

Fu, B. and Chen, L. 2000. Agricultural landscape spatial pattern analysis in the semi-arid hill area of the Loess Plateau, China. Journal of Arid Environments, 44: 291–303.

Fu, B. and Gulinck, H. 1994. Land evaluation in area of severe erosion: the Loess Plateau of China. Land Degradation and Rehabilitation, 5: 33–40.

Fu, B., Gulinck, H. and Masum, M.Z. 1994. Loess erosion in relation to land-use changes in the Ganspoel catchment, central Belgium. Land Degradation and Rehabilitation, 5: 261–270.

Hakansson, I., Voorhees, W.B., Riley, H., 1988. Vehicle and Wheel factors infuencing soil compaction and crop response in different traffic regimes. Soil Tillage Research 11, 239– 282

Halfmann, D. M., 2005. Management system effects on water infiltration and soil physical properties. M. Sc Thesis. Texas Tech University, Faculty of Soil science. Texas (Unpubl.) pp 9-11, 35, 85, 92

Hawley, M.E., Jackson, T.J. & McCuen, R.H. 1983. Surface soil moisture on small agricultural watersheds. Journal of Hydrology, 62: 179–200.

Horn, R., 1986. Aus wirkung unterschiedlicher bodenbearbeitung auf die mecanische belastbarkeit von Ackerbo¨den. Z. Pflanzenerna¨hrung Bodenkunde 149, 9–18 (in German with English summary

Jin Ke, Wim M. Cornelis, Wouter Schiettecatte, Junjie Lu, Yuqing Yao, Huijun Wu, Donald Gabriels, Stefaan De Neve, Dianxiong Cai, Jiyun Jin, Roger Hartmann., 2007. Effects of different management practices on the soil - water balance and crop yield for improved dryland farming in the Chinese Loess Plateau.,Soil and Tillage Research 96., pp 131 – 144

Kitanidis P.K and Bras R.L 1999 red time forecasting with a conceptual hydrological model 2. Application and results. Water resource journal 16 page 1034-1044

Miller, R.E., J. Hazard, and J. Howes. 2001. Precision, Accuracy, and Efficiency of Four Tools for Measuring Soil Bulk Density or Strength. USDA Forest Service Pacific Northwest ResearchStation Gen. Tech Report PNW-RP-532, April 2001

Mohanty B.P., Skaggs T.H., Famiglientti J.S. 2000. Analysis and mapping of field scale soil moisture variability using high resolution ground based data in the southern great plains page 17-29

Mulholland. B. and Fullen, M.A. 1991. Cattle trampling and soil compaction on loamy sands. Soil Use and Management 4: 189-192

Olorunfemi, I. E. and Fasinmirin, J. T., 2011. Hydraulic conductivity and Infiltration of Soils of Tropical Rainforest Climate of Nigeria. Proceedings of the Environmental Management Conference (EMC), Federal University of Agriculture, Abeokuta, Nigeria.2011. (1) pg 397 – 413.

Osunbitan, J.A., Oyedele, D.J., Adekalu, K.O., 2005. Tillage effects on bulk density, hydraulic conductivity and strength of a loamy sand soil in southwestern Nigeria. Soil Till. Res. 82, 57–64

Qiu, Y., Fu, B., WangA , J., & Chen, L. 2001. Spatial variability of soil moisture content and its relation to environmental indices in a semi-arid gully catchment of the Loess Plateau, China Journal of Arid Environments (2001) 49: 723–750

Reeb J.E. 1999. Errors incurred during the measurement of the volumetric moisture content by the weight. Pp 30.

Reichert, J.M.; Suzuki, L.E.A.S.; Reinert, D.J.; Horn, R. & Hakansson, I. 2009. Reference bulk density and critical degree-of-compaction for no-till crop production in subtropical highly weathered soils. Soil Till. Res., 102:242- 254, 2009.

Reynolds, S.G. 1970c. The gravimetric method of soil moisture determination, III: An examination of factors influencing soil moisture variability. Journal of Hydrology, 11: 288–300

Rodriguez-Iturbe, I. 2000. Ecohydrology: A hydrologic perspective of climate– soil – vegetation dynamics, Water Resour. Res., 36(1), 3 –10.

Shafiq, M., Hassan, A., Ahmad, S., 1994. Soil physical properties as influenced by induced compaction under laboratory and field conditions. Soil Tillage Res. 29, 13–22.

Soane, B.D., Blackwell, P.S., Dickson, J.W., Painter, D.J., 1981. Compaction by agricultural vehicles: a review. 1. Soil and wheel characteristics. Soil Till. Res. 1, 207–237.

Soil Survey Staff. 1999. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436.

Suzuki L.E.A.S., Reinert D.J., Reichert J.M. 1994. Degree of compactness for no-tillage soils: reference bulk density and effects on soil physical properties and soybean yield page 2

Vereecken, H., Feyen, J., Maes, J., Darius, P., 1989. Estimating the soil moisture retention characteristic from texture, bulk density and carbon content. Soil Sci. 148, 389-403

Warren, S.G., C.J. Hahn, J. London, R.M. Chervin and R.L. Jenne, 1986: Global distribution of total cloud cover and cloud type amounts over land. NCAR Tech. Note, NCAR/TN-273+STR, 29 pp. + 200 maps.

Western, A.W., Grayson, R. B., and ¨Oschl, G. B., 2002. Scaling of Soil moisture: A Hydrologic Perspective. Annu. Rev. Earth Planet. Sci. 2002. 30:149–80 DOI: 10.1146/annurev.earth.30.091201.140434

White, R.E. 1997. Principles and Practice of Soil Science. The Soil as a Natural Resource. Oxford, UK: Blackwell Sci. 348 pp.

Wolkowski, R., and lowery, B. 2008. Soil Compaction: causes, concerns and cures (A3367).

PERFORMANCE EVALUATION OF A SLIDER CRANK BASED SUGAR CANE JUICE EXTRACTOR

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ABSTRACT

The performance evaluation of slider crank based sugarcane juice extractor was undertaken. The machine was evaluated using five grating speeds: 602, 765, 791, 1176 and 1520 rpm, to determine the machine's grating capacity, grating efficiency, extraction capacity, extraction efficiency, juice yield, fibre content, moisture content of juice after extraction, machine losses and brix value. Each speed sample was tested 243 times using three different operators for the overall operation based on a 3x3x3x3x3 factorial experiment in a split-split-split-split-plot design with three replicates. Average values of measured parameters obtained from the five grating speeds were used in plotting series of graph in order to establish the relationship that exist between the measured parameters and speed of operation. A number of predictive equations were developed during the course of this study from the graphs obtained using Excel Microsoft package to establish their relationship theoretically. The nine measured parameters produced a graph trend captured by a polynomial of order 3. Predictive equations were established to describe the influence of the operating speed on the grating capacity, grating efficiency, extraction capacity, extraction efficiency, juice yield, fibre content, moisture content of juice after extraction, machine losses and brix value. These predictive equations are essential in determination of appropriate operating parameters for the sugarcane juice extractor.

KEYWORDS: Sugar, extractor, cane, machine, juice, efficiency.

1. INTRODUCTION

Sugarcane is one of the most important crops from which sugar is produced. According to Naidu (1998) and Fry (1997), sugarcane accounts for 68% of the total world's sugar while the remaining 38% is produced from beet known as the second crop which sugar is conventionally obtained. Milling of sugarcane is an operation that is crucial and necessary for making sugarcane juice available for its various applications. The commonly available sugarcane juice extractors require high energy with sophisticated mechanism (Olaoye 2008). Some of these commonly available sugarcane juice extractors are for industrial applications which are out of reach of small scale and rural farmers who are deeply involved in the processing of cane juice into ethanol, brown sugar and other related products at small scale level. Therefore the development of small scale sugarcane juice extractor should be encouraged in Nigeria to meet the needs of the small scale farmers who cannot afford high capacity and complex sugarcane juice extractor.

Olaoye (2011) designed and constructed a motorised sugarcane juice extractor which has both the crushing and extraction units. The machine's crushing unit macerates the sugarcane stem. The crushed canes are passed out through the outlet into the extraction chamber where the extraction of the juice takes place by exerting a certain amount of pressure on the press head. The machine still has a press head for the juice extraction unit that is manually operated. The machine produces coarse macerated sugarcane fibre instead of producing fine macerated sugarcane fibre found suitable for the extraction of sugarcane juice. Likewise the manually operated press head makes the operator of the machine to be tired after a while. The machine was tested with a maximum speed that did not exceed 500 rpm.

Olaoye and Oyelade (2012) developed a sugarcane juice extractor with a slider crank based unit. Performance evaluation was carried out on the machine. The speed, variety of cane stalk, diameter size of cane stalk and loading rate at various levels of operation affects the grating capacity of the machine. The speed of operation of the machine was a major factor that determines the output and efficiency of the machine in the five parameters measured. The variety of cane stalk and diameter size of cane stalk at various levels of operation affects the extraction capacity of the machine and the variety of the cane stalk is a major factor affecting the extraction efficiency of the machine. The variety of cane stalk at various levels of operation affects the moisture content of the cane stalk.

Detailed performance evaluation of the sugarcane juice extractor with a slider crank based unit (Olaoye and Oyelade, 2012) was undertaken. The main objective of this study was to develop predictive equations to describe the influence of the operating speed on the grating capacity, grating efficiency, extraction capacity, extraction efficiency, juice yield, fibre content, moisture content of juice after extraction, machine losses and brix value.

2. MATERIALS AND METHODS

2.1 Machine Description

The machine consists of grating cylinder made of stainless steel, gravimetric and volumetric capacity of the hopper, automated spring loaded vertical press as pressure vessel, belt and pulley drive, electric motor, speed reduction gear electric motor, idler pulley and slider crank device. (Fig. 1).

Fig. 1: Pictorial view of the modified machine

2.2 Principle of Operation

Feeding of freshly harvested sugarcane stalks into the machine takes place at the machine’s hopper. The electric motor is already switched on to provide the crushing force needed for the maceration of the cane stalks at the macerating/grating cylinder carrying the central shaft. Arranged on the central shaft are sets of pyramid sharp shaped teethes that causes the crushing action. The crushed cane otherwise called wet baggasse is then channeled to the extraction chamber through the connection provided to the grating cylinder at the bottom.

At the extraction section of the machine the crushed or macerated canes are pressed against a perforated metallic plate by the press head been powered by a slider crank assisted unit. The extracted juice is collected through a tap provided at the bottom of the extraction chamber.

2.3 Predictive Equation

Average values of measured parameters obtained from the five grating speeds were used in plotting series of graph in order to establish the relationship that exist between the measured parameters and speed of operation. A number of predictive equations were developed during the course of this study from the graphs obtained using Excel Microsoft package to establish their relationship theoretically.

2.4 Performance Evaluation of the Machine

2.4.1 Test Materials

Freshly harvested sugarcane stalks from the Unilorin Sugar Research Institute farm were used for testing the machine. Factors involved in the test were three levels each of variety of cane stalk, feed rates, loading rate and diameter of cane stalks. These factors were combined using five grating speeds of 602, 765,791, 1176 and 1520 rpm under no load condition to test the machine in evaluating the performance of the machine The grating speeds used were established using a tachometer manufactured by Venture Smiths Industries Instrument Company with model number HT 330 T 42 and Serial number 8103779.

2.4.2 Grating Efficiency

Grating efficiency is the amount of sugarcane stalk grated per total amount of sugarcane stalk fed into the machine. The mathematical expression for grating efficiency as used by Sunmonu, 2007 is given as:

$$\text{Grating Efficiency (\%)} = \frac{M_2 - M_1}{M_2} X\ 100\% \qquad (1)$$

Where: M_2 = Total mass fed into the machine (g); M_1 = Total mass ungrated (g)

2.4.3 Moisture Content

The moisture or juice content of sugarcane stalk is the amount of moisture content in percent contained in a given weight of stalk. This can be obtained either ways. Either in its dry basis form or it could be in its wet basis form.

For the purpose of this experiment the wet basis form is needed. This can be expressed as follows:

$$\text{Moisture content (\%); Mcdb} = \frac{M_w}{M_d} X\ 100\% \qquad (2)$$

$$\text{or Mcwb} = \frac{M_w}{M_{d} + M_w} X\ 100\% \qquad (3)$$

Where: Mcdb = Moisture content on dry basis; Mcwb = Moisture content on wet basis; M_w= Mass of moisture in the cane (g); M_d = Mass of bone dried sugar cane (g).

2.4.4 Extraction Efficiency

Extraction efficiency is the ratio of the percentage of weight of juice extracted to the product of weight of feed and moisture content of the cane. This was expressed mathematically by Tressler and Joslyn (1961) as follows:

$$\text{Extraction Efficiency (\%)} = \frac{J_e}{X.F} X\ 100\% \qquad (4)$$

Where: J_e = Weight of extracted juice (g); X = Juice content of the cane (%); F = Weight of feed (g).

The juice content of each of the cane samples used for the test was established by summing up the percentage of juice yield with the percentage of juice yield contained in the fibre content. This percentage of juice yield contained in the fibre content is a function of the fibre's moisture content in wet basis after extraction process has taken place.

2.4.5 Juice Yield

Juice yield can be defined as the ratio of the weight of juice extracted to the total weight of wet baggasse. All expressed in percent. This can be expressed mathematically by Tressler and Joslyn (1961) as follows:

$$\text{Juice Yield (\%)} = \frac{J_e}{J_e + W_r} X\ 100\% \qquad (5)$$

Where: J_e = Weight of extracted juice (g); W_r = Weight of residue (g).

2.4.6 Fibre Content

Fibre content is the residue left after squeezing out the juice from the macerated cane. This can be expressed mathematically as:

$$\text{Fibre Content (\%)} = \frac{W_r}{J_e + W_r} X\ 100\% \qquad (6)$$

2.4.7 Grating Capacity

Grating capacity can be defined as the amount of cane grated or macerated per unit time. This can be expressed mathematically as:

$$\text{Grating Capacity (kg/hr)} = \frac{M_3}{T_1} \qquad (7)$$

Where: M_3 = Weight of grated cane (g); T_1 = Time taken to grate (sec).

2.4.8 Extraction Capacity

Extraction capacity can be defined as the amount of juice extracted per unit time. This can be expressed mathematically as:

$$\text{Extraction Capacity (kg/hr)} = \frac{M_4}{T_2} \qquad (8)$$

Where: M_4 = Weight of juice extracted (g); T_2 = Time taken to extract (sec).

2.4.9 Machine Losses

This is the total losses encounter during the grating and extraction operation of the machine. This can be expressed mathematically as:

Machine Losses (%) = Grating Loss (%) + Extraction Loss (%)

Where: grating loss can be simplified further as:

$$\text{Grating Loss (\%)} = \frac{M_2 - M_5}{M_2} X\ 100\% \qquad (9)$$

or

$$\frac{M_6}{M_2} X\ 100\% \qquad (10)$$

Where: M_2 = Total mass fed into the machine (g); M_5 = Weight of collected macerated sugarcane at the extraction chamber before extraction (g). M_6 = Total mass ungrated cane (g) + Mass of grated cane (g) that did not fall into the extraction chamber during the process of grating (g).

Extraction Loss is simplified further using the expression given by Tressler and Joslyn (1961) as follows:

$$\text{Extraction Loss (\%)} = 100\ \frac{Q_f - (Q_p + Q_r)}{Q_f} \qquad (11)$$

Where: Q_f = Weight of collected macerated sugarcane at the extraction chamber before extraction (g); Q_p = Weight of extracted juice (g); Q_r = Residue left after the juice have been extracted (g).

2.4.10 Brix Value (%)

The brix value of the extracted juice was determined directly using a brix refractrometer manufactured by Bellingham Stanles Limited, England.

3. RESULTS AND DISCUSSION

3.1 Results

Results of the test conducted on the slider crank sugarcane juice extractor are presented in Table 1.

Table 1. Means for Different Parameters Measured at Different Speeds

Measured parameters	Speed (rpm)				
	602	765	791	1176	1520
Grating Capacity (kg/hr)	14.64	15.78	15.71	19.50	27.74
Grating Efficiency (%)	97.30	97.46	97.37	97.27	97.37
Extraction Capacity (kg/hr)	300.76	305.99	317.27	353.34	305.30
Extraction Efficiency (%)	40.21	41.01	44.02	46.84	41.04
Juice Yield (%)	31.08	31.59	32.73	36.41	31.47
Fibre Content (%)	68.84	68.44	67.36	63.59	68.53
Machine Losses (%)	12.34	12.22	12.11	12.12	11.98
Moisture Content (%)	61.05	60.42	60.80	60.66	60.83
Brix (%)	22.81	22.43	22.77	23.41	22.89

3.2 Grating Capacity

The results obtained from the measured samples for grating capacity during the evaluation of the machine showed that the highest mean grating capacity of 27.74 kg/hr was obtained using a grating speed of 1520 rpm. The graph of mean grating capacity versus speed of operation is presented in Fig. 2. It can be deduced from Fig. 2 that mean grating capacity increases with speed of operation. The graph was also captured in a polynomial of order 3 with a predictive equation of $y = 1.52e^{-08}x^3 – 3.3e^{-05}x^2 + 0.0303x + 5.155$ having a 'r' value which is approximately 1, which indicates that there exist a very strong relationship between grating capacity and speed of operation. It might be of interest to us to note that values obtained through the use of the predictive equation as shown in the predicted graph showed that mean grating capacity increases directly with speed of operation with no sign of abnormality as observed along the graph trend presented in the observed graph trend where there was a slight drop difference in the values obtained for grating capacity from speed of operation of 765 to 791 rpm as shown in Fig. 2.

3.3 Grating Efficiency

The results obtained from the measured samples for grating efficiency during the evaluation of the machine showed that the highest mean grating efficiency of 97.46% was obtained using a grating speed of 765 rpm. Fig. 3 shows the graph of mean grating efficiency versus speed of operation. It can be deduced from Fig. 3 that mean grating efficiency increases initially from speed of 602 rpm to speed of 765 rpm and then decreases from speed of 765 rpm to speed of 1176 rpm before it finally increased from speed of 1176 rpm to speed of 1520 rpm. The graph was also captured in a polynomial of order 3 with a predictive equation of $y = 2.86e^{-09}x^3 – 9.1e^{-06}x^2 + 9.011e^{-04}x + 94.536$ having a 'r' value of 0.89, which indicates that there exist a strong relationship between grating efficiency and speed of operation.

3.4 Extraction Capacity

The results obtained from the measured samples for extraction capacity during the evaluation of the machine showed that the highest mean extraction capacity of 353.34 kg/hr was obtained using a grating speed of 1176 rpm. Fig. 4 shows the graph of mean extraction capacity versus speed of operation. It can be deduced from Fig. 4 that mean extraction capacity increased from speed of 602 rpm to speed of 1176 rpm and starts to descend from speed of 1176 rpm to speed of 1520 rpm. This increase in the mean of extraction capacity as speed of operation increases may be as a result of more cane stalks are macerated as shown in Fig. 2. But in the case of the decrease in mean value of extraction capacity noticed in the grating speed of 1176 to 1520 rpm may be due to diminishing return. The graph was also captured in a polynomial of order 3 with a predictive equation of $y = -4.4e^{-07}x^3 + 1.19e^{-03}x^2 - 0.94976x + 536.299$ having a ‘r’ value of 0.99, which indicates that there exist a very strong relationship between extraction capacity and speed of operation.

3.5 Extraction Efficiency

The results obtained from the measured samples for extraction efficiency during the evaluation of the machine showed that the highest mean extraction efficiency of 46.84% was obtained using a grating speed of 1176 rpm. Fig. 5 shows the graph of mean extraction efficiency versus speed of operation. It can be deduced from Fig. 5 that mean extraction efficiency also followed the same trend with extraction capacity. This is to say that their graph patterns are the same. The graph was also captured in a polynomial of order 3 with a predictive equation of $y = -3.5e^{-08}x^3 + 8.55e^{-05}x^2 – 5.321e^{-02}x + 48.874$ having a ‘r’ value of 0.94, which indicates that there exist a very strong relationship between extraction efficiency and speed of operation.

3.6 Juice Yield

The results obtained from the measured samples for juice yield during the evaluation of the machine showed that the highest mean juice yield of 36.41% was obtained using a grating speed of 1176 rpm. Fig. 6 shows the graph of mean juice yield versus speed of operation. It can be deduced from Fig. 6 that mean juice yield also followed the same trend with extraction capacity and extraction efficiency implying that their graph patterns are the same. The graph was also captured in a polynomial of order 3 with a predictive equation of $y = -4.5e^{-08}x^3 + 1.23e^{-04}x^2 – 9.835e^{-02}x + 55.578$ having a ‘r’ value of 0.99, which indicates that there exist a very strong relationship between juice yield and speed of operation.

3.7 Fibre Content

The results obtained from the measured samples for fibre content during the evaluation of the machine showed that the highest mean fibre content of 68.84% was obtained using a grating speed of 602 rpm. Fig. 7 shows the graph of mean fibre content versus speed of operation. It can be deduced from Fig. 7 that mean fibre content followed opposite trend with extraction capacity, extraction efficiency and juice yield. This is to say that mean fibre content decreased from speed of 602 rpm to speed of 1176 rpm and increased from speed of 1176 rpm to speed of 1520 rpm. This decrease in the mean of fibre content as speed of operation increases may be as a result of more juice are extracted from the macerated cane stalks as shown in Fig. 2. But in the case of grating speed of 1520 rpm it may be an unusual situation which may be due to diminishing return. The graph was also captured in a polynomial of order 3 with a predictive equation of $y = 4.71e^{-08}x^3 - 1.3e^{-04}x^2 + 0.105751x + 41.939$ having a ‘r’ value of 0.99, which indicates that there exist a very strong relationship between fibre content and speed of operation.

In addition to this, the theory of juice yield and fibre content shows that the relationship between juice yield and fibre content are inversely proportional to each other. This also explains why the graph produced in this two occasions were inversely proportional to each other as shown in Figures 6 and 7.

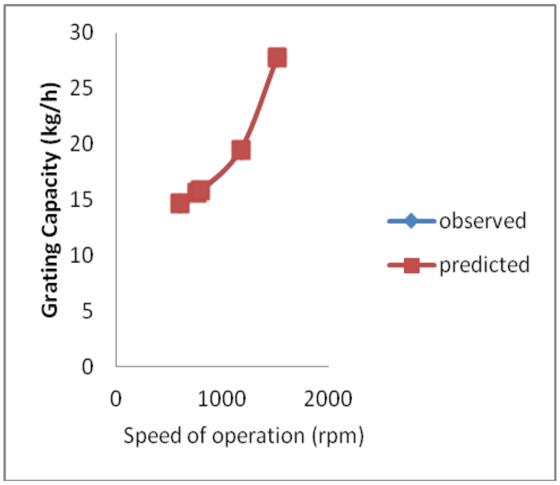

Fig. 2 Graph of Grating Capacity versus speed of operation

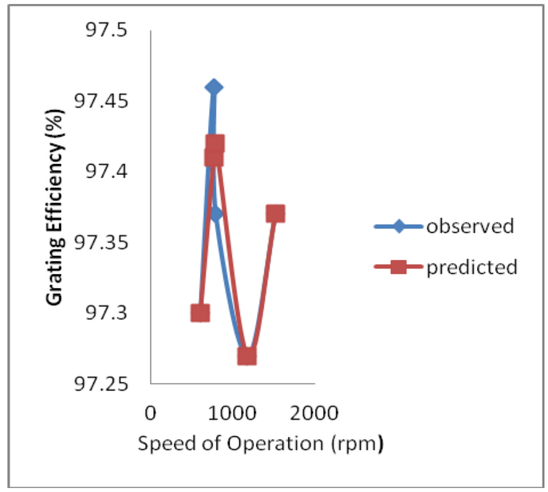

Fig. 3 Graph of Grating Efficiency versus speed of operration

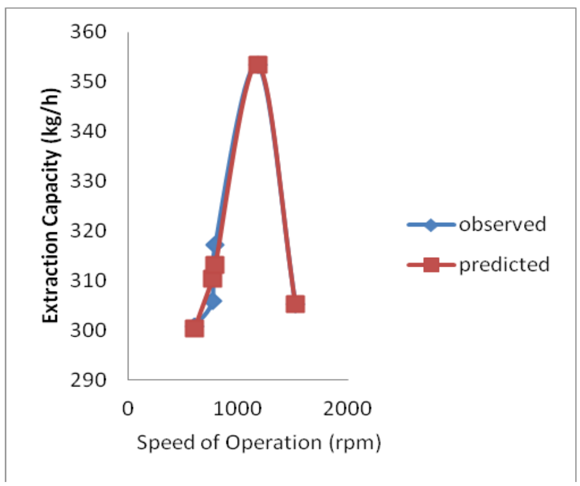

Fig. 4 Graph of Extraction Capacity versus speed of operation

3.8 Machine Losses

The results obtained from the measured samples for machine losses during the evaluation of the machine, the highest mean machine loss value of 12.34% was obtained using a grating speed of 602 rpm. Fig. 8 shows the graph of mean machine losses versus speed of operation. It can be deduced from Fig. 8 that mean machine losses decreases with increase in speed of operation i.e. from 602 rpm to 1520 rpm. The little difference observed in speeds 791 and 1176 rpm may be unusual. The above statement is true because at lower grating speed the grating capacity is low as shown in Fig. 2 which results in many ungrated cane stalk leading to high losses during grating. The graph was also captured in a polynomial of order 3 with a predictive equation of $y = -2.1e^{-09}x^3 + 7.07e^{-06}x^2 – 7.7e^{-03}x + 14.886$ having a 'r' value of 0.97, which indicates that there exist a very strong relationship between machine losses and speed of operation. It might be of interest to us to note that values obtained through the use of the predictive equation as shown in the predicted graph showed that mean machine losses decreases as speed of operation increases with no abnormality witnessed along the graph trend as noticed in the observed graph values (Fig. 8).

3.9 Moisture Content of Macerated Cane after Extraction Process

The results obtained from the measured samples for moisture content during the evaluation of the machine showed that the highest mean moisture content value of 61.05% was obtained using a grating speed of 602 rpm. Fig. 9 shows the graph of mean moisture content versus speed of operation. It can be deduced from Fig. 9 that mean moisture content decreased from speed of operation of 602 rpm to 765 rpm. Which later increased from speed of 765 rpm to 791 rpm and then dropped from speed of 791 rpm to 1176 rpm and finally increased from speed of 1176 rpm to speed of 1520 rpm. The irregular graph trend produced in this graph may be as a result of the individuals differences observed in the varieties of cane stalks used for the test. The graph was also captured in a polynomial of order 3 with a predictive equation of $y = -4.3e^{-09}x^3 + 1.54e^{-05}x^2 – 1.742e^{-02}x + 66.888$ having a 'r' value of 0.78, which indicates that there exist a strong relationship between moisture content of macerated cane after extraction process and speed of operation.

3.10 Brix Value

The results obtained from the measured samples for brix value during the evaluation of the machine showed that the highest mean brix value of 23.41% was obtained using a grating speed of 1176 rpm. Fig. 10 shows the graph of mean brix value versus speed of operation. It can be deduced from Fig. 10 that mean brix value decreased from speed of operation of 602 rpm to 765 rpm. Which later increased from speed of 765 rpm to 1176 rpm and then dropped from speed of 1176 rpm to 1520 rpm. This graph indicates that sugar rupturing decreased from speed of 602 rpm to 765 rpm and then increased from speed of 765 rpm to 1176 rpm before it finally dropped from speed of 1176 rpm to speed of 1520 rpm. This implies that more sugar were ruptured using a grating speed of 1176 rpm. The graph was also captured in a polynomial of order 3 with a predictive equation of $y = -1.1e^{-08}x^3 + 3.42e^{-05}x^2 – 3.217e^{-02}x + 32.218$ having a 'r' value of 0.95, which indicates that there exist a very strong relationship between brix value and speed of operation.

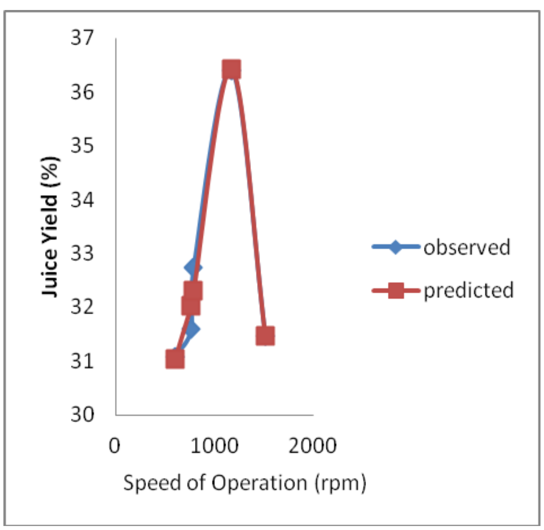

Fig. 5 Graph of Extraction Efficiency versus speed of operation

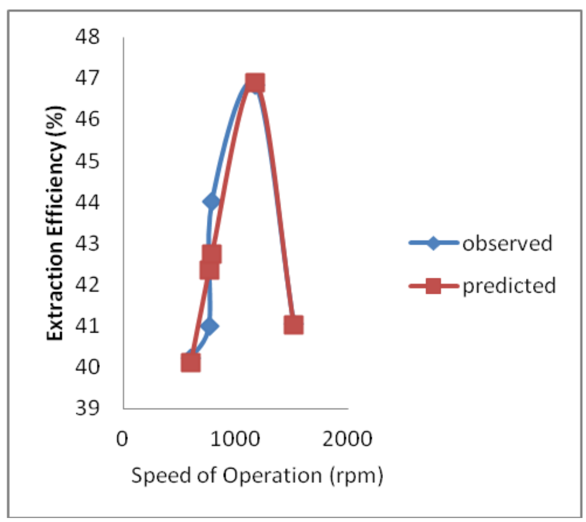

Fig. 6 Graph of Juice yield versus speed of operation

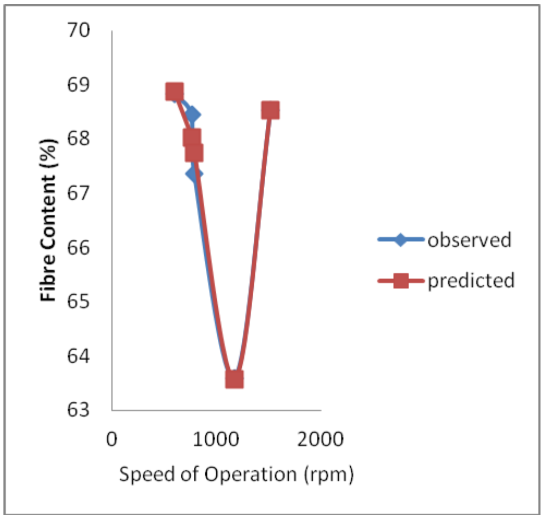

Fig. 7. Graph of Fibre content versus speed of operation

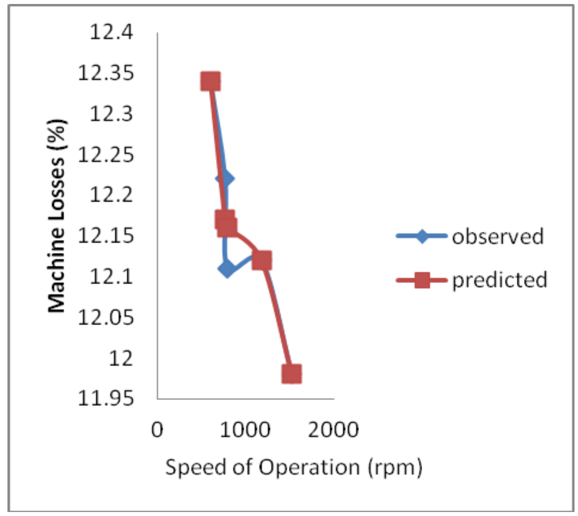

Fig. 8 Graph of Machine losses versus speed of operation

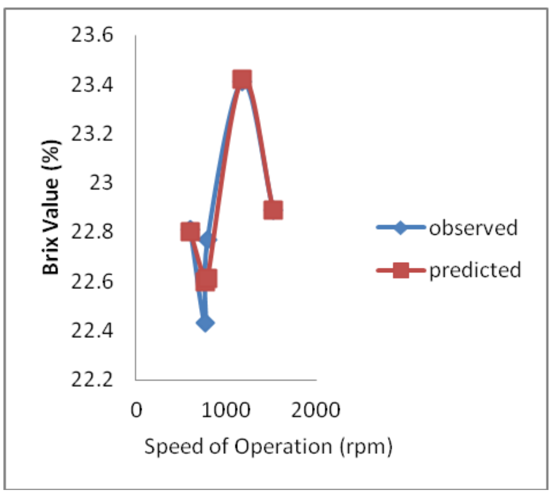

Fig. 9 Graph of Moisture Content after extraction versus speed of operation

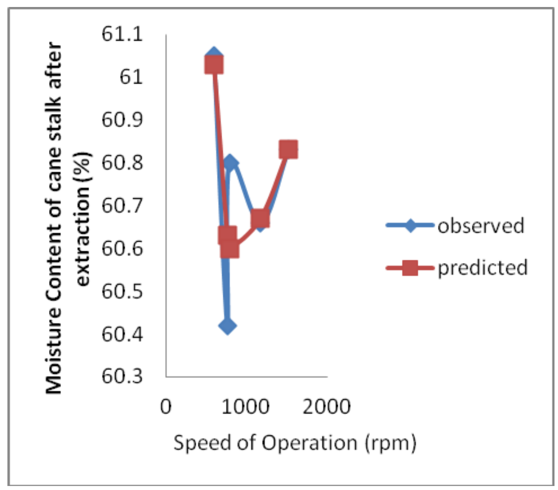

Fig. 10. Graph of Brix value versus speed of operation

4. CONCLUSION

A number of predictive equations were obtained during the test for the parameters measured. The predictive equations generated from Excel package were as good as the observed values obtained during test which resulted from the various observed values of “r” generated from the graphs which makes the machine operation easy for the operator to determine at what speed of machine operation would certainly generated a certain amount of value without subjecting the machine to much stress. The predictive equations generated for this machine will also serve as a tool for judicious application of the machine and to increase the life span of the machine.

REFERENCES

Fry, J. 1997. Global Perspective of the Sugar Industry. In: Intensive Sugarcane Production: Meeting the Challenges beyond 2000. Proceedings of the sugar 2000 Symposium. Brisbane, Australia, 20 – 23 August 1996. Pp 1 – 16.

Naidu, K. M. 1998. Potential Yield in Sugarcane and its Utilization through varietal improvement Pp. 1 – 17In: Sugarcane varietal Improvement. Proceedings of the International Symposium on Sugarcane Varietal Improvement. Sugarcane breeding Institute, Combatore, India.

Olaoye, J. O. 2008. Partial Mechanization of Sugarcane Juice Extraction Process. UniIlorin Sugar Research Institute. End of Session Report 2008/2009. Page 21.

Olaoye, J. O. 2011, Development of a Sugarcane Juice Extractor for Small Scale Industries. Journal of Agricultural Technology. Available online http://www.ijat-aatsea.com. ISSN 1686-9141. Vol. 7(4): 931-944.

Olaoye, J. O. and A. O. Oyelade. 2012, Synthesis and Analysis of a Slider Crank Linkages in Sugarcane Juice Extractor. Global Journal of Pure & Applied Science and Technology (GJPAST), http://gjpast.com/Vol2Iss1.php ISSN: 2249 – 7188. 2(1): 10 – 26.

Sunmonu, S. E. 2007. Modification and Performance Evaluation of a Motorized Sugarcane Juice Extractor. Unpublished B.Eng. Project Report. Department of Agricultural Engineering, University of Ilorin, Ilorin.

Tressler, D. K and Joslyn, M. A. 1961. Fruit and Vegetable Juice Technology. AVI Publishing Company INC., West Port, Connecticut. Pp. 155 - 158.

QUALITY OPTIMIZATION OF BREAD BY ADDITION OF SELECTED MUSHROOM VARIETIES AND COMPOSITE FLOURS (PLANTAIN/WHEAT, COWPEA/WHEAT BLENDS)

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ABSTRACT

The feasibility of adding mushrooms in a partially replaced wheat flour, with plantain and cowpea flour in bread were investigated. The physical analysis, proximate analysis and sensory evaluation of the samples were determined. Two varieties of mushrooms were processed into powdered form. Matured unripe plantain *(Musa paradisiacal)* and cowpea *(Vigna unguiculata)* were also processed into flour. Wheat flour was substituted by plantain and cowpea flour at 20 and 30% levels. 5g, 10g and 15g of mushrooms A (Shiitake) and B (Marchella) were added for each of the substituted composite flour during production of the composite breads and then baked in an oven at 180^{o}C.The loaves were then subjected to physical and chemical analysis. The volume of the samples ranged from 29.19cm^3 to 35.34cm^3, while density ranged from 5.39g/cm^3 to 7.33g/cm^3. Crude protein ranged from 10.77 to 17.20%, fat content varied from 5.08 to 6.96%, while ash contents increase from 2.17 to 3.89%. Crude fibre contents ranged from 1.10 to 1.53%, carbohydrate content varied from 71.12% to 97.73%. Moisture contents increased from 31.63 to 36.58%. Significant difference were obtained in the sensory attributes of taste, aroma and texture ($P<0.05$), however, the whole wheat bread was more accepted in all tested attributes.

KEYWORDS*:* Composite bread, cowpea, mushroom, plantain, sensory attributes*.*

1. INTRODUCTION

The word mushroom derived from the French “Mousseron”, a term that includes edible mushrooms as well as poisonous varieties. Mushrooms are actually the fruits of fungus. The fungus itself is simply a net of threadlike fibre, called a mycelium, growing in soil, wood or decaying matter, (Ogundan, 1982). Mushrooms have been food supplement in various cultures and they are cultivated and eaten for their edibility and delicacy. They fall between the best vegetables and animal protein sources. Mushrooms are considered as source of protein, vitamins, fats, carbohydrates, amino acids and mineral (Jiskani, 2001). Thus when added as an adjunct in bread production would enhance protein quality and overall nutritive value. In villages where mushrooms abound, edible varieties are recognized by inspection but where there is any doubt, the mushrooms are first fed to chicken and/or other animal and if they are refused by the animals the mushrooms are assumed toxic. Mushrooms are the best non-animal source of vitamin D and have high levels of the vitamins niacin, thiamin (B_1) and riboflavin (B_2). Up to 70 percent of the ash content of mushrooms consists of minerals, notably potassium (Ogundan, 1982).

Bread is an important staple food, the cost of which is highly increasing in the developing countries including Nigeria, due to importation of wheat, high cost of additives, etc. Although bread is prepared by baking a dough of flour, water, salt and yeast, which are the basic ingredients, bread may also contain a range of other ingredients such as milk, sugar, egg, margarine, improver, preservatives etc. (Edema *et al*, 2005). The application of edible mushroom which is cheaper would help to replace a portion of some additives. Such as egg-yellow, bread preservatives etc. resulting in a price reduction of the bread.

Due to high cost, geographical scarcity and high demand of wheat flour, efforts have been made to promote the use of composite flours in which flour from locally grown crops and high protein seeds replace a portion of wheat flour for use in bread making, thereby decreasing the demand for imported wheat and producing protein enriched bread. Nigeria and most developing countries are largest importers of American wheat (David *et al*, 2006). This implies that these countries are totally dependent on foreign country for their bread production, therefore, the use of plantain, cowpea *(Vigna unguiculata)* and other indigenous flour for production of bread would help to lower the dependency of developing nations on bread production. According to FAO (2004), over 2.11 million metric tons of plantains are produced in Nigeria annually. However, about 35%-60% post harvest losses of plantain *(Musa parasiaca)*, had been reported and attributed to lack of appropriate technologies for food processing.

Although, production of composite bread has been reported by several investigators (Bressani, 1985; Vanez *et al*, 1981; Horsefall *et al*, 2007) but the addition of edible mushroom has not been demonstrated. At present there is high cost and low quality bread in Nigeria and this gives impetus for further research into the use of edible mushrooms and composite flour for bread making. This investigation evaluates the quality of wheat-plantain and wheat-cowpea breads with addition of two varieties of mushrooms (Shiitake/Lentinula Edodes & Marchella).

2. MATERIALS AND METHODS

2.1 Materials

Mature unripe plantain *(Musa Paradisiaca)* and cowpea *(Vigna unguiculata)* were purchased from Akpan Andem Market, Uyo, Akwa Ibom State, Nigeria. The wheat flour as well as sugar, salt, yeast, margarine, powdered milk, improver, preservative and egg were purchased from a baking shop in the same market. Mushrooms were collected from various locations in Nigeria, cleaned and sun-dried to a constant weight. All reagents used were of analytical grade. The baking process and proximate analyses were carried out at Food Science and Technology and Biochemistry Laboratories University of Uyo respectively.

2.2 Methods

Bread were produced using whole wheat and composite flour (wheat-plantain and wheat-cowpea) at 80:20% and 70:30% with addition of 5, 10 and 15g of granulated mushrooms (Shiitake/Lentinuk Edodes and Marchella) per 500g of flour. Both physical and proximate analysis were carried out and later subjected for sensory evaluation.

2.2.1 Preparation of Mushroom Powder

Mushrooms were collected from various locations in Nigeria, cleaned and sun-dried for 3 consecutive days to a constant weight. The dried mushrooms were homogenized using blender and stored in an airtight container at room temperature until used.

Fresh Mushroom
↓
Dressing/Sorting
↓
Cleaning
↓
Sun Drying (3 days)
↓
Grinding (using blender)
↓
Mushroom Powder

Fig. 1: Flow Chart for the Production of Powdered Mushroom

2.2.2 Preparation of Plantain Flour

Five (5) kg of unripe plantain were processed into flour by adopting the method of Kure *et al.*, (1998). Plantain were washed, peeled and sliced to about 5mm diameter using a slicer. The slices were then steamed for 15min to inactivate enzymes. The pulp was drained and dried in a cabinet drier at 60°C for 24 hours, after which it was milled into flour. The flours were screened through a 0.25mm sieve and packed in a sack bag.

Matured Unripe Plantains
↓
Washing
↓
Peeling
↓
Slicing (5mm diameter)
↓
Steam Blanching (for 15min)
↓
Drying (60°C for 24 hours)
↓
Dry Milling
↓
Screening (through 0.25mm aperture)

Fig. 2: Flow Chart for the Production of Plantain Flour

2.2.3 Preparation of Cowpea Flour

A 5kg of cowpea seeds were processed into flour, using the method described by Okaka (1997). The process ensures effective removal of most anti-nutritional factors as well as reducing the raw legume flavor and improves on the texture of the end products.

Cowpea Seed
↓
Sorting/Cleaning
↓
Roasting (until light brown)
↓
Parboiling (10 mins)
↓
Decortications (Testa removal)
↓
Draining
↓
Drying (110°C for 3 hours)
↓
Dry Milling
↓
Screening (through 0.25mm aperture)

Fig. 3: Flow Chart for the Production of Cowpea Flour

2.2.4 Preparation of Composite Flour

Twenty (20) and 30 part by weight of plantain and cowpea flour were intimately mixed with 80 and 70 part by weight of 100% wheat flour to obtain 20 and 30% of plantain-wheat and cowpea-wheat composite flour respectively. They were stored in flour sack in a dried condition for use.

2.2.5 Baking Process

Five hundred (500)g of whole wheat and composite dough were prepared and baked, using straight dough method of mixing specified by Kate, (2007). The dough were scaled to 250g dough pieces, proofed in the laboratory for 11/2 hours at room temperature (about 29^{o}C) and baked at 190^{o}C for 50 minutes.

Table 1. Ingredients used in making Whole Wheat and Composite Bread

	Whole Wheat Bread	Composite Bread
Component	Composition (%)	Composition (%)
Flour	100	100
Yeast	0.2	0.2
Salt	0.07	0.07
Water	5.0	5.0
Sugar	0.5	0.5
Margarine	0.2	0.2
Milk	0.15	0.15
Egg (No)	1	1
Ascorbic Acid	0.025	-
Calcium Propionate	0.025	-
Mush rooms (g)	-	5, 10 and 15

2.3 Proximate Analysis

25 bread samples were analyzed for moisture, crude protein, fat, Ash and carbohydrate contents, using analytical methods recommended by Okon (2005).

2.3.1 Moisture Content Determination

The moisture content of the samples was determined using the method of Okon, (2005). Moisture was determined on 5g of samples, after raising the temperature to 105^{o}C for 3 hours for each subsequent drying till constant weight were obtained in an electric oven.

The loss in weight during drying equals to the moisture content of the samples.

$$\text{Moisture (\%)} = \frac{\text{Loss Weight due to drying}}{\text{Weight Sample taken}} \times \frac{100}{1} \quad (1)$$

$$= \frac{W_2 - W_3}{W_2 - W_3} \times \frac{100}{1}$$

Where, W_1 = Weight of aluminium foil

W_2 = Weight of aluminium foil + sample

W_3 = Final weight after drying

2.3.2 Crude Protein Determination

Protein is the major compound containing Nitrogen in any food sample, so Nitrogen is used as an index of protein term “crude protein”. The Kjeldahl method as described by Onwuka (2005) was used to determine the crude protein on 5g of bread samples. A factor of 6.25 was used in converting nitrogen to protein. This was done by accurately weighing of 5g of the smple into a standard 250ml Kjeldahl flask containing

1.5g $CuSO_4$ and 1.5g Na_2SO_4 as catalyst and 5ml concentrated H_2SO_4. The Kjeldahl flask (digestion) was placed on a heating mantle and was heated gentle to prevent frothing for some hours until a clear bluish solution was obtained. The digested solution was allowed to cool and this was quantitatively transferred to 100ml standard flask and make up to the mark with distilled water.

20ml portion of the digest was pipette into a semi-micro Kjeldahl distillation apparatus and treated with equal volume of 40% NaOH solution. The ammonia evolved was steam distilled into a 100ml conical flask containing 10ml solution of saturated boric acid to which 2 drops indicator (double indicator) had been added.

The tip of the condenser was immersed into the boric acid double indicator solution and then the distillation continued until about 2/3 of the original volume obtained. It was then titrated with 0.2NHCl until a purple-pink end point was observed. A blank determination was also carried out in the similar manner as described above except for the omission of the sample. The crude protein was obtained by multiplying the percentage of Nitrogen content by a factor (6.25).
Crude Protein = % Nitrogen x factor

The basis for Kjeldahl is as follows:

$$\%N\ 6.25 = \frac{(\text{Sample Titre-Blank Titre})\ 0.1 \times 0.04}{\text{Weight of Sample}} \times \frac{100}{20} \times \frac{100 \times \text{Weight of Sample}}{1} \qquad (2)$$

2.3.3 Fat

Fat constitutes a high source of energy (1g fat "fully" oxidized yields, 37.5KJ energy as compared with values of 29.8, 17 and 16kg yielded by equal amount of alcohol (ethanol), protein and carbohydrate respectively) and are needed especially by growing animals hence, their determination in food is important.

The fat content was determined using petroleum ether and soxhlet extraction method as described by Onwuka (2005). The fat value was determined in 5g of bread samples.

$$\text{Fat (\%) (w/w)} = \frac{\text{Weight gain in flask}}{\text{Weight of sample}} \times \frac{100}{1} \qquad (3)$$

$$\text{Fat (\%) (w/w)} = \frac{W_2 - W_1}{\text{Weight of sample}} \times \frac{100}{1}$$

Where:

W_2 = Weight of flask + fat

W_1 = Weight of empty flask only

2.3.4 Ash

The ash content of a biological material is an analytical term for the inorganic residue that remains after the organic matter has been burnt away (Okon, 2005). The value of ash content in any sample is useful in assessing the quality or grading of certain edible materials.

The ash content was determined on 5g of bread samples as described by Okon, (2005).

2.3.5 Crude Fibre

The bulky roughage in foods referred to as the fibre, it is estimated as crude fibre (Okon, 2005). The AOAC (2000) method as described by Okon 2005 was used. The crude fibre was determined on 5g of samples.

2.3.6 Carbohydrate

The ethanol soluble carbohydrate was calculated using estimation by "difference" method as described by Okon (2005). The carbohydrate was given as: % Carbohydrate = 100 – % (Protein + Fat + Fibre + Ash).

2.4 Physical Analysis/Sensory Evaluation

2.4.1 Volume

Loaf volume was measured 50 minutes after loaves were removed from the oven by using the vapeseed displacement method modified by Giami *et al.,* (2004). Briefly, loaf volume was measured by seed displacement using dried garri in place of vapeseed. A box of fixed dimensions (12.00 x 11.50 x 11.85cm) of internal volume 1635cm^3 was put in a tray, half filled with dried garri, shaken vigorously 4 times, they filled till slightly overfilled, so the overspill fell into the tray. The box was shaken again twice, then a straight edge (or rule) was used to press across the top of the box once to give a level surface. The garri was decanted from the box into a receptacle and weighed. The procedure was repeated three times and the mean value for garri weight was noted (Bg). A weighed loaf was placed in the box and weighed garri (1250g) were used to fill the box and leveled off as before. The overspill was weighed and from the weight obtained the weight of garri around the loaf and volume of garri displaced by the loaf were calculated using the following equations.

Garri displaced by loaf (L) = Overspill Weight – 1250g.

$$\text{Volume of loaf (V)} = \frac{L \times 1635\text{cm}^3}{Bg} \quad (4)$$

The density was given by:

$$\text{Density} = M/V \ (\text{g/cm}^3 \text{ or g/ml}) \quad (5)$$

Where:

M = Mass (weight) of the sample(kg)
V = Volume occupied by the sample(g/cm^3)

2.4.2 Sensory Evaluation

Sensory evaluation was performed 4 hours after baking to evaluate loaf taste, crust colour, texture, aroma and general acceptability of the bread samples. The bread samples were sliced into pieces of uniform thickness and served with water. 19 semi-trained panel members were randomly selected from students and staff of the Department of Food Science and Technology to perform the evaluation. Panelists evaluated the bread samples on a 9 point hedonic scale quality analysis with

9 = liked extremely, 8 = liked very much
7 = liked moderately, 6 = liked slightly
5 = neither like nor dislike, 4 = dislike slightly
3 = dislike moderately, 2 = dislike very much and
1 = dislike extremely

3. RESULTS AND DISCUSSION

3.1 Physical Analysis of Bread

Table 2: Effect of complementation with Mushrooms on the Volume of Wheat/Plantain and Wheat/Cowpea Composite Bread.

	5g		**10g**		**15g**		**-**
Samples	A (cm^3)	B(cm^3)	A (cm^3)	B(cm^3)	A (cm^3)	B(cm^3)	cm^3
100% Wheat	-	-	-	-	-	-	35.34
80/20 W/P	30.85	31.26	31.11	29.57	32.50	29.60	-
70/30 W/P	29.90	30.50	30.60	29.67	31.08	29.19	-

80/20 W/P	32.93	34.63	33.69	33.31	33.99	32.74	-
70/30 W/C	31.28	32.21	31.96	31.67	32.57	31.07	-

Where: A = Variety of A Mushroom
B = Variety of B Mushroom
100% Wheat = Whole Wheat Bread
80/20% W/P = 80/20% Wheat/Plantain Composite Bread
70/30% W/P = 70/30% Wheat/Plantain Composite Bread
80/20% W/C = 80/20% Wheat/Cowpea Compostie Bread
70/305% W/C = 70/30% Wheat/Cowpea Composite Bread
5g, 10g and 15g = Proportions of Mushrooms.

Table 2 shows the Volume performance of the various loaves. A volume is used to indicate a quality loaf in term of rising. The bread produced from the 100% wheat without mushroom had the highest volume of 35.34cm^3 followed by 80/20 % wheat/cowpea blends with 15g mushroom A, while the least was 29.19cm^3 in 70/30% W/P with 15g mushroom B. The volume decrease or increase was observed to have no regular pattern but could only be said to decrease less than the control due no gluten in the plantain or cowpea as was observed by Idowu *et al*., (1996) .The table showed that the huger the substitution level the lower the volume for both plantain and cowpea irrespective of mushroom type but mushroom B showed a higher volume than A.

Table 3 Effect of Mushrooms on the Protein Content of Wheat/Plantain, Wheat/Cowpea Breads

	5g		10g		15g		-
Samples	A(%)	B(%)	A(%)	B(%)	A(%)	B(%)	%
100%Wheat	-	-	-	-	-	-	14.44
80/20W/P	14.70	13.65	15.49	13.99	15.55	14.12	-
70/30W/P	11.55	10.77	12.26	11.11	13.41	12.16	-
80/20W/C	14.49	14.10	14.54	14.28	15.18	15.80	-
70/30W/C	15.18	15.00	16.99	16.68	17.20	16.03	-

As shown in Table 3 the composite bread produced from 70/30 W/C composite bread at 15g mushroom A had the highest crude protein contents of 17.20% while the lowest crude protein contents was observed to be 10.77% in 70/30% W/P composite bread with 5g of mushroom B. The crude protein contents of W/P and W/C composite bread increased with progressive increase in the proportion of mushrooms A and B, indicating that, the addition of mushroom A and B would greatly improve the nutritional protein quality of bread. This could obviously be due to the significant quantity of protein in mushrooms (Ogundan, 1982). This high protein content of mushroom would be of nutritionally importance in most developing countries such as Nigeria, where many people can hardly afford high proteinous foods because of the expensive cost.

The protein content of W/P composite bread decreased as the level of supplementation of wheat flour with plantain flour increases. This is as a result of low protein content in plantain, while a progressive increase was observed with increase in the proportion of W/C composite bread at 5, 10 and 15g of mushrooms A and B. this is because, cowpea contains substantial quantities of lysine and when blended with cereal grains, gives mixtures with complementary amino acid profiles and improved protein quality (Bressani, 1985). The result on the effect of mushrooms on the protein content conforms to the findings of various authors (Asiedu,1989.,Kure *et al*.,1998;Basman *et al*.,2003) where the addition of soybean increased protein to 8.39% ,but here addition of cowpea at 30% supplementation with mushroom A at 15% increase protein to 17.20% against the 14.44% in the control.

Table 4: Effect of complementation with Mushrooms on the Fat Contents of Wheat/Plantain and Wheat/Cowpea Composte Bread

	5g		10g		15g		-
Samples	A(%)	B(%)	A(%)	B(%)	A(%)	B(%)	%
100% Wheat	-	-	-	-	-	-	1.17
80/20 W/P	5.25	5.43	5.52	5.63	5.71	5.86	-
70/30 W/P	5.08	5.15	5.26	5.34	5.42	5.52	-
80/20 W/C	6.05	6.30	6.68	6.85	6.87	6.96	-
70/30 W/C	6.00	6.09	6.13	6.34	6.54	6.60	-

Lipid contents were found to be in high values in all the samples compared with control. However, the highest fat content of 6.96 was recorded for the 80/20% W/C composite bread with 15g mushroom A, while the lowest of 1.77 was observe in the control. The lipid content of W/P and W/C composite bread increases with a progressive increase in the proportion of mushrooms A and B. this indicated that mushrooms contain a higher fat comparing with wheat, plantain and cowpea.

The lipid contents of W/P and W/C composite bread were found to decrease as the level of supplementation increases at 5, 10 and 15g of mushroom A and B. This shows that the composition of plantain and cowpea flour may have had a negative effect on the fat content of the composite bread.

Table 5. Effect of Complementation with Mushrooms on the Ash Contents Wheat/Plantain and Wheat/Cowpea Composite Bread

	5g		10g		15g		-
Samples	A(%)	B(%)	A(%)	B(%)	A(%)	B(%)	%
100% Wheat	-	-	-	-	-	-	2.06
80/20 W/P	2.54	2.17	2.83	2.60	2.96	2.75	-
70/30 W/P	3.10	3.20	3.22	3.29	3.33	3.46	-
80/20 W/C	3.14	3.26	3.28	3.33	3.40	3.54	-
70/30 W/C	3.40	3.43	3.48	3.50	3.52	3.89	-

From Table.5 above, it can be deduced that the ash content of W/P and W/C composite bread increases with progressive increase in the proportion of mushrooms A and B, indicating the high content of organic matter in mushrooms.

The ash content of W/P and W/C composite bread were observed to increase as the level of supplementation increases at 5, 10 and 15g of mushroom A and B, implying that inorganic nutrient in composite bread is richer than that of wheat bread. Horsfall *et al*,(2007) has reported 0.95 % ash in a 15% plantain supplemented bread, while this work has shown the highest ash of 3.46% in 30% plantain supplemented bread with addition of mushroom. The additional ash could only come from these mushrooms.

Table 6. Effect of Complementation with Mushrooms on the Fibre Contents of Wheat/Plantain and Wheat/Cowpea Composite Bread

	5g		10g		15g		-
Samples	A(%)	B(%)	A(%)	B(%)	A(%)	B(%)	%
100% Wheat	-	-	-	-	-	-	1.07
80/20 W/P	1.31	1.10	1.39	1.14	1.17	1.26	-
70/30 W/P	1.39	1.15	1.46	1.22	1.53	1.53	-
80/20 W/C	1.17	1.11	1.23	1.21	1.34	1.24	-
70/30 W/C	1.30	1.28	1.41	1.32	1.62	1.41	-

As shown in Table 6 above, it can be seen that the value of all the samples were relatively low. The highest fibre contents of 1.62 was recorded for the 70/30% W/C composite bread with 15g mushroom A, while the lowest of 1.07 was recorded for the control. Nevertheless, the fibre content of W/P and W/C composite bread increases with a progressive increase in the proportion of mushrooms A and B.

The fibre contents of W/P and W/C composite bread were observed to increase as the level of supplementation increases at 5, 10 and 15g mushroom A and B. This increase can be attributed to the negative effect of the composition of plantain and cowpea although, the nutritional roles of fibre have not been fully established but it is known that fibre contributes to the health of the gastrointestinal system and metabolic system in man. Because crude fibre consists of cellulose and lignin, its estimation affords an index for evaluation of dietary fibre whose efficiency has been implicated in a variety of gastrointestinal disorder. By increasing intestinal mobility, fibre causes increased transit time for bile salt derivatives as deoxycholate, which are effective chemical carcinogen, hence reducing incidence of carcinoma of the colon (Eddy *et al.,* 2007).

Table 7: Effect of Complementation with Mushrooms on the Carbohydrate Contents of Wheat/Plantain and Wheat/Cowpea Composite Bread.

	5g		10g		15g		-
Samples	A(%)	B(%)	A(%)	B(%)	A(%)	B(%)	%
100% Wheat	-	-	-	-	-	-	75.25
80/20 W/P	76.21	77.65	74.77	76.64	74.61	76.01	-
70/30 W/P	78.88	79.73	77.80	79.04	76.31	77.33	-
80/20 W/C	75.15	75.23	74.27	74.33	73.21	72.46	-
70/30 W/C	74.12	74.20	71.99	72.16	71.12	72.07	-

The carbohydrate contents of the bread samples ranged from 71.12 to 79.73. the highest carbohydrate was observed in 70/30T W/P composite bread with 5g of mushroom B, while the lowest value was recorded for the 70/30% W/C composite bread with 15g of mushroom A. The carbohydrate content of W/P and W/C composite decreases with progressive increase in the proportion of mushrooms A and B.

The carbohydrate content of W/P composite bread was observed to increase with progressive increase in the order of supplementation. This observation may be attributed to high content of carbohydrate in plantain. The carbohydrate content of W/C composite bread was found to decrease with progressive increase in the level of supplementation, indicating that supplementation of wheat flour with cowpea flour would greatly reduce the energy potential in composite bread.

3.3 SENSORY EVALUATION OF BREAD

Table 8. Mean Score for Hedonic Sensory Attribute (Aroma) of Samples.

	5g		10g		15g		-
Samples	A(%)	B(%)	A(%)	B(%)	A(%)	B(%)	%
100% Wheat	-	-	-	-	-	-	7.68
80/20 W/P	6.84	6.00	5.68	5.42	5.41	5.21	-
70/30 W/P	6.63	7.31	6.05	5.52	5.26	5.21	-
80/20 W/C	6.00	6.05	5.78	5.78	5.42	5.47	-
70/30 W/C	6.84	6.15	5.73	5.84	5.43	5.78	-

LSD = 1.49

Any two sample means differing by (1.49) or more is significantly different at 5% level of probability.
The mean sensory scores obtained for the samples, ranges from 7.68 to 5.21 (Table 8) with the highest being recorded for 100% wheat bread, and lowest for 80/20% W/P composite bread at 15g of mushroom B.

Based on the LSD obtained, it was noticed that there is a significant difference in all the samples except on 80/20% W/P, 70/30% W/P and 70/30% W/C composite bread at 5g mushroom B. This implies that the composition of composite flour and mushrooms (A and B) significantly affect the aroma of the composite bread. However, the analysis of variance (ANOVA) shows that the whole of wheat bread differs significantly from composite bread with mushroom A and B ($P > 0.05$) in the sensory attribute of aroma.

Table 9: Mean Score for Hedonic Sensory Attribute (Colour) of Samples

	5g		10g		15g		-
Samples	A(%)	B(%)	A(%)	B(%)	A(%)	B(%)	%
100% Wheat	-	-	-	-	-	-	7.74
80/20 W/P	6.32	5.84	5.53	5.79	5.47	4.58	-
70/30 W/P	6.21	7.26	5.95	5.63	5.42	5.53	-
80/20 W/C	6.00	6.26	5.53	6.21	5.21	6.05	-
70/30 W/C	6.00	6.58	5.74	5.74	5.16	4.89	-

The mean sensory scores obtained for the samples ranges between 7.74 and 4.58 (Table 9) with the highest being recorded for 100% wheat bread and lowest for 80/20% W/P composite bread at 15g of mushroom B. The analysis of variance (ANOVA) shows that the whole wheat bread did not differ significantly from other samples of composite bread ($P < 0.05$). This implies that the level of supplementation of plantain and cowpea as well as the proportion of variety A and B mushroom does not reduce the caramilization and maillard browning reaction which forms the brown colour during baking.

Table 10: Mean Score for Hedonic Sensory Attribute (Taste) of Samples.

	5g		10g		15g		-
Samples	A(%)	B(%)	A(%)	B(%)	A(%)	B(%)	%
100% Wheat	-	-	-	-	-	-	7.47
80/20 W/P	6.42	5.47	6.21	5.47	5.47	4.68	-
70/30 W/P	5.94	5.89	5.73	5.63	5.47	5.57	-
80/20 W/C	6.47	6.43	5.89	5.89	5.78	5.57	-
70/30 W/C	6.63	7.37	5.89	5.26	5.57	4.78	-

LSD = 0.56

Any two sample means differing by (0.56) or more is significantly different at 5% level of probability. Taste is related to aroma. A good level of aroma intensity influences taste. The taste of the sample ranged from 4.68 to 7.47 with the highest obtained in the control and lowest in the 80/20% W/P composite bread at 15g of mushroom B.

The analysis of variance (ANOVA) shows that the whole wheat bread was significantly different from all other samples ($P > 0.05$) in the sensory attributes of aroma. Based on the LDS, there is also significant difference among the samples including the control. This implies that the taste of samples was affected by the level of supplementation of plantain and cowpea flour and also by the proportion of mushroom A and B.

Table 11: Mean Score for Hedonic Sensory Attribute (Texture) of Samples**.**

	5g		10g		15g		-
Samples	A(%)	B(%)	A(%)	B(%)	A(%)	B(%)	%
100% Wheat	-	-	-	-	-	-	7.21
80/20 W/P	6.32	5.84	6.10	5.26	5.42	4.16	-
70/30 W/P	6.05	6.08	6.00	6.10	5.05	5.34	-
80/20 W/C	5.58	5.63	5.21	5.63	5.10	5.00	-
70/30 W/C	5.53	6.05	6.26	5.95	5.16	5.21	-

LSD = 0.72

Any two sample means differing by (0.72) or more is significantly different at 5% level of probability. The texture of the samples ranged from 4.61 to 7.58 with the highest obtained in the control and lowest in the 80/20% W/P composite bread at 15g of mushroom A (Table 11). The analysis of variance (ANOVA) shows a significant difference (P > 0.05) in the sensory attributes of texture. Indicating that the level of supplementation of composite flours, and the proportion of mushrooms (A and B) influences the quality of dough that could provide the texture known for a good quality bread. Although with the use of LSD significant difference were observed between the samples.

Table 12: Mean Score for Hedonic Sensory Attribute (General Acceptability) Bread of Samples.

	5g		10g		15g		-
Samples	A(%)	B(%)	A(%)	B(%)	A(%)	B(%)	%
100% Wheat	-	-	-	-	-	-	7.63
80/20 W/P	5.89	6.21	5.84	5.10	5.63	4.42	-
70/30 W/P	6.57	5.73	5.78	5.52	5.47	5.05	-
80/20 W/C	5.94	5.84	5.42	5.73	4.84	5.42	-
70/30 W/C	5.73	6.31	5.31	5.89	5.26	5.73	-

From Table 12 above, it was observed that the mean sensory scores for the sample ranged from 4.42 to 7.63 with the highest being recorded for the control and lowest for 80/20% W/P composite bread at 15g of mushroom B. The analysis of variance (ANOVA) shows no significant difference (P > 0.05) in the general acceptability of the samples. This implies that the level of plantain and cowpea supplementation in the composite bread, and the proportions of mushrooms (A and B) do not significantly affect the acceptability of the samples. This may be attributed to good colour, aroma and taste of the samples.

REFERENCES

Asiedu, J. J. 1989. Processing Tropical Crops MaCMillan Education LtD. London P.21

Basman, A., Koksei, A and Ngoka, W. 2003. Utilization of Transglucanase used to increase the level of Barley and Soy flour Incorporation in Wheat flour Bread. J. Food Sci.68(8)2453-2460.

Bressani, R. 1985. Nutritive Value of Cowpea. Production and Utilization.Chichester.John Wiley and Sons. 353-359.

David, M. O. 2006. Nigeria, No 1 market for US wheat; potential for other grains and feeds,USAD foreign Agric.Serv.Bull.,Pp.1-2.

Eddy, N, O., Udofia, P. G. and Eyo,D 2007.Sensory Evaluation of Wheat/Cassava Composite Bread and effect of Label information on acceptance and preference.African Journal of Biotechnology Vol. (20).,Pp.2415-2418.

Edema, M. O., Sanni, L. O. and Sanni, A. I. 2005. Evaluation of Maize-Soybean Flour Blends for Soy-maize Bread Production in Nigeria. Afri .Journal Biotechnol.4:911-918.

FAO, 2004. Food and Agriculture Organization,Statistics Series No.95.Food and Agricultural Organization of the United Nation ,Rome.

Giami, S. Y., Amasisi,T., and Ekiyor,G. 2004.Comparison of Bread Making properties of composite flour from kernels of Roasted and Boiled African Bread fruit Seeds.P.62-65.

Horsefall, D. M., Lucy, E., and Nwaojigwa, S. U. 2007. Chemical Composition,Functional and Baking properties of Wheat/Plantain Composite Flours.Published by Rural Outreah Program Vol.&(1);Pp2-17.

Idowu, M. A., Oni, A. and Musa, B. M. 1996. Bread and Biscuit making potential of some Nigerian Cocoyam Cultivar.Nig. Food Journal 14:1-12(.IITA) (2005).Production of Cassava Flour. Research Papers.

Jiskani, M. H. 2001. Some Edible Mushrooms from Nigeria. Nigeria Field 38:81-91

Kate, U. P. 2007. Baking Demonstrations .Industrial Microbiology Pp.12-16.

Kure, O. A., Bahago, E. J. and Daniel, E. A. 1998.Studies on the proximate composition and effect of flour particle size on acceptance of Biscuits produced from blend of soybean and plantain flour. Namoda Tech. Scope J. 3(2):17-22.

Ogunden, S. K. 1982. Nutritive value of some Nigerian edible mushroom .Food Chem.8:263-268.
Okaka, J. C. 1997. Cereals and Legumes Storage and Processing Technology. Data and MicroSystem publishers,Enugu,Pp 70-100.
Okon, E. U. 2005. Handbook of Basic and Beverage Analysis. Etovin Publishers.4:53-76.
Onwuka, G. I. 2005. Food Analysis and Instrument. Theory and Practice. Food Science and Technology. Michael Okpara University of Agriculture Umudike, Umuahia. Nig.Pp 63-75.
Venez, E., Ballester, D., Wuth, H., Orrrego,W., Gattas,V and Estay, S. 1981. Potato Flour as partial replacement of wheat flour in bread. Baking studies and nutritional value of bread containing graded levels of potato flour. Journal Food technol.16:291-298.

CHEMICAL AND FUNCTIONAL PROPERTIES OF FLOUR FROM SPROUTED AND UNSPROUTED LEGUMES (AFRICAN YAM BEAN, BAMBARA GROUNDNUT AND COWPEA) FOR *MOI-MOI AND AKARA* PRODUCTION

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ABSTRACT

Flour samples were prepared from sprouted and unsprouted legume seeds of African yam bean (AYB) (*Sphenostylis stenocarpa*), Bambara groundnut (BG) (*Voandzeia subterrena*) and Cowpea (CP) (*Vigna unguiculata*). The flours were used to make fried bean paste (akara) and steamed bean paste (moi-moi). The effect of sprouting on the protein ,moisture, ash, fat and carbohydrate contents, swelling index ,bulk density, water and oil absorption capacities were studied. Spouting increased the protein, crude fiber ,moisture and ash ,but decreased the fat and carbohydrate contents of flours from AYB,BG and CP. Sprouting significantly (P<0.05) increased the swelling index by as much as 7.2% in AYB,10.1% in BG and 7.2% in CP. The increase in the water absorption capacity of the sprouted BG was insignificant, while the bulk densities of the sprouted AYB, BG, and CP were reduced by 17.7%, 21.9% and 20% respectively. The sensory evaluation tests revealed that BG was preferred for making akara and moi-moi, followed by CP and AYB in that order, in terms of colour, flavor taste and general acceptance.

KEYWORDS: Legumes, sprouted, unsprouted, nutrient composition, *akara and moi-moi.*

1. INTRODUCTION

Legumes belong to the family, leguminasae (Kay, 1979; Cobley and Steele, 1976, Kordylas, 1990) which is one of the most important sources of food. They are a vital food resource, contributing to the nutritional well being of a diverse human diet. Kordylas (1990) reported that legumes in general contain 22-26% protein, in addition are soluble carbohydrate. Silano *et al*, (1980), Enwere, (1988) reported that legumes are also rich in lysine and tryptophan but low in sulphur containing amino-acids.

However, the most commonly used legume in Nigeria is cowpea (*Vigna unguiculata*). They can be boiled and eaten alone or with cereal (Onuorah *et al*.,1989) or used in preference of some derbies as 'akara' (fried bean paste), 'moi-moi' (steam bean pasta) (Onuorah *et al*., 1989; IFT, 1991; Okechukwu et al., 1992) Cowpea is also used as weaning food in Nigeria (Akobundu,1980;Uwaegbute,1991). However, other legumes such as bambara groundnut (*Voandzeia subterranean)* and African yam bean (*Sphenotylin stenocarpa*) have limited uses but have been used to prepare *moi-moi* or *akara* with little acceptance as reported Elegbede (1998). Onyekaba (1999), Onwuka and Abasiekong (2006) found that these legumes could be partially incorporated into chocolate bars.

However, the ever escalating prices of animal protein sources and insufficient local production led to an increasing demand for these cheap and quality protein foods. The production of these legumes has increased in recent years, but without much impact on its availability in the market, due to post harvest losses of these grains (Agboola, 1986). Another limiting factors present in these legumes has been observed by Kordylas (1990) such as the anti-physiological factors, which attacks splitting enzymes, Tannin and other anti nutrient such as protease inhibitor, trypsin inhibitor, Lecithin and phyto-heamagglutinnins, coupled with the flatulence factors.

The nutritional benefits of legumes can be improved if they are sprouted or germinated before using them to make *akara* or *moi-moi.* A process of germination has often been proposed as a means by which nutrient composition and functional properties of legumes seed might be improved. Therefore, this work is geared toward evaluating the physiochemical properties of sprouted legumes and their usage and acceptability in local dishes such as *moi-moi* and *akara.*

The work will help to create a standard recipe for preparation of *moi-moi* and *akara* using sprouted legumes removing the doubt against the limited uses and also reduce storage losses by discouraging discard of sprouted beans into waste bin.

2. MATERIALS AND METHOD

2.1 Materials

Mature seeds of Bambara groundnut (*Voandzeia substennanea*) cowpea (*Vigna unguiculata*) and African yam bean (*Sphenostrylis stenocarpa*), ---- containers, muslin cloth, rubber band and strings were bought from Umuahia main market Abia State, Nigeria.

2.2 Processing Methods

2.2.1 The Flours

The seeds of the unsprouted legumes were soaked in water for 12 hours, rubbed between the palms to facilitate removal of seed coat. Then the seed without coat were dried at 60^0C for 24 hours, and milled into flour using a local hand mill, sieved through 0.5mm sieve aperture. The flours obtained were packaged in glass bottles and stored for further analysis and processing.

2.2.2 Sprouting of Seeds

The legume seeds were washed and soaked in water, the cowpea for about 3 hours, the bambara groundnut and African yam bean for 24 hours. The difference in soaking time was due to the hard seed coats in the bambara and yam bean. The soaked water was then drained off, the seed rinsed before placing them in the container for sprouting. The muslin cloth was spread over the container and held by a rubber band. The seeds were rinsed twice daily by filling the container with fresh water, skirmishing it briskly around the seed and draining the water out.

Sprouting was done at room temperature and away from direct sunlight, harvested after 18 hours for cowpea and 3 days for bambara and yam bean when their sprout attained 1 cm in length. The sprouted seed were oven dried at 60^0C for 24 hours and milled to pass 0.5mm sieve. The flour were packaged and stored appropriately at 4^0C.

2.2.3 Determination of Proximate Composition

Moisture content of the flours of unsprouted and sprouted seed was determined by oven method The mcro kjeldahl method was used to determine protein by a digestion technique, fat, was determined by solvent ether extraction method in a continuous reflux system, while ashing method was used to determine ash, and carbohydrate content by difference while weende method Pearson (1976) was used to determine crude fiber.

2.2.4 Functional Properties of the Legume Flours

The bulk density and water absorption capacity were determined by method of Okezie and Bello (1988), the method of Ukpabi and Ndimele (1996) was used to determine swelling index, while oil absorption capacity was determined by method of Abbey and Ibeh (1998)

2.2.5 Preparation of Akara

The method and the recipe for akara preparation were adopted from Enwere (1988). The flour obtained from both the unsprouted and sprouted legumes were reconstituted by adding 750ml water to 500g portion of the legume flour mixed to slurry and left for 5-10 minutes to absorb water, the paste formed was then whipped with a wooden spoon to thicken. Oil was heated while a ball formed from the mixture legume paste with 60g ground pepper 130g onions, 20g salt to taste. The ball was fried for about 6-8 minutes until golden brown, then removed from the drying pan with a perforated spoon and drained in a colander.

2.2.6 Preparation of Moi-moi

The method and recipe for *moi-moi* described by (kordylas, 1990) was used. This involves steaming of the decorticated legume flour, which was reconstituted to a paste form then mixed with seasonings.- ground fresh onion, pepper, ginger with a liquid vegetable oil and salt to taste. Water at 50^0C was added while the mixture was vigorously stirred, then steamed for 1 hour and dished out by spoonfuls into polyethene bag or aluminum foil, allowed to cool before it is ready to be eaten.

2.2.7 Sensory Evaluation

Moi-moi and *akara* produced were evaluated by a 22 man test panelists made up of students from the Department of food science and Technology and other Departments, lectures and technical staff. Among the panelist were 11 men and 11 female aged between 19-45 years, all of Michael Okpara University of Agriculture, Umudike, Nigeria. They assessed the taste, colour, flavor texture and general acceptability under the following grading:

1. extremely disliked,
2. moderately disliked
3. neither liked nor disliked
4. moderately liked,
5. extremely liked.

The products were coded with three digit random numbers to remove bias.

2.2.8 Data Analysis

Data produced from the work on proximate analysis, functional properties and sensory scored were subjected to statistical analysis using analysis of variance (ANOVA) (Steel and Torrie (1980) while means were separated by least significant difference (LSD)

3. RESULT AND DISCUSSION

3.1 Proximate Composition of Legumes Flour and Products

Table 1: Nutrient Composition of Sprouted and Unsprouted legume Flour Sample.

Legumes	Percentage Composition					
	Moisture Content	Crude fibre	Protein	Ash	Fat	Carbohydrate
African Yam Bean (U)	7.2^{bc}	2.3^{a}	21.1^{bc}	3.5^{b}	1.9^{bc}	64.0^{a}
African Yam Bean (S)	7.5^{b}	2.5^{a}	23.40^{b}	4.0^{a}	1.0^{bcd}	61.60^{b}
Bambara Groundnut (U)	7.3^{bc}	3.42^{a}	17.2^{bcd}	3.30^{b}	5.0^{a}	63.78^{a}
Bambara Groundnut (S)	9.0^{a}	3.60^{a}	23.3^{b}	3.80^{ab}	3.93^{b}	56.37^{bcd}
Cowpea (U)	7.4^{bc}	2.1^{a}	24.0^{ab}	3.10^{b}	1.7^{bcd}	61.70^{b}
Cowpea (S)	8.2^{b}	2.2^{a}	24.9^{a}	3.20^{b}	1.40^{bcd}	60.10^{bc}
(LSD≤0.05	0.39		1.17	0.41	0.33	0.22

Means with the same superscript within the same column do not differ (P>0.05)
U = unsprouted
S = sprouted

The nutrient composition of the sprouted and unsprouted flour samples are presented in table 1. There was no significant difference (P>0.05) in the crude fiber content of the legume flours, which implies that they are statistically the same.

Sprouting increased the protein content (P<0.05) with significant difference among the three legumes. The protein increase was highest in sprouted bambara groundnut t(6.1%), then African yam bean (2.3%) the least in cowpea (0.9%) respectively. The high difference between cowpea and the other legumes could be due to the length of Soaking and sprouting time which was less in cowpea then in both bambara and African yam bean. Another reason could be attributed to biochemical changes taking place in the individual legumes which might very naturally. Further to the above is that biochemical/molecule makers in plant systematic are based on deoxy ribonucleic acid (DNA) polymorphism or polymorphisms among the structural genes for protein as reported by Asiedu (1992). This means that each strait of plant have different DNA structures which will have different cell division rate.

The protein content of legumes has been shown to generally increase during germination (Kylen and McCreeady, 1975), this is due to the biochemical changes induced by sprouting, producing an increase in free linking amino acids. Fat decreased significantly (P<0.05), the highest fat was found in bambara (5-3.93%). The decrease in fat content of the legumes on sprouting the seeds was partly due to the breakdown of fat into glycerol and fatty acid and its subsequent hydrolysis for energy production during exothermic reaction of germination process. The depletion of fats in germinating legumes has been reported by Nsu *et al* (1980) for lentils, mung bean and soya beans.

The carbohydrate levels were also observed to decrease on sprouting of the legumes, which agrees with the finding of Albrecht *et al* (1966) who attributed such decrease to the loss of solid materials on sprouting. Okaka (2005) noted the slight decrease in the calories value of some fermented vegetables due to the utilization of the sugar in the fresh vegetable) by fermentation organisms. This is possible here since the carbohydrate content measures the sugar level hence sprouting utilizes sugar of the grain thereby reducing the carbohydrate content. The decrease in carbohydrate while sprouting was higher in bambara groundnut (7.41%) and the least in cowpea (1.6%). This agrees with the earlier observation that more biochemical changes place in the bambara groundnut than in other legumes.

3.2 Functional Properties of the Legume Flours

Table 2 shows the swelling index, water and oil absorption capacity, and the bulk density of the sprouted and unsprouted legume flours. There were significant difference (P<0.05) between the legume flour in their old absorption and swelling index, while only bambara differed in water absorption capacity.

The water and oil absorption capacities of food materials indicate how they would interact respectively in hydrophobic and hydrophilic environment of food preparations and /or systems (Okezie and Bellow 1988; Abbey and Ibeh, 1998).

Table.2. Functional Properties of Legume Flour Samples

Legumes	Swelling index	Water Absorption (g/g)	Oil absorption (g/g)	Bulk density (g/ml)
African yam bean(U)	1.25^{bcd}	1.30^{a}	1.23^{b}	0.34^{a}
African yam bean(S)	1.34^{bcd}	1.30^{a}	1.34^{b}	0.28^{a}
Bambara	1.69^{b}	1.00^{ab}	1.64^{ab}	0.32^{a}

groundnut(U)				
Bambara groundnut (S)	1.86^{a}	1.50^{a}	1.70a	0.25a
Cowpea (U)	1.53^{bc}	1.25^{a}	1.30^{b}	0.30^{a}
Cowpea (S)	1.64^{ab}	1.25^{a}	1.43^{b}	0.24^{a}
(LSD≤0.05	0.28	-	0.21	-

Means with the same superscript within the same column do not differ (P>0.05)
U = unsprouted
S = sprouted

For example the water absorption capacity will help to determine if the product could be incorporated into an aqueous food preparation, while the fat binding capacity of proteins from these legumes would find useful Application in ground and meat formulations, meat replacers and extenders

The bulk density of 0.28-0.34g/ml for the dehydrated legumes flours indicates its levels of lightness and therefore can be used to prepare breakfast foods as reported by Ukpabi (2003). The information on bulk density (amount of space occupied by a given food mass) is necessary for the packaging and warehousing the products. Sprouting did not affect the bulk density significantly hence both sprouted and unsprouted legume can be packaged in the same volume also been observed in human who eat *moi-moi* and *akara*, which is a reflection of high water absorption capacity and dehydration

The swelling index of the various flours varied significantly. African yam bean had the least while Bambara groundnut the highest. Sprouting increased the swelling index across all the legumes. Balagopalan *et al* (1988) noted that pregelatinized starch and particulate products have relatively high swelling index in cold and warm water-even before reaching gelatinization temperature of the species starch. The high swelling index noticed in bambara groundnut flour and cowpea will be appreciated in moi-moi /akara production

3.3 Sensory Evaluation of "Moi-Moi" and Akara

The mean sensory scores on *akara* from sprouted and unsprouted legumes are presented in table 3 a. In terms of colour, *akara* made from unsprouted bambara groundnut was the most accepted, while the colour of the akara from sprouted and unsprouted African yam bean were unacceptable and did not differ from sprouted Bambara groundnut –akara.

Table.3a: Mean Sensory Scores of Akara from Sprouted and Unsprouted Legume Flours

Akara	Colour	Taste	Flavour	Texture	General Acceptance
Africa yam bean (U)	2.045^{d}	1.955^{d}	2.409^{d}	2.091^{c}	2.091^{c}
African yam bean (S)	2.818^{c}	2.864^{bc}	2.636^{cd}	2.455^{bc}	2.636^{bc}
Bambara groundnut (U)	4.500^{a}	3.409^{b}	3.682^{ab}	3.045^{ab}	3.591^{a}
Bambara groundnut (S)	2.636^{c}	2.773^{c}	3.136^{bc}	2.591^{bc}	$2{\cdot}864^{b}$
Cowpea (U)	3.864_{b}	4.045^{a}	3.773^{a}	3.591^{a}	3.909^{a}
Cowpea (S)	3.500^{b}	2.682^{c}	3.000^{c}	3.000^{ab}	2.773^{b}
(LSD<0.05	0.5495	0.5834	0.5462	0.5698	0.5689

Table.3b Mean Sensory Scores of akara from Various Legumes

Akara	Colour	Taste	Flavour	Texture	General Acceptance
Africa yam bean	2.432^{b}	2.409^{b}	2.523^{b}	2.273^{c}	2.364^{b}
Bambara groundnut	3.568^{a}	3.091^{a}	3.409^{a}	2.818^{b}	3.227^{a}
Cowpea	3.682^{a}	3.364^{a}	3.386	3.295^{a}	3.341^{a}
(LSD<0.05	0.3885	0.4125	0.3862	0.4029	0.4023

Unsprouted cowpea indicated the best taste in akara production followed by unsprouted bambara while the sprouted legumes with African yam bean had the worst taste.

Significance difference existed in the flavor ($p<0.05$) with unsprouted cowpea and bambara the same range but differed from others. Sprouting induces off flavor in food materials, like fermentation process, that is why the taste and flavor of the sprouted legume –akara were not liked by the panel.

Texture however was tolerated by the panel for --- samples except African yam bean and the sprouted bambara-akara.

The mean scores from the panelists on evaluation of moi-moi made from the various legumes is shown in table 4a and 4 b. There was significant difference at 5% between moi-moi made from cowpea, Bambara and African yam bean (AYB) in terms of color, taste, flavor ,texture and general acceptability(see fig 2)

This research has shown the feasibility of producing akara balls from sprouted Bambara groundnut and cowpea with their products comparable to the unsprouted .It further revealed that products from bambara are best in comparism to other legumes. This could help to reduced post storage losses and enhance nutritional quality of legume products

Table.4a: Mean Sensory Scores of Moi-Moi from Sprouted and Unsprouted Legume Flours

Moi-moi	Colour	Taste	Flavour	Texture	General Accept.
Africa yam bean (U)	2.318^{e}	2.364^{cd}	2.500^{c}	2.682^{c}	2.409^{c}
African yam bean (S)	3.318^{cd}	3.273^{b}	3.136^{b}	3.591^{b}	3.227^{b}
Bambara groundnut (U)	4.636^{a}	4.273^{a}	4.318^{a}	4.409^{a}	3.591^{a}
Bambara groundnut (S)	2.909^{d}	2.864^{bc}	2.909^{bc}	3.636^{b}	2.864^{bc}
Cowpea (U)	3.909^{b}	4.273^{a}	3.909^{a}	3.591^{a}	3.909^{a}
Cowpea (S)	3.773^{bc}	2.273^{d}	2.818^{bc}	3.636^{b}	2.955^{bc}
(LSD<0.05	0.4637	0.5293	0.5770	0.5575	0.5337

Table.4b: Mean Sensory Scores of Moi-Moi from Various Legumes

Moi-moi	Colour	Taste	Flavour	Texture	General Acceptance
Africa yam bean	2.818^{b}	2.818^{b}	2.818^{b}	3.136^{b}	2.818^{b}
Bambara groundnut	3.773^{a}	3.568^{a}	3.614^{a}	4.023^{a}	3.591^{a}
Cowpea	-	-	-	-	-
(LSD<0.05	0.3279	0.3743	0.4080	0.3942	0.3774

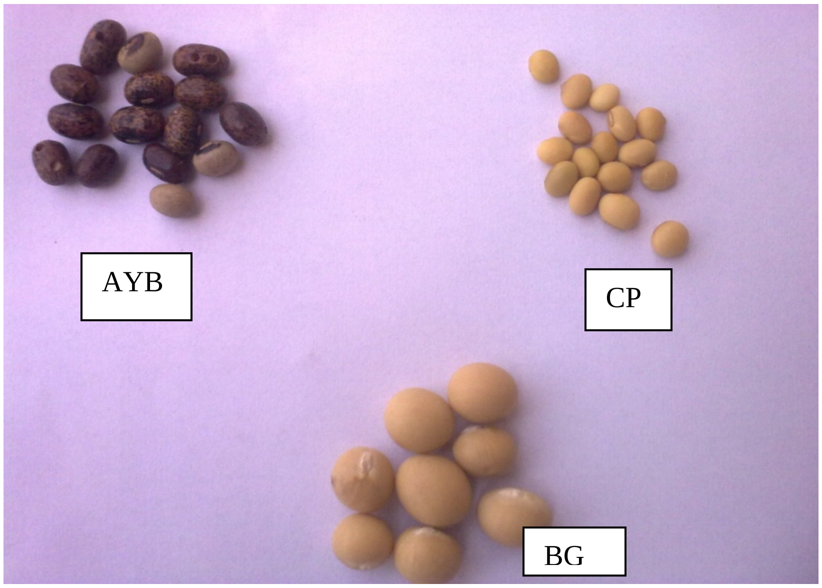

Fig 1. Picture of the Legumes
AYB- African yam bean
CP –Cowpea
BG-Bambara groundnut

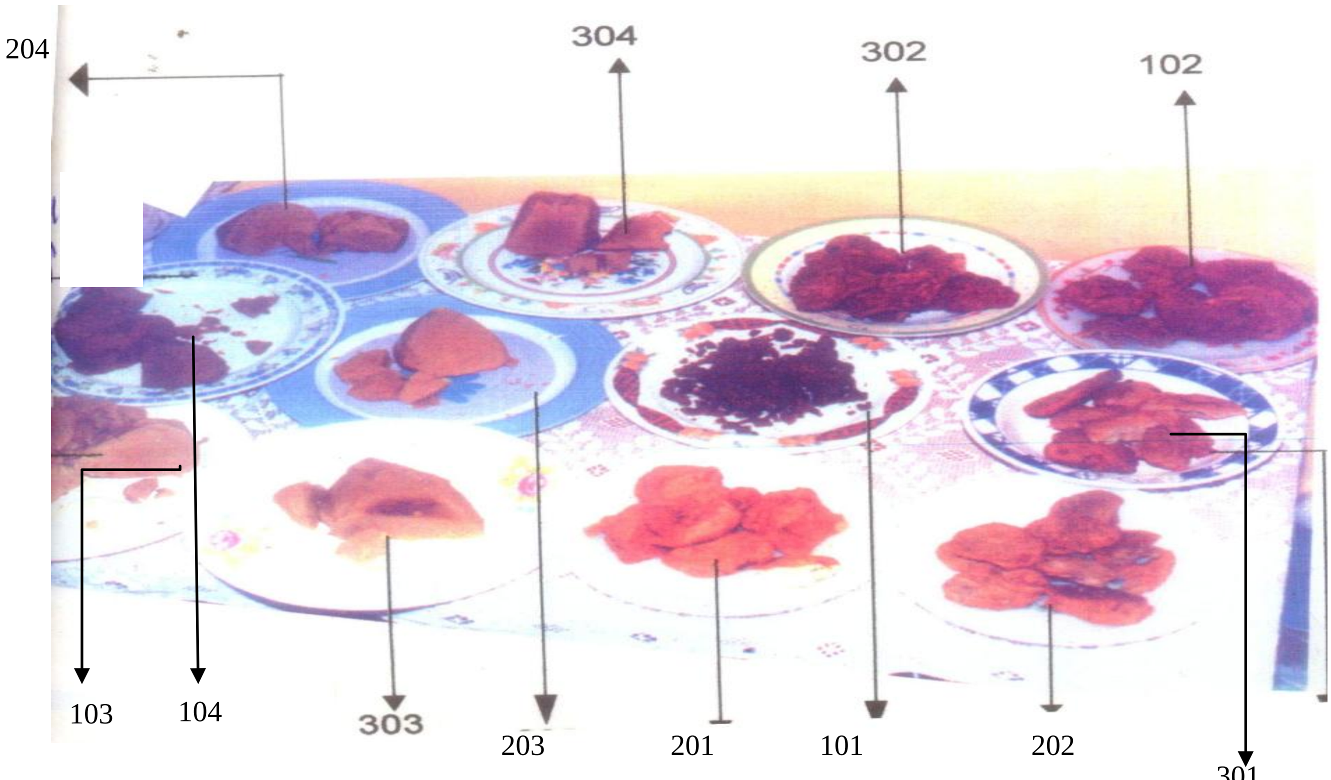

Fig 2 Pictorial view of the various fried bean samples

Where,
204-moi-moi made from sprouted bambara groundnut flour,
104-moi-moi made from sprouted African yam bean flour,
103-moi-moi made from unsprouted African yam bean,
304-moi-moi from sprouted cowpea flour, 303-moi-moi from unsprouted cowpea flour.
203-moi-moi from unsprouted bambara groundnut flour,

302-akara from sprouted cowpea, 301- akara from unsprouted cowpea flour
101-akara from unsprouted African yam bean, 102- akara from sprouted AYB
201-akara from unsprouted bambaragroundnut, 202- akara from sprouted bambara.

4. CONCLUSION

This work has shown that bambara groundnut could be used to produce akara ball and the sensory quality of the akara surpasses the popular “akara-beans” (akara ball from cowpea). Sprouting increased the protein content of the legumes and did not negatively affect the moi-moi or akara products except for bambara where product from sprouted nuts was not acceptable. This work therefore encourage the production of moi-moi and akara from bambara groundnuts, while discourages wastages due to sprouting of cowpea since it can be used in production of even more proteinous products.

REFERENCES

Abbey, B. W. and Ibeh, G. O. 1998. Functional properties of raw and heat processed cowpea (*Vigna unguiculata*, walp) flour. *J. Food Sci*. 53: 1775 – 7, 1791

Agboola, S. D. 1986. The effect of storage conditions on the nutrition composition of common Nigerian grains. Proceedings of the first national workshop on food composition, University of Ibadan, Nigeria (edited by I.O. Akinyele) Ibadan, Nigeria. Ibadan University Press.

Akobundu, E.N.T. 1980. Development and evaluation of corn-cowpea mixtures as protein sources for Nigerian infants.Ph.D Dissertation Louisiana State University of Agriculture and Mechanical College, Baton Rouge, Louisiana, USA

Albrecht, W. J., Mustakes, G. C. and Mcghee, J. E. 1966. Rate studies on atmospheric steaming and immersion cooking by soy beans. Cereal Chem. 43: 400-7.

Asiedu, R. 1992. Isozyme analysis and its implication in plant breeding.In Biotechnology: Enhancing Research on Tropical Crops in Africa (Thottappidly G;Mont, L. M., Mohanran, D. R., and Moor, E.A.W.eds) CTA/IITA co-publication. International Institute of Tropical Agriculture, Ibadan., Pp 261-265.

Balagopalan C., Padmaga, G., Nanda, S. K. and Moorthy S. N.1988. Cassava in foods, feed and industry. CRC press, Boca Raton, Florida USA, pp 79-83.

Cobley, L. S. and Steele, W. M. 1976. An introduction to the botany of tropical crops 2nd edition, longman, London.Pp 71-110.

Elegbede, J. A. 1998. Legumes. In: Nutrition quality of plant foods. Edited by Osagie

Enwere, N. 1988. Food of plant origin. Afro-orbis publication ltd., Nsukka.

IFT 1991. Legumes: Production, food value and health benefits. Food Technology. 45: 96-130

Kay, D. E. 1979. Food legumes Crops and Product Digest No.3 Tropical Products Institute, London

Kordylas, J. M. 1990. Processing and Preservation of Tropical and sub-tropical foods. Macmillan Education Ltd, Hampshire. Page 109-119.

Kylen, A. M. and McCreeady, R. M. 1975. Nutrients in seeds and sprouts of alfafa, lentil,mung beans and soybean. *J. Food Sci*. 40:1008

Nsu, D. L., Leung, H. K., Finney, P. L. And Morad, M. M, 1980. Effects of germination on the nutritive value and baking properties of dry peas,lentils and faba bean. *J food Sci*., 45:87-90.

Okaka, J .C. 2005.Cereal and legumes; Storage and Processing Technology. Data and Micro System Publishers Enugu, Nigeria pp 88-89

Okechukwu, P. E., Ngoddy, P. O, and Nnanyelugo, D. O. 1992. The effect of slurring procedure on firmness distribution and heat penetration in moi-moi .*Nig Food J.* 10:34-43.

Okezie, B. O. and Bello, A. B. 1988. Physico chemical and functional properties of winged bean flour and isolate compared with soy isolate. *J Food Sci*. 53:450-454

Onuorah, V. I., Uwaegbute, A. C. and Enwere, N. J. 1989. Cowpea utilization and nutrition (practical). In: Food crops production, utilization and nutrition

Onwuka, U. N and Abasiekong, K. S 2006. Production and Evaluation of Chocolate Bars from roasted and unroasted African breadfruit and bambara groundnut flour .Journal of Food Processing and preservation 30(2006) 534-548

Onyekaba, U. 1999. Legume based chocolates, BSc Thesis p.57 Michael Okpara University of Agriculture Umudike ,Nigeria.

Siloano, V., Bansul, H. C and Bozzini, A. 1982. Improvement of nutritional quality of food crops. FAO Plant Production and Protection paper, 34, FAO Rome

Pearson,D. 1976.Chemical Analysis of Foods. J. A. Churchhill. London, UK. 6th ed.P 499.

SteeL ,R. G. D. and Torrie, J. H. 1980:Principles and Procedures of Statistics: McGraw-hill Book Company New York

Ukpabi, U.J and Ndimele, C. 1996. Evaluation of quality garri produced in Imo State. Nig *Food J*. 8: 105-110

Ukpabi, U. J. 2003. In Production and Evaluation of breakfast food from trifoliate yam (D. dumentorum) A Ph.D thesis, department of food science and technology Michael Okpara University of Agriculture, Umudike, Nigeria.

Uwaegbute, A.C. 1991. Weaning Practices and Weaning foods of the Hausas', Yorubas' and Ibo' of Nigeria. Ecol. Food Nutrition., 26: 139-153.

DEVELOPMENT OF PREDICTIVE EQUATIONS FOR OPTIMIZING THE WHOLE KERNEL OUT-TURN OF PRE-TREATED CASHEW NUTS USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT

The whole kernel out-turn (WKO) of processed cashew nuts was investigated using Response Surfaced Methodology (RSM). The data were analyzed using Statistical Analysis Software (SAS) and predictive models were fitted and validated by comparison with experimental data. Response surface graphs were generated to determine the treatment combination(s) for optimum WKO. There was no significant difference between the experimental and predicted values. For steam-boiled nuts, the response surfaces showed that WKO increased as steam exposure time (SET) increased and moisture content (MC) decreased; whereas for roasted nuts, WKO increased as roasting time (RT) and MC increased. The treatment combinations for optimum WKO of large steam-boiled nuts (89.70%) occured when MC<9% and SET>28 min. For medium nuts, optimum WKO (89.68%) occured when MC<11% and SET>32 min. For small nuts WKO was optimum (83.38%) at MC<11% and SET<32 min. The combination of parameters for optimum WKO of large roasted nuts (93.53%) converged at MC>16% and RT>60 s and afterwards WKO decreased. For medium roasted nuts the treatment combination at which WKO was optimum (91.01%) converged at MC>14.8% and RT>60 s in a trend similar to the former. For small roasted nuts, the combination of treatment for optimum WKO of 89.68% converged at MC range of 12.7-17% and RT of 60-90 s.

KEYWORDS: Predictive equations, optimization, whole kernel out-turn, cashew nuts, response surface methodology.

1. INTRODUCTION

Cashew (*Anacardium occidentale*) belongs to the *Anacardiaceae* family of plants and is principally grown in the tropics particularly, America (Mexico, Peru, Brazil), India and Africa (Gomez-Caravasa, Verardo, & Caboni, 2010*)*. The prized edible kernel that the fruit provides gives impetus to global vested interest in cashew production and processing; in almost all countries where conditions for its growth is favourable. Cashew kernel is widely eaten as a food snack for accompanying drinks at cocktails and as enrichment or garnish for confectioneries and baked food products. Like some other edible kernels, cashew nut processing requires that kernels turn out as wholes because the visual appeal that whole kernels give is a major quality index that determines price (Hebbar & Ramesh, 2005). Due to the caustic liquid in the mesocarp of the shell, certain pre-treatments (in the form of hot-oil roasting or steam-boiling) are usually required to liberate the kernel from the shell (Oloso & Clarke, 1993; Ogunsina & Bamgboye, 2011). Previous studies by Jain and Kumar (1997), Balasubramanian (2001) and Araujo and Ferraz (2006) identified moisture content, method of pre-shelling treatment and nut size as some of the parameters that may affect yield or whole kernel out-turn (WKO) of cashew nuts. Hitherto, the control of these parameters relies largely on the skill level and experience of processors rather than clear scientific understanding of the process (Kahyaoglu, 2008). As the local consumption of cashew kernels and its demand by importing countries continue to increase worldwide, the industry is therefore in dire need of ways of improving WKO and minimizing kernels damage based on clear understanding of the parameters that affect the mechanical behavior of cashew nuts during shelling (Albiero, Araújo, de Oliveira Ferraz, da Silva Maciel & Dal Fabbro, 2012). Cashew kernels consumers worldwide are willing to pay more for the mouth-filling meat in whole kernels than small or broken pieces (Ogunsina, 2010); hence the premium price that whole cashew kernels attract in the world's edible nuts trade necessitates that processors optimize processes for higher WKO.

Araujo and Ferraz. (2006) found that the moisture content of the entire nut, the shell and the kernel before and after pre-shelling treatment determines the fracture behavior of the nutshell. In the presence of high level of moisture content, edible nuts generally become less susceptible to brittle fracture; for cashew nuts, this makes cracking difficult and reduces the chances of producing whole kernels. Balasubramanian (2006) added that ungraded cashew nuts yield lower whole kernels than graded ones and inferred that nut size also play a significant role in WKO. Ogunsina and Bamgboye (2007) reported that the physical properties and cracking force of cashew nuts are affected significantly ($p<0.05$) by method of pre-shelling treatment. It therefore follows that WKO of cashew nuts is not determined by a single factor but by several factors and their interaction.

When analyzing problems wherein several factors and their interactions influence a desired response surface methodology (RSM) has been a powerful technique for determining the best combination of factor levels for different responses depending on the nature of the process being characterized, the knowledge and skill of the researcher (Berger & Maurer, 2002; Shakerardekani, Karim, Mohd Ghazali & Chin, 2011). RSM uses a collection of experimental design and multiple regression-based techniques (Gardiner & Gettingby, 1998) to determine the relationship between independent factors and measured responses based on one or more selected criteria (Jiao, Li, Huang, Zhang, Bhandari, Chen & Mao, 2008; Sin, Yusof, Abdul-Hamid & Rahman, 2006). This has been applied in optimizing the processing conditions for hazelnut (Saklar & Katnas, 2001; Ozdemir & Devres, 2000); coffee (Mendes, de Menezes, Aparecida & da Silva, 2001); peanut (Slade & Levince, 2006) sesame seed (Kahyaoglu & Kaya, 2006) and pistachio (Nikzadeh & Sedaghat, 2008; Kahyaoglu, 2008; Shakerardekani *et al.*, 2011). Although substantial literatures are available on cashew nut processing, information regarding pre-shelling parameters and conditions for optimizing WKO is rarely found. Adequate representation over this broad factors domain involves fitting an empirical, first or second-order polynomial model to data using least square techniques. The adequacy of models generated may be checked by analysis of variance and response surface graphs or contours may be used to locate optimum points (Gardiner & Gettingby, 1998). Previous efforts in this direction was an investigation by Ogunsina and Bamgboye (2012) where moisture content; nut size and method of pre-shelling heat treatment (either by hot-oil roasting or by steam-boiling) were found to affect WKO of cashew kernels significantly ($p<0.05$). The development of predictive equations based on knowledge of the rightful combination of parameters will provide valuable information for optimizing WKO; thereby facilitating secondary processing of cashew-based products and by-products.

In this work, RSM was used to determine the parameters for optimizing WKO during cashew nut shelling considering moisture content, nut size distribution and methods of pre-shelling treatment. Regression analysis was applied to fit the best relationships between these variables and used to predict WKO using data generated from preliminary studies.

2. EXPERIMENTAL METHODS

2.1 Source of Materials and Sample Preparation

About 1000 kg of raw cashew nuts procured from cashew plantations in Iwo and Oro areas of Osun and Kwara states, Nigeria during peak harvest period (February-April, 2008) were used for this investigation. The nuts were sun-dried to average moisture content (MC) of 8.34% and cleaned of foreign and extraneous materials such as leaves, stones, immature and spoilt nuts. The bulk was sorted into three size categories based on their major axial dimensions as large (26-35 mm), medium (23-25 mm), small (18-22 mm) (Balasubramanian, 2001). The nuts were kept on raised pallets for good ventilation until the time of use according to industrial practice.

The investigation was carried out in two modules, each being a 3×5×4 factorial experiment considering three nut sizes: large, medium and small; five levels of MC: 8.34, 11.80, 12.57, 15.40, 16.84 %; and four levels of duration of pre-shelling treatment (*i.e.* 28, 30, 32, and 34 min of steam exposure time for steam-boiling and 45, 60, 75 and 90 s for hot-oil roasting. Moisture adjustment of samples from 8.34% to the desired level was carried out as documented by Ogunsina and Bamgboye (2012).

2.2 Samples Preparation and Shelling

The pre-shelling treatment methods used for this investigation were steam boiling and hot-oil roasting (Ogunsina & Bamgboye, 2007). For steam-boiling, about 3 kg of sample from each category of nut size was obtained and wrapped inside a piece of cloth in four groups. The samples were exposed to steam at 700 kPa (Azam-Ali & Judge, 2001 and Balasubramanian, 2006) first for 28 mins; then 30, 32, and 34 mins; afterwards they were cooled in desiccators at room temperature. For hot-CNSL roasting, about 3 kg of sample from each category of nut sizes were loaded inside a mild steel basket. The basket was dipped inside pre-heated CNSL for 45 s during which the temperature of the CNSL roasting medium fluctuated between 185 and 190^{o}C (Andrighetti, Bassi, Capella, De Logu, Deolalikar, Haeusler, Franca, Rivoira, Vannini & Deserti, 1994; Oloso & Clarke, 1993; Ogunsina & Bamgboye, 2012). Afterwards, the nuts were discharged onto a heap of wood ash to mop the CNSL film on the shell and they were cooled under ambient conditions in desiccators (Andrighetti *et al.*, 1994 and Oloso & Clarke, 1993). This procedure was repeated for 60, 75 and 90 s and each treatment was replicated five times. Raw nuts from the same lot were used as control in each case.

Pretreated samples were shelled using a hand-operated knife cutter and WKO estimated as percent ratio of the weight of whole kernels to the total weight of kernels recovered (Ajav, 1996; Balasubramanian, 2001; Ogunsina & Bamgboye, 2011, 2012).

2.3 Theoretical Background for Model Development and Optimization

The authors in previous works (Ogunsina, 2010 and Ogunsina & Bamgboye, 2012) have documented data on the effect of moisture content, nut size and two different methods of pre-shelling treatment (hot-oil roasting and steam-boiling) on the whole kernels out-turn of cashew nuts during shelling. The development of predictive Equations and Optimization by Response Surface Methodology presented herein is based on the documented data. The third-order polynomial model used to simulate the experimental data is of the general form:

$$Y = \beta_0 + \sum_{i=1}^{3}\beta_i X_i + \sum_{i=1}^{3}\beta_{ii} X_i^2 + \sum_{i=1}^{3}\beta_{iii} X_i^3 + \sum_{i=1}^{2}\sum_{j=i+1}\beta_{ij} X_i X_j \qquad (1)$$

For each of three categories of nut size, regression models expressed WKO (Y) as a function of the method and duration of pre-shelling treatment (X_1) and moisture content (X_2). Statistical Analytical Systems (SAS Institute, Inc., 1990) was used for regression analysis, analysis of variance (ANOVA), canonical analysis and analysis of ridge maximum of data. The SAS procedure employed the stepwise regression method. The models were evaluated for each response and the significant terms found by analysis of variance using F-test. The independent variables therefore were X_i and X_j are the independent variables; Y was the predicted response while β_0, β_i, β_{ii}, β_{iii}, and β_{ij} are the intercept, linear, quadratic, cubic and interaction coefficient of the regression respectively. The proportion of variance explained by the polynomial models obtained is given by the multiple coefficient of determination, R^2. The accuracy of the models were assessed by comparing the predicted and experimental values of WKO using relative error (RE) and standard error of estimate (SE) which are of the form:

$$RE = \frac{Q_p - Q_e}{Q_e} \tag{2}$$

$$SE = \sqrt{\left[\sum \frac{(Q_p - Q_e)^2}{n}\right]} \tag{3}$$

Where Q_p and Q_e are the predicted and experimental WKO respectively, n is the number of Q values. Usually, these statistics are useful tools in quantifying the degree of over/under prediction and correlation by models as well as reveal systematic deviations (Sepaskhah, Bazrafshan-Jahromi & Shirmohammandi-Aliak-Barkhani, 2006).

Response surface methodology for process optimization (Design Expert 6.1 Trial version, StatEase) was used to determine the conditions for optimum WKO (Myers & Montgomery, 1995; Gardiner & Gettingby, 1998; Jiao *et al.*, 2008). The behaviour of the surface was investigated for the response function using the regression equations. Response surfaces and contour plots were developed using the fitted polynomial equations, holding the independent variable with the least effect on the response at a constant value, and changing the other two variables. This helped in visualising the relationship between the response and experimental levels of each factor and to deduce the optimum conditions. Confirmatory experiments were carried out to validate the model, using combinations of independent variables that were not part of the original experimental design and within the experimental region. Regression analyses of experimental and predicted responses were carried out.

3. RESULTS AND DISCUSSION

3.1 Fitting the Models

The multiple regression coefficients of third-order polynomial models are presented in Table 1. The regression equations show the empirical relationship between WKO and the varied parameters in coded units. From ANOVA, all the linear, quadratic and cubic terms and their interactions were significant at $p<0.01$; while the cubic term β_1^3 of roasted small nuts, interactions $\beta_1\beta_2$ of steam-boiled large nuts and $\beta_1^3\beta_2^3$ of roasted large nuts were significant at $p<0.05$; and the cubic term β_2^3 of large roasted nuts was not significant. Substituting these coefficients into the generalized third-order polynomial model in equation (1), six different models were obtained for predicting WKO on the basis of moisture content, nut size and method of pre-shelling treatment (Table 2). The term X_1 refers to the steam exposure time in models 1-3; whereas, it refers to roasting time in models 4-7.

Considering model 1 in Table 2, steam exposure time (X_1) and moisture content (X_2) had the most significant effect ($p<0.01$) on WKO of large cashew nuts followed by interaction X_1X_2 which was significant at $p<0.05$. In model 2, the interaction of X_1X_2; interaction of X_1 and quadratic term of X_2 ($X_1X_2^2$); interaction of quadratic term of X_1 and X_2 ($X_1^2X_2$); interaction of cubic term of X_1 and X_2 ($X_1^3X_2$) and interaction cubic term of X_1 and cubic term of X_2 ($X_1^3X_2^3$) had same significant effect ($p<0.01$) on the WKO of steam-boiled medium cashew nut. Similarly, for steam-boiled small cashew nuts depicted by model 3, the effects of X_1 and interaction X_1X_2 were significant on WKO ($p<0.01$).

Table 1. Regression coefficients of the predicted third order polynomial models for the response of WKO on pre-shelling treatment and nut size

Steam-boiled nuts													
Large	β_0	β_1	B_2	β_1^2	β_2^2	β_1^3	β_2^3	$\beta_1 \beta_2$	$\beta_1 \beta_2^2$	$\beta_1 \beta_2^3$	$B_1^2 \beta_2$	$\beta_1^3 \beta_2$	$\beta_1^3 \beta_2^3$
β_i	80.32	2.5×10^{-1}	2.34					-6.63×10^{-2}					
F_i	60.46[b]	16.19[b]	9.14[b]					5.67[a]					
Medium													
β_i	56.12							2.94	-3.87×10^{-2}		$1.51 \text{ X } 10^{-1}$	2.27×10^{-3}	8.55×10^{-7}
F_i	314.35[b]							23.62[b]	46.18[b]		15.23[b]	13.35[b]	16.15[b]
Small													
β_i	47.12	1.25						-9.67×10^{-2}					
F_i	256.46[b]	76.84[b]						34.83[b]					
Roasted nuts													
Large													
β_i	84.25	9.87					-2.41×10^{-3}		1.03×10^{-2}	7.32×10^{-3}			1.12×10^{-8}
F_i	153.98[b]	46.55[b]					2.34[ns]		24.23[b]	8.59[b]			4.23[a]
Medium													
β_i	86.13					-1.16×10^{-4}		2.61×10^{-1}	-6.43×10^{-3}		-2.71×10^{-3}	2.61×10^{-5}	
F_i	359.99[b]					44.33[b]		77.95[b]	40.31[b]		14.36[b]	23.78[b]	
Small													
β_i	86.62			1.92		8.02×10^{-6}		1.65		-2.63×10^{-4}			
F_i	742.07[b]			17.18[b]		5.41[a]		74.86[b]		47.52[b]			

[a]significant at 0.05; [b]significant at 0.01; [ns]not significant

Table 2. Model equations for predicting whole kernel of pre-treated cashew nuts

s/n	Type of pre-treatment	Nut size	Predictive Models for WKO (Y)	R^2
	Steam-Boiled Nuts			
1		Large	$Y = 80.32 + 0.25X_1 + 2.34X_2 - 6.63\times10^{-2} X_1X_2$	0.73
2		Medium	$Y = 56.12 + 2.94X_1X_2 - 3.87\times10^{-2} X_1X_2^2 + 1.51 \times10^{-1} X_1^2X_2 + 2.27\times10^{-3} X_1^3X_2 + 8.55\times10^{-7} X_1^3X_2^3$	0.85
3		Small	$Y = 47.12 + 1.25X_1 - 9.67\times10^{-2} X_1X_2$	0.82
	Hot-oil roasted nuts			
4		Large	$Y = 84.25 + 9.87X_1 - 2.41\times10^{-3} X_2^3 + 1.03 \times10^{-2} X_1X_2^2 + 7.32\times10^{-3} X_1X_2^3 + 1.12\times10^{-8} X_1^3X_2^3$	0.77
5		*Large	$WKO = 84.25 - 9.87X_1 + 1.03\times10^{-2} X_1X_2^2 + 7.32\times10^{-2} X_1X_2^3 + 1.12\times10^{-8} X_1^3X_2^3$	0.77
6		Medium	$Y = 86.13 - 1.16\times10^{-4} X_1^3 + 2.61\times10^{-1} X_1X_2 - 6.43 \times10^{-3} X_1X_2^2 - 2.71\times10^{-3} X_1^2X_2 + 2.61\times10^{-5} X_1^3X_2$	0.89
7		Small	$Y = 86.62 + 1.92X_1^2 + 8.02\times10^{-6} X_1^3 + 1.65X_1X_2 - 2.63\times10^{-4} X_1X_2^3$	0.86

*modified model equation (4) after elimination of the terms that are not significant

Considering model 4, the interaction of X_1 and quadratic term of X_2 ($X_1X_2^2$), the interaction of X_1 and cubic term of X_2 ($X_1X_2^3$) had the most significant effect ($p<0.01$) on the WKO of large roasted cashew nuts. The interaction of the cubic term of X_1 and the cubic term of X_2 ($X_1^3X_2^3$) were significant at $p<0.05$; whereas, the effect of the cubic term of X_2 (X_2^3) was not significant on WKO of large roasted cashew nut; the modified polynomial after eliminating the term which was not significant was re-written as model 5. In model 6, the linear, quadratic and cubic terms of the polynomial had equal significant effects ($p<0.01$) on WKO of medium roasted cashew nuts. In model 7, the effect of the quadratic term of X_1 (X_1^2), interaction X_1X_2 and interaction X_1 and the cubic term of X_2 ($X_1X_2^3$) had the most significant effect ($p<0.01$) on WKO of small roasted cashew nuts followed by the cubic term of X_1 (X_1^3) which was significant at $p<0.05$.

The respective coefficients of determination (R^2) for the models ranged between 0.77 and 0.89 suggesting the adequacy of the models in predicting WKO as a function of the parameters that were investigated. Although, there are other parameters in other unit operations that may affect WKO (Ojolo & Ogunsina, 2007) which were outside the scope of this work; to a very large extent, WKO is determined during shelling.

From regression analysis, the canonical values of estimated moisture content and steam exposure time for the predicted optimal WKO of steam boiled nuts were 12.59% and 17 mins respectively. As steam exposure time increased and moisture content reduced, WKO increased within the experimental range.

Whereas, the moisture content and roasting time for the predicted optimal WKO of roasted nuts were 12.59% and 45 s respectively. It was observed that WKO increased as roasting time and moisture content increased. The maximum WKO for each nut size are shown in Table 3. This trend validates previous experimental data (Ogunsina & Bamgboye, 2012).

3.2 Validation of the Models

Comparison between predicted and experimental values of WKO, the RE, SE and level of significance of indicated differences by paired-t test are presented in Table 4. The differences between the predicted and experimental values are significant ($t<0.01$); and this may have resulted from other factors that were outside this investigation and not inaccuracy of the model predictions. The RE and SE of medium and small roasted nuts were 0.1351 and 0.0868 respectively. These may be due to the fact that there was substantial population of medium and small nuts in the sample. Steam-boiling was a form of hydrothermal treatment during which some moisture got absorbed by the shell; whereas, treatment by hot-oil roasting is purely thermal; during which CNSL and moisture got lost from the shell. This had earlier been shown by the differences indicated in the WKO.

3.3 Optimization of the Process

The interaction effects of the independent variables (moisture content and pre-shelling treatment) on the dependent one (WKO) on the basis of nut size and pre-shelling treatment are shown in Figs. 1 & 2. For steam-boiled nuts, the trend shown by the response surface graphs is similar for the three nuts sizes; WKO increased as steam exposure increased and moisture content decreased (Fig. 1a, b, c). However, for roasted nuts the trend is different (Fig. 2 a, b, c); WKO increased as roasting time and moisture content increased. There was reduction in WKO when roasting time and moisture content fell outside the domain of maximum response.

Table 3. Critical values of independent variables for which WKO is maximum

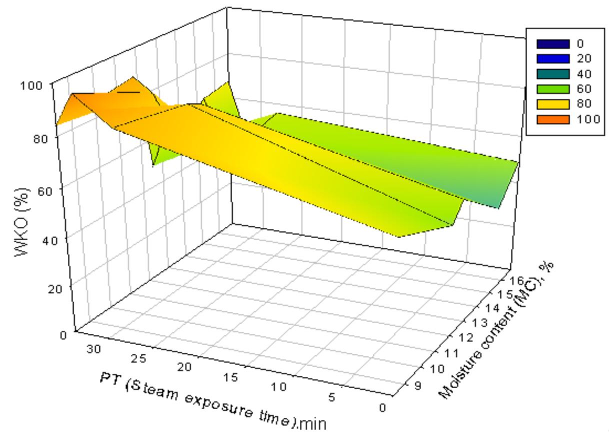
PT/NS	PT_1	MC(%)	WKO(%)	Stationary Points
Steam-boiled nuts				
Large	24.46	8.77	85.90	Maximum
Medium	33.00	11.16	84.19	Maximum
Small	31.90	10.54	81.43	Maximum
	PT_2			
Roasted nuts				
Large	68.0	16.26	93.96	Maximum
Medium	72.0	15.98	93.24	Maximum
Small	77.4	15.51	91.93	Maximum

PT_1 = steam exposure time (min); PT_2 = roasting time (s) and MC = moisture content

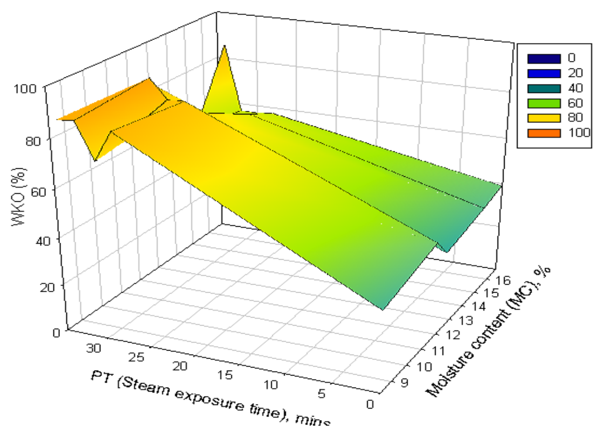
Table 4. Comparison of predicted and experimental values of WKO

	Predicted values	Experimental Values	RE	SE	t<0.01
Steam-boiled nuts					
Large	87.85	91.74	0.0424	0.0389	-
Medium	94.23	90.94	-0.0362	0.0329	0.0045
Small	84.38	86.98	0.0299	0.026	0.0048
Roasted nuts					
Large	94.11	96.96	0.0294	0.0285	-
Medium	86.17	99.63	0.1351	0.1346	0.1881
Small	91.32	100	0.0868	0.0868	0.0016

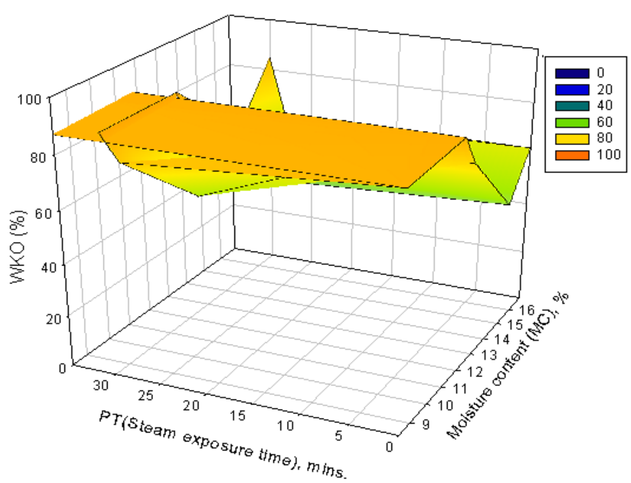
relative error = RE; standard error of estimate = SE



a, (Large)

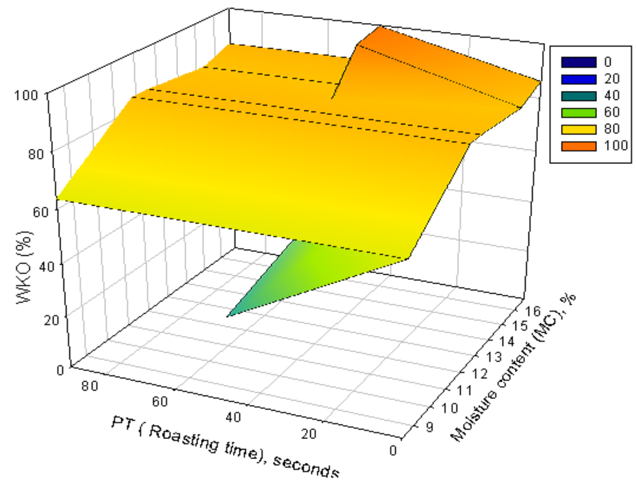


b, (Medium)

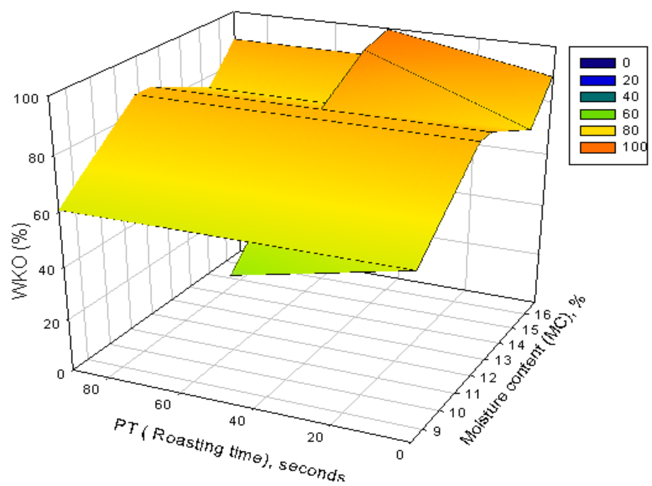


c, (Small)

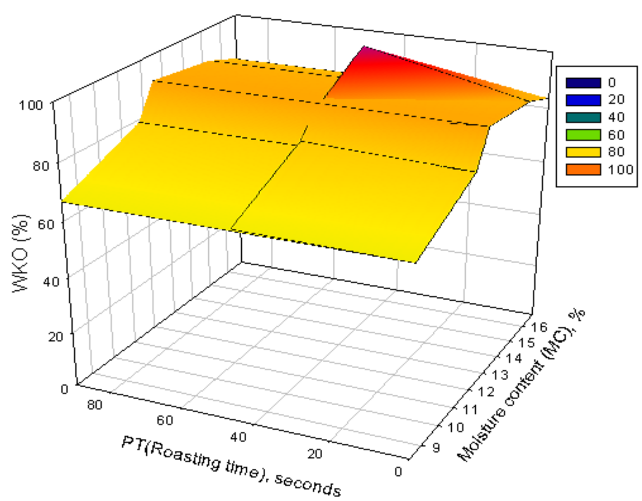
Fig. 1. Response surfaces for the effects of moisture content and steam exposure time on the WKO of cashew nuts.



a, (Large)



b, (Medium)

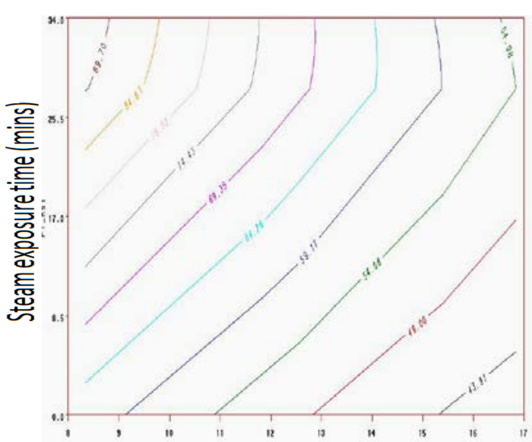


c, (Small)

Fig. 2. Response surfaces for the effects of moisture content and roasting time on the WKO of cashew nuts.

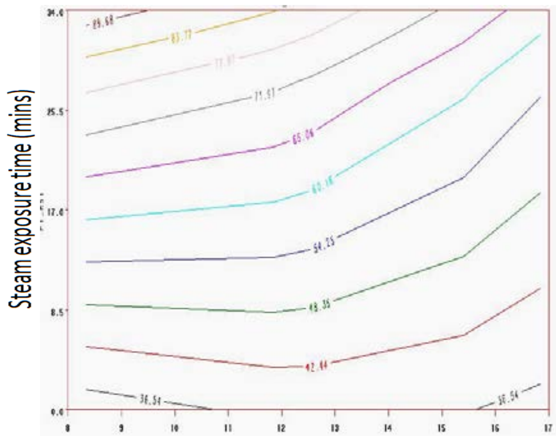
The contour plots in Figs. 3 & 4 illustrate the main and interactive effects of the independent variables on the WKO. The general observation was that increase or decrease in MC affected WKO to a very large extent for the two methods of pre-shelling treatments that were considered. In Fig. 3a, for large steam-boiled nuts, it was observed that WKO decreased from 89.70 - 43.91% as moisture content increased from 8.34 - 16.84% respectively. The trend indicated that WKO decreased consistently between the stated ranges. The treatment combinations for optimum WKO (89.70%) was at moisture content below 9% and steam exposure time above 28 min, however the upper limit fell outside the range of treatment considered in this study. The contour plots of other nut sizes that were subjected to the same treatment (*i.e* steam-boiled medium and small nuts) followed similar trends but the pattern was different. In Fig. 3b, for medium nuts the contour indicated that WKO decreased from 89.68 - 36.54% as moisture content increased from 8.34 - 16.84%. The combination of parameters for optimum WKO (89.68%) was at moisture content below 11% and steam exposure time above 32 min, however the upper limits were outside the range considered in this study. The rate of decrease in WKO was gradual up to 17 mins of steam exposure time after which WKO dropped sharply from 69.16 to 54.25%. For small cashew nuts (Fig. 3c), a decrease was observed in WKO from 83.38 - 48.04% as moisture content increased from 8.34 - 16.84%. This implies that the range of treatment combinations for optimum WKO fell outside the range of treatment. It was however observed that the highest noticeable WKO (83.38%) was obtained at moisture content below 11% and steam exposure time below 32 min. For steam-boiled nuts, as moisture content increased and steam exposure time decreased, there was a decrease in WKO; whereas for roasted nuts, it is observed that WKO increased as moisture content increased.

In Fig. 4a, it is shown that within the range of the experiment, WKO of large nuts, increased from 42.11 - 93.54% as moisture content increased from 8.34 - 16% respectively. The combination of parameters for optimum WKO (93.53%) converged at moisture content above 16% and roasting time above 60 s showing a near-ellipsoid shape and afterwards WKO decreased. However, on the other side after WKO converged was outside the experimental range. Therefore, for any given roasting time, as moisture content increased, WKO increased up till 16% moisture content at which WKO converged. For medium roasted nuts (Fig. 4b), it was observed that WKO increased from 41.19 - 91.01% as moisture content increased from 8.34 - 14.8% respectively. The treatment combination at which WKO was optimum (91.01%) converged at moisture content above 14.8% and roasting time above 60 s showing a pattern similar to the former. Similarly, in Fig. 4c for small roasted nuts, it was observed that WKO increased from 48.96 - 89.68% as moisture content increased form 12.7 - 17%. The combination of treatment for optimum WKO of 89.68% converged at moisture content range of 12.7-17% and roasting time between 60 - 90 s showing a near ellipsoid shape.



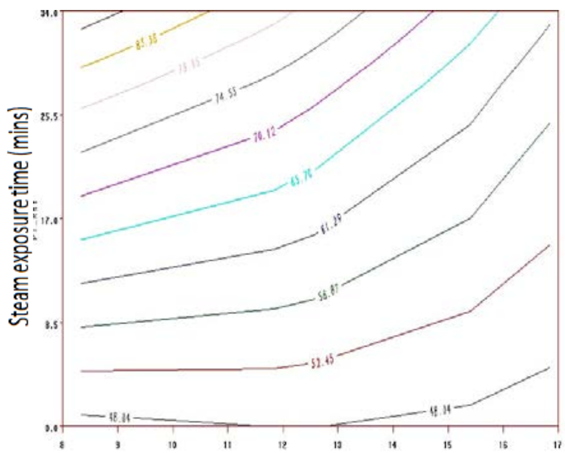
a, (Large)

Moisture content (%)



b, (Medium)

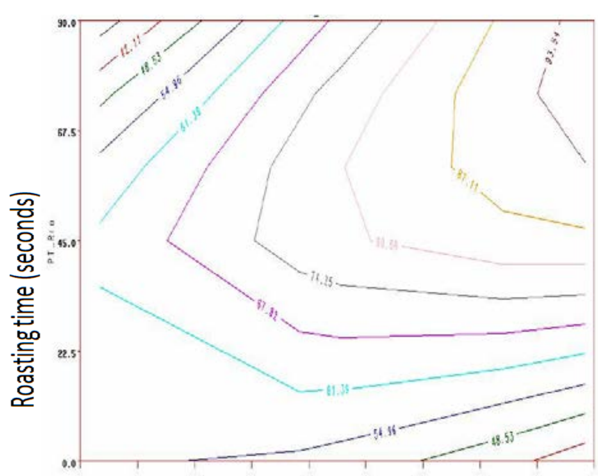
Moisture content (%)



c, (Small)

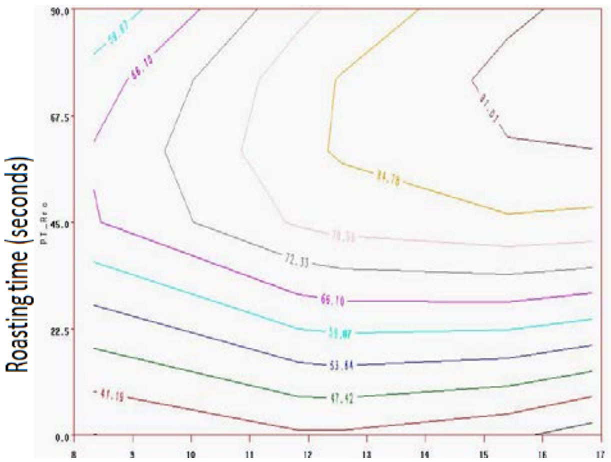
Moisture content (%)

Fig. 3. Contour plots obtained from canonical analysis of quadratic polynomial equations for the effect of moisture content and steam exposure time on the WKO of cashew nuts



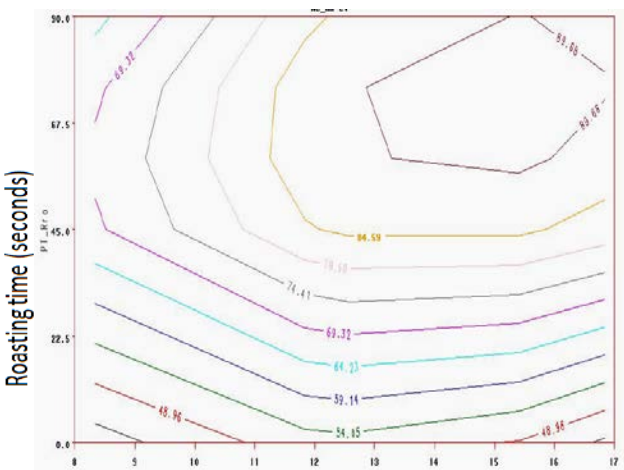
a, (Large)

Moisture content (%)



b, (Medium)

Moisture content (%)



c, (Small)

Moisture content (%)

Fig. 4. Contour plots obtained from canonical analysis of quadratic polynomial equations for the effect of moisture content and roasting time on the WKO of cashew nuts

4. CONCLUSIONS

The pre-shelling processing conditions for optimizing WKO (Y) of cashew nuts were established on the basis of nut sizes considering duration of pre-shelling treatment (X_1) and moisture content (X_2). For steam-boiled nuts, as moisture content increased and steam exposure time decreased, there was a decrease in WKO; whereas for roasted nuts, WKO increased as moisture content increased. Regression of WKO on moisture content and pre-shelling treatment for each nut size category was significant ($p<0.05$) and the models showed good correlation between WKO and the processing parameters. The adequacy of models was confirmed by comparing experimental values with predicted values. This result provides valuable information for the cashew nut processing industry on pre-export value addition to cashew nuts and promises a boost to the income obtainable from cashew nut in Nigeria.

REFERENCES

Ajav, E. A. 1996. The design and testing of a low cost cashew nut cracker for peasant farmers. Tropical Agriculture, Trinidad and Tobago. 73(3), 180 - 186.

Albiero, D, Araújo, M. C., de Oliveira Ferraz, A. C, da Silva Maciel, A. J, Dal Fabbro, I. M. 2011. Moiré optical technique for evaluation of cashew nuts (Anacardium occidentale, L.) isostrain. Engenharia Rural Revista varia Scientia Agrárias. 2(2), 9-20.

Araújo, M.C. & Ferraz, A.C. 2006. Effect of moisture content, thermal treatment and deformation on decortication of cashew nuts 'CCP - 76' by means of a guided single impact. Engenharia Agrícola. 26(2), 590 -599.

Andrighetti, L., Bassi, G. F., Capella, P., De Logu, A. M., Deolalikar, A. B., Haeusler, G., Franca F. M. C., Rivoira, G., Vannini, L. and Deserti, R. N. 1994. The World Cashew Economy. (2nd Edtion). Linchiostroblu, Italy. p 11 - 48, 79 - 80.

American Society of Agricultural Engineers (ASAE). 1998. Standards S 410.1. Moisture Measurement - Peanuts. http://www.google.com/search?hl=en&q=ASAE+standards+%2B+moisture+content+%2B+pea+nuts&aq=f&oq=&aqi= Accessed on January 10, 2009

Azam-Ali, S. H. and Judge, E. C. 2001. Small scale cashew nut processing. Intermediate Technology Development Group. Schumacher Center for Technology Development. Warwickshire, UK. FAO. p 1 - 7.

Balasubramanian, D. 2001. Physical properties of raw cashew nut. Journal of Agricultural Engineering Research. 78(3), 291 – 297.

Balasubramanian, D. 2006. Improving whole kernel recovery in cashew nut processing. Agricultural Mechanisation in Asia Africa and Latin America. 37(1), 58 - 64.

Berger, P. D. & Maurer, R. E. 2001. Experimental Design with Applications in Management, Engineering and the Sciences. 1st Edn., Duxbur Press, USA., pp: 496.

Gardiner, W. P. & Gettinby, G. 1998. Experimental Design Techniques in Statistical Practice a Practical Software based Approach. Harwood Publishing Ltd., Chichester, England. p 30 - 38.

Gómez-Caravaca, A. M., Verardo, V., Caboni, M. F. 2010. Chromatographic techniques for the determination of alkyl-phenols, tocopherols and other minor polar compounds in raw and roasted cold pressed cashew nut oils: Journal of Chromatography. 1217(47), 7411-7417

Hebbar, U. H. & Ramesh, M. N. 2005. Optimisation of processing conditions for infrared drying of cashew kernels with testa. Journal of Science Food & Agriculture, 85, 865 - 871

Jain, R. K. & Kumar, S. 1997. Development of a cashew nut sheller. Journal of Food Engineering. 32(3), 339 - 345.

Jiao, S. Li, D., Huang, Z., Zhang, Z., Bhandari, B., Chen, X. D. & Mao, Z. 2008. Optimization of supercritical carbon dioxide extraction of flaxseed oil using response surface methodology. International Journal of Food Engineering. 4(4), 1 - 16.

Kahyaoglu, T. 2008. Optimization of the pistachio nut roasting process using response surface methodology and gene expression programming. LWT Food Science and Technology, 41, 26 – 33

Kahyaoglu, T. and Kaya, S. 2006. Modelling of moisture, colour and texture changes in sesame seeds during the conventional roasting. Journal of Food Engineering, 75, 167-177.

Mendes, L. C., de Menezes, H.C., Aparecida, M. & da Silva, A. P. 2010. Optimization of the roasting of robusta coffee (C. canephoraconillon) using acceptability tests and RSM. Journal of Food Quality and Preference, 12(2), 153-162

Myers, R. H. & Montgomery, D. C. 1995. Response Surface Methodology: Process and Product in Optimization Using Designed Experiments. John Wiley and Sons, Inc., New York, USA. p 67

Nikzadeh, V. & Sedaghat, N. 2008. Physical and sensory changes in pistachio as affected by roasting temperature and storage. American-Eurasian Journal Agriculture Environment Science, 4(4), 478-483

Ogunsina, B. S. & Bamgboye A. I. 2007. Effect of pre-shelling treatment on the physical properties of cashew nut (Anacardium occidentale). International Agrophysics, 21(4), 385-389.

Ogunsina, B. S. 2010. Parameters for optimizing whole kernel out-turn of cashew nuts. PhD Thesis, Department of Agricultural and Environmental Engineering. Faculty of Technology, University of Ibadan, Nigeria.

Ogunsina, B. S. and Bamgboye, I. A. 2012. Effect of moisture content, nut size and hot-oil roasting time on the whole kernels out-turn of cashew nuts during shelling. Nigerian Food Journal. 30 (2). (In press)

Ogunsina, B. S. and Bamgboye, I. A. 2011. Crackability and whole kernel out-turn of pre-treated cashew nuts using a hand operated knife cutter. Proceedings of the 11th International Conference and 32nd Annual General Meeting of the Nigerian Institution of Agricultural Engineers, October 17–20, 2011, Ilorin, Nigeria. NIAE/2011/PHEP/004/1-8.

Ojolo, S. J. and Ogunsina, B. S. 2007. Development of a cashew nut cracking device. Agricultural Engineering International. The CIGR Ejournal. Vol. IX. Manuscript PM 06 030 June, 2007. International Commission of Agricultural Engineering. USA.

Oloso, A. O. and Clarke, B. 1993. Some aspects of strength properties of cashew nut. Journal of Agricultural Engineering Research. 55(1), 27-43

Ozdemir, M. and Devres, O. 2000. Kinetics of colour changes of hazel nuts during roasting. Journal of Food Engineering. 44, 31-38

Saklar, S. and Katnas, S. 2001. Determination of optimum hazelnut roasting conditions. International Journal of Food Science and Technology 36(2): 271-281

SAS 2002. Statistical Analytical Software Guide for Personal Computers. Release 9.1. SAS Institute inc., Cary NC 27513, USA.

Sepaskhah, A. R., Bazrafshan-Jahromi, A. R. & Shirmohammandi-Aliak-Barkhani, Z. 2006. Development and evaluation of a model for yield production of wheat, maize and sugarbeet under water and salt stresses. Biosystems Engineering. 93(2), 139-152

Shakerardekani, A. 1, Karim, R., Mohd Ghazali, H. & Chin, N. L. 2011. Effect of roasting conditions on hardness, moisture content and colour of pistachio kernels. International Food Research Journal. 18, 723-729

Slade, L. and Levine, H. 2006. Optimization of roasting process and product quality of peanuts. Journal of Thermal Analysis and Calorimetry 83(1), 163-166

Sin, H. N., Yusof, S., Abdul Hamid, N. S. & Rahman, R. A. 2006. Optimization of hot water extraction for sapodilla juice using response surface methodology, Journal of Food Engineering. 74(3), 352 - 358.

SOME ENGINEERING PROPERTIES OF PROSOPIS AFRICANA (OKPEYE) SEEDS

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ABSTRACT

An investigation was carried out on some engineering properties of Prosopis Africana seeds (Okpeye) which are needed for machine/ system design, construction and fabrication. The engineering properties investigated were both the physical and mechanical properties. The physical properties investigated include seed length, width, thickness, geometric mean diameter, arithmetic mean diameter, sphericity, aspect ratio, surface area and specific surface area. Others are solid volume, bulk volume, solid mass, solid density, bulk density, density ratio, porosity, 1000 unit mass, coefficient of static friction, moisture content and angle of repose. The mechanical properties studied were bio-yield force, rupture force, compressive strength, deformation at rupture and total strain energy.

The mean length, width and thickness of the seed were found to be 0.96 cm, 0.62 cm, and 0.42 cm respectively. The geometric mean diameter, equivalent mean diameter, arithmetic mean diameter, sphericity and aspect ratio were found to be 0.63 cm, 0.77 cm, 0.67 cm, 0,66 cm and 0.65 cm respectively while the surface area, specific surface area, solid volume and bulk volume were 1.98 cm^2, 10.92 cm^2/cm^3, 0.19 cm^3 and 50 cm^3 respectively. The coefficient of static friction obtained on three surfaces namely asbestos, aluminium, and plywood were 0.32, 0.31 and 0.33 respectively. The solid mass, 1000 unit mass, solid density, bulk density, density ratio and porosity were 0.17 g, 16.15 g, 0.94 g/cm^3, 0.84 g/cm^3, 120.03 and 13.13 % respectively. By emptying method, the angle of repose was found to be 22.5^o while moisture content wet and dry basis were 6.00 % and 5.63 % respectively. In the mechanical aspect, the average the average bio-yield force needed to crack the seed across the length width and thickness were 162.54 N, 161.28 N, and 116.55 N respectively while the average force needed to rupture the seed across the same dimensions were 175.14 N, 174.14 N and 129.15 N respectively. The mean compressive strength applied on the seed length, width and thickness were 0.88 N/mm^2, 0.88 N/mm^2 and 0.65 N/mm^2 respectively. The deformation at rupture for the three dimentions were 2.6 mm for length, 2.28 mm for width and 2.48 mm for thickness. The total strain energy expended for the length, width and thickness were 425.41 J, 396.24 J and 315.11 J respectively.

KEYWORDS: Prosopis Africana, okpeye, engineering properties, deformation at rupture, sphericity, aspect ratio.

1. INTRODUCTION

Prosopis is a genus of flowering plants in the pea family, fabaceae. It contains around 45 species of spiny trees and shrubs found in subtropical and tropical regions of the Americas, Africa, Western Asia, and South Asia. They often thrive in arid soil and are resistant to drought, on occasion developing extremely deep root systems. Their wood is usually hard, dense and durable. Their fruits are pods and may contain large amounts of sugar. The generic name means "burdock" in late Latin and originated in the Greek language. It reaches 4 – 20 m in height; has an open crown and slightly rounded buttresses; bark is very dark, scaly, slash, orange to red-brown with white streaks. The English name of Prosopis Africana (Okpeye) is a matter of controversy as some people call it iron tree while others identify iron tree as a different tree but it is popularly known all over the world as mesquite. Due to the large numbers of species, however, most research reports use the scientific name to identify the particular specy which is under study. It was once said that Prosopis Africana is the only tropical Africana Prosopis species, occurring from Senegal to Ethiopia in the zone between the Sahel and savannah forests of Africa especially in Nigeria and Senegal. Due to extensive over exploitation, it has disappeared from extensive parts of the Southern Sahel and the adjacent Sudan savannahs (Von May dell, 1986; Vogt, 1995). The trees of Prosopis Africana are common in the Middle belt and Northern parts of Nigeria. The local names In Nigeria are Ayan (Yoruba), Ubwa (Igbo), Kiriya (Hausa), Kohi (Fula) and Okpeye (Idoma/Tiv). Though this fruit is edible, it is often not deliberately cultivated but grows wild which makes it an endangered specy.

Prosopis africana is a perennial leguminous tree of the subfamily of mimosoidae (Keay et al., 1964; Agboola, 2005) In Nigeria, the seeds are very important to the Idomas, Tives, Igbos, Igalas and Ebiras who use them to prepare delicacious, spicious food condiment known as Okpeye which is consumed by more than 10 million people (Onyeyiola, 1999). The condiment which is prepared by the fermentation of the seed is very rich in protein, ash, fibre, fatty acid and a little quantity of vitamins (Barminas *et al*., 1998). The pod pulp of Prosopis africana contains an energy value of 1168 J, 9.6 % protein, 3 % fat and 53 % carbohydrate. It contains 160 mg of calcium and 70 mg of iron per 100 g of fresh weight (FAO, 2003). Prosopis Africana trees have multiple applications. The trees can be used as valuable sources of fuel by rural communities of developing countries for cooking, heating and drying of fishes and other crops. It can also be a source of timber for the construction of furniture, hoes, pestles, bows and mortars as well as for fencing. It could also be used as shade from the sun and shelter from wind, food for people and fodder for animals. In many instances it could be used for erosion control, soil stabilization and soil nutrient. When dried the roots could be used as chewing stick by the Yorubas in Nigeria in order to promote dental health and improve oral hygiene. Almost all parts of the plants has medicinal uses. In Mali the leaves are used to treat headache, tooth ache as well as other head ailment. The bark and leaves are combined to treat rheumatism. The bark, twigs and roots are used to treat and relieve bronchitis. Fishermen use the pounded dried fruit as fish poison. The bark and root can be used as tannin or dyestuff and the pod ashes are a source of potassium for making soap used to treat skin disease, fevers and as eyewashes. The bark and root contain 14 – 16 % tannin and a colouring matter that gives a reddish tint to leather. Kerry (2008) reported that the plants have also been incorporated in the treatment of dermatitis, tooth decay, dysentery, malaria and stomach cramps. In Ghana, boiled roots serve as poultice for sore throat; root decoction for toothache and the bark are used for the treatment and dressing or lotion for wounds or cuts (World Agroforestry Centre, 2008).

Despite the huge economic and agricultural potential of this seed, very little information is available in literature on the engineering properties (physical and mechanical properties) of the seed. Yet these are all relevant parameters in the design of machines, systems, controls and equipment for the mechanization of processing, storage, harvesting and transportation of these seeds. All that are avalaible in literature are Phytochemical Composition and Antimicrobial Activity of *Prosopis africana* Against Some Selected Oral Pathogens **(**Kolapo *et al*., 2009),

Many researchers have determined the physical properties of other seeds and grains, viz., pigeon pea (Shepherd & Bhardwaj, 1986), gram (Dutta *et al*., 1988), soyabean (Sreenarayanan *et al*., 1988; Deshpande *et al*., 1993), oil bean seed (Oje & Ugbor, 1991), neem nuts (Visvanathan et al., 1996), karingda seed (Suthar & Das, 1996), cumin seed (Singh & Goswami, 1996), lentil seeds (Carman, 1996), sunflower seeds (Gupta & Das, 1997), coffee (Chandrasekar & Viswanathan, 1999), green gram (Nimkar & Chattopadhyaya, 2001), chick pea seeds (Konak *et al*., 2002), quinoa seeds (Vilche *et al*., 2003), hemp seed (Sacilik *et al*., 2003), faba bean (Haciseferogullaria *et al*., 2003), African yam beans (Asoiro and Ani, 2011), rapeseed (Calisir *et al*., 2005) and Jatropha (Shkelqim and Joachim, 2010) but only few information on engineering properties- physical and mechanical properties of this seed. The only available work in this area was by Akaimo and Raji (2006) which concentrated on the physical properties of this seed alone and nothing on the mechanical properties. The size and shape are, for instance, important in their electrostatic separation from undesirable materials and in the development of sizing and grading machinery (Mohsenin, 1986). The shape of the material is important for an analytical prediction of its drying behavior (Esref and Halil, 2007). Bulk density, true density and porosity (the ratio of intergranular space to the total space occupied by the grain) can be useful in sizing grain hoppers and storage facilities; they can affect the rate of heat and mass transfer of moisture during aeration and drying processes. Seed bed with low porosity will have greater resistance to water vapor escape during the drying process, which may lead to higher power to drive the aeration fans. Grain or seed densities have been of interest in breakage susceptibility and hardness studies. The static coefficient of friction is used to determine the angle at which chutes must be positioned in order to achieve consistent flow of materials through the chute. Such information is useful in sizing motor requirements for seed transportation and handling (Ghasemi *et al*., 2007). The design of storage and handling systems for seeds requires data on bulk and handling properties, friction coefficients on commonly used bin wall materials (galvanized steel, plywood and concrete) and emptying and filling angles of repose (Parde *et al*., 2003). Theories used to predict the pressures and loads on storage structures (Lvin, 1970), require bulk density, angle of repose and friction coefficients against bin wall materials. Also the design of grain hoppers for processing machinery requires data on bulk density and angle of repose. An example of the use of various bulk and handling properties of seeds in the design of storage structures is given by Singh and Moysey (1985). The angle of repose determines the maximum angle of a pile of seeds with the horizontal plane. It is important in the filling of a flat storage facility when seeds are not piled at a uniform bed depth but rather is peaked (Mohsenin, 1986). Hence, current study was conducted on investigate some engineering properties (physical and mechanical) of Prosopis africana seed (Okpeye) in other to come up with a valuable design data for its mechanization and processing.

2. MATERIALS AND METHODS

2.1 Sample

The matured - dried seed pod of Prosopis Africana (Figure 1) were sourced from some local farmers in Allome village, Kogi state of Nigeria. The seeds (Figure 2) were removed from the pod and cleaned manually by hand to remove all foreign matter such as dust, dirt, pieces of stones, chaff as well as broken and immature seeds. Measurement of the physical and mechanical properties were later carried out in the Food and Bioprocess Laboratory and Civil Engineering Laboratory, respectively both in the University of Nigeria, Nsukka.

Figure 1. Mature Pods of Prosopis Africana

Figure 2. Matured Seeds of Prosopis Africana with a Vernier Calliper for Measurement

2.2 Physical Properties

2.2.1 Determination of Moisture Content

The moisture content of the seed was determined using the ASAE (1983) recommended method for edible beans. This involves the oven drying of seed samples at 103^{o}C for 72 hours. The samples were allowed to cool in a dessicator (Glaswerk Wertheim, Model 471, Size 1172, Germany) after which it was weighed and recorded using an electronic balance (Yamato, model HB 3000, Japan) reading to 0.01g in order to determine the moisture loss. Twenty (20) samples were randomly collected from 50 kg of Prosopis africana. Each of the samples used weigh 20g. The measurement on each sample were replicated three times and the average moisture content taken. The moisture content of the seed in % (wet and dry basis) was calculated with the following formula:

$$MC_{wb} = 100\frac{M_i - M_f}{M_i} \qquad (1)$$

$$MC_{db} = 100\frac{M_i - M_f}{M_f} \qquad (2)$$

Where MC_{wb} and MC_{db} are moisture content wet basis and moisture content dry basis of seed (%) respectively, M_i and M_f are initial mass and final mass of seed (g or kg) respectively.

2.2.2 Determination of Solid Density, Bulk Density, Density Ratio and Porosity

The solid density is the ratio of mass sample of the seed to its solid volume. It was determined by the water displacement method (Mohsenin, 1986).

Bulk density is the ratio of the mass sample of the seed to its total volume. It was determined by filling a predefined container from a constant height, striking the top level and then weighing the constants (Deshpande et al., 1993; Gupta and Das, 1997; Konak et al., 2002; Paksoy and Aydin, 2004; and Asoiro and Ani, 2011).

The density ratio D_r is the ratio of solid density to bulk density expressed as a percentage as follows:

$$D_r = \frac{\ell_s}{\ell_b} \times 100 \qquad (3)$$

The porosity is the ratio of free space between seed to total of bulk seed. It is expressed in percentage. This was determined as:

$$\varepsilon = \frac{\ell_s - \ell_b}{\ell_s} \times 100 \qquad (4)$$

Where ε is porosity in percentage, ℓ_b and ℓ_s are bulk density and solid density (g/cm^3 or kg/m^3) respectively.

2.2.3 Determination of Size and Shape

A Vernier caliper (Mitutoyo, model Absolute Digimatic, Japan) reading to 0.01 mm was used to measured the lenght, width and thickness of Prosopis africana seed. This was done using 100 randomly selected seeds from a 50kg weight as demonstrated by Mohsenin (1980). The geometric mean diameter, D_g , equivalent mean diameter, D_p and arithmetic mean diameter, D_a , in cm was calculated by using equations (5), (6) and (7) respectively as presented in the expressions:

$$D_g = (LWT)^{\frac{1}{3}} \qquad (5)$$

$$D_p = \left[L \frac{(L+T)^2}{4} \right]^{\frac{1}{3}} \qquad (6)$$

$$D_a = \frac{(L+W+T)}{3} \qquad (7)$$

Where, L=length;W=width and T=thickness in cm

The sphericity (S_p) defined as the ratio of the surface area of the sphere having the same volume as that of seed to the surface area of seed. It was determined using the expression in equation (8) (Mohsenin, 1986):

$$S_p = \frac{(LWT)^{\frac{1}{3}}}{L} \text{ or } \frac{D_g}{L} \qquad (8)$$

The aspect ratio (R_a) was calculated using equation. (9) as given by Omobuwajo *et al.* (1999)

$$R_a = \frac{W}{L} \qquad (9)$$

2.2.4 Determination of Surface Area and Specific Surface Area

Surface area S (mm^2) and specific surface area Ss (cm^2 /cm^3) were estimated by the relationship given by Asoiro and Ani (2011) which is given in equation (10) as:

$$S = \prod D_g{}^2 \text{ or } \prod (LWT)^{\frac{1}{3}} \qquad (10)$$

Where S is surface area (cm^2) and D_g is geometric mean diameter (cm).

The specific surface area is given by the expression in equation. (11)

$$S_s = \frac{S}{V} \text{ or } \frac{S\ell_b}{M_s} \qquad (11)$$

Where S_s is specific surface area (cm^2 /cm^3), S is the surface area (cm^2), M_s is mass of unit seed (grams) and ℓ_b is the bulk density of seeds (g/cm^3)

2.2.5 Determination of Solid Volume and Bulk Volume

The volume of the individual and bulk seeds were determined by water displacement method equations (12) and (13) were used for their calculations.

$$V_s = \frac{M_w}{\ell_t} \qquad (12)$$

Where V_s is solid volume (cm^3), M_w is the mass of individual seed in water (grams) and ℓ_t is density of water (1.0 g/cm^3).

$$V_b = \frac{M_{wb}}{\ell_t} \qquad (13)$$

Where V_b is bulk volume (cm^3), M_{wb} is the mass of bulk seed in water (grams) and ℓ_t is the density of water (1.0 g/cm^3)

2.2.6 Determination of Coefficient of Static Friction on Various Surfaces

The coefficient of static friction of the seeds was determined against three structural materials: asbestos, aluminum and plywood. A wooden box measuring 450 mm X 300 mm X 120 mm was constructed without a base (Olajide *et al*., 2000) and placed on an adjustable tilting plate, facing the test surface. There were two pieces of plastic between the box and the plate placed under the sides of the walls of the box oppositely to raise the box up and not to touch the plate surface. Then the box was filled with the sample, the two pieces of plastic removed which made the box to remain above the plate, but the sample touched the plate. The inclination of the plate was increased gradually by a screw device until the box just starts to slide down. The angle of tilt ϕ in degree was read from a graduated scale. This was done in five replicates and the coefficient of static friction, μ calculated from the expression (Shepherd and Bhardwaj, 1986; Joshi *et al*., 1993; and Pliestic et al., 2006) in equation (14) below:

$$\mu = \text{Tan}\,\phi \qquad (14)$$

Where μ is the coefficient of friction

2.2.7 Determination of Angle of Repose

The angle of repose indicates the cohesion among the individual units of the seed. The higher the cohesion, higher is the angle of repose. The dynamic angle of repose is the angle with the horizontal at which the material will stand when piled. The angle of repose is determined using a hollow cylinder and then trigonometry rules (Heidarbeigi *et al*. 2008). The angle of repose of Prosopis africana seed was measured by the emptying method put forward by Shkelqim and Joachim (2010), and calculated using the expression in equation (15).

$$\theta = Tan^{-1}\left(\frac{2H}{D}\right) \qquad (15)$$

Where θ is angle of repose (^{o}), H is height of the pile (cm) and D is diameter of the pile (cm).

2.2.8 Determination of Solid Mass and Thousand Unit Mass of Seeds

1000 units of the seed were randomly selected from a mass of 50 kg, weighed and recorded. This was replicated five times and the average taken.

2.3 Mechanical Properties

Mechanical properties such as bio-yield force, rupture force, compressive strength, deformation at rupture and total strain energy of Prosopis africana seed were evaluated using 15 samples of the seed. Five samples of the seed were tested for each of the lenght (a), width (b) and thickness (c) loading direction and replicated. This was done by means of a UK- made Universal Testing Machine (Monsanto Tensometer A220 - 9) with Prosopis Africana under test, as shown in Figure 3. The machine was equipped with a load cell of 500 N at a compressive rate of 25 mm/min.

Figure 3. Universal Testing Machine (Monsanto Tensometer) with Prosopis Africana Seed under test.

2.3.1 Determination of Bio-yield Force

The bio-yield force is the force at which the sample begins to fail. This is the force at which the material yields. Further application of force beyond the bio-yield force ruptures the sample.

2.3.2 *Determination of Rupture Force*

The rupture force, F_R (N) is the minimum force required to break the sample. Rupture force and deformation of samples were expressed in terms of the peak of force - deformation curve.

2.3.3 *Determination of Compressive Strength*

Compressive strenght was calculated as the rupture force divided by the deformation. Compressive strength, H (N/mm) is the ratio of rupture force and deformation at rupture point. It was calculated using equation 16:

$$H = \frac{F_R}{R_{DR}} \qquad 16$$

2.3.4 *Determination of Deformation at Rupture*

Deformation at rupture point, R_{DR} (mm) is the deformation at loading direction.

2.3.5 *Determination of Total Strain Energy*

Energy for rupture, E_R (Nmm) is the energy needed to rupture the sample, which could be determined from the area under the curve between the initial point and the rupture point. The area was measured by using a polarplanimeter with accuracy of ±0.2% (model: OTT - Kompensations - Polarplanimeter).

3. RESULTS AND DISCUSSION

3.1 Physical Properties

Table 1 shows the summary results of the physical and mechanical properties of prosopis africana.

Table 1. Summary of the engineering properties (physical and mechanical properties) of prosopis africana (Okpeye)

Physical Properties					
Property	N	Mean	Standard Deviation (SD)	Maximum Value	Minimum Value
Length, L(cm)	100	0.9649	0.0848	1.25	0.76
Width,W(cm)	100	0.6236	0.0525	0.76	0.52
Thickness, T(cm)	100	0.4186	0.0413	0.53	0.3
Geometric Mean Diameter,Dg(cm)	100	0.6300	0.0361	0.7453	0.5490
Equivalent Mean Diameter, Dp(cm)	100	0.7728	0.0567	0.9704	0.642
Arithmetic Mean Diameter, Da(cm)	100	0.6690	0.0394	0.81	0.5767
Sphericity, Sp	100	0.6557	0.0432	0.7469	0.4963
Aspect Ratio, Ra	100	0.6500	0.0676	0.8333	0.4262
Surface Area, S(cm^2)	100	1.9794	0.1135	2.3417	1.7250
Specific Surface Area, Ss(cm^2/cm^3)	100	10.9173	1.7692	17.0531	7.4919
Solid Volume, Vs(cm^3)	100	0.1852	0.0272	0.2567	0.1305
Bulk Volume, V_b (cm^3)	20	50	0.0000	50	50
Solid Mass, M_s (g)	100	0.1705	0.0322	0.2273	0.0612
Solid Density, ℓ_s (g/cm^3)	100	0.9374	0.2135	1.5939	0.3031
Bulk Density, ℓ_b (g/cm^3)	20	0.8375	0.0355	0.9051	0.8020
Density Ratio, D_r	20	120.0276	21.7929	145.94	65.3455
Porosity, ε	20	13.1313	21.2134	31.4787	-53.0327
1000 Unit Mass (g)	5	16.1488	0.3538	16.4930	15.6344
Coefficient of static friction on various surfaces					
Asbestos	5	0.3228	0.0318	0.352	0.2772
Aluminium	5	0.3092	0.00904	0.3162	0.2944
Plywood	5	0.3331	0.00858	0.343	0.3207
Angle of repose					
Emptying Method	5	22.5	0.37	22.72	21.58

(°)					
Moisture content					
Dry Basis,db(%)	20	5.9988	0.8040	7.8620	4.8715
Wet Basis, wb(%)	20	5.6257	0.6483	7.0853	4.6452
MECHANICAL PROPERTIES					
Seed Length, L					
Bio-yield Force (N)	5	162.54	21.6641	182.7	126
Rupture Force (N)	5	175.14	18.9786	189	141.75
Compressive Strenght(N/mm^2)	5	0.8848	0.0959	0.9548	0.7161
Deformation at Rupture (mm)	5	2.6	0.9454	3.75	1.75
Total Strain Energy (J)	5	425.4075	149.8677	639.45	248.0625
Seed Width, W					
Bio-yield Force (N)	5	161.28	28.3850	185.85	116.55
Rupture Force (N)	5	175.14	26.5050	204.75	135.45
Compressive Strenght(N/mm^2)	5	0.8848	0.1339	1.0344	0.6843
Deformation at Rupture (mm)	5	2.276	0.3583	2.75	1.75
Total Strain Energy (J)	5	396.2386	72.4442	487.305	292.1625
Seed Thickness, T					
Bio-yield Force (N)	5	116.55	37.0711	163.8	78.75
Rupture Force (N)	5	129.15	38.1267	185.85	97.65
Compressive Strenght(N/mm^2)	5	0.6525	0.1926	0.9389	0.4933
Deformation at Rupture (mm)	5	2.476	0.5330	3.25	1.75
Total Strain Energy (J)	5	315.1071	103.5567	491.4	244.125

The discussion on the results is as follows:

3.1.1 Moisture Content

The moisture content value dry basis vary from 4.87 % to 7.87 % with mean value of 6.00 % and a standard deviation of ±0.80. For wet basis, the moisture content mean was slightly lower than that of dry basis by 6.63%. The mean moisture content, wet basis is 5.63 % with a minimum and maximum value of 4.65 % and 7.09 % respectively.

3.1.2 Solid Density, Bulk Density, Density Ratio and Porosity

The mean solid density and bulk density are 0.93 g/cm^3 and 0.84 g/cm^3 respectively. The solid density is a slightly more than the bulk density by a value of 11.93%. From the results, the seeds are less dense than water. This makes it possible to separate them from materials that are more dense in water. The density ratio is very high with a mean value of 120.03 and a standard deviation of ±21.80. The density ratio range from a minimum value of 65.35 to a maximum value of 145.94. Prosopis Africana seeds have less pore spaces. The porosity value ranges from -51.03 % to 31.48 % with a mean value of 13.13 %. This value shows how easily a stream of heated air for drying will pass through a pack of material. This will affect the rate of drying of the material. This very important property is required in air and heat flow in agricultural materials. Seeds with low porosity has less pore spaces and hence will dry very slowly. During aeration of this seeds, high power fans and motor is needed to pass cold air through the pore spaces. Natural aeration will be very difficult and an unlikely choice.

3.1.3 Size and Shape

The mean seed length, width and thickness are 0.96 cm, 0.62 cm and 0.42 cm respectively. The mean for the geometric mean diameter, equivalent mean diameter, and arithmetic mean diameter are 0.63 cm, 0.77 cm and 0.67 cm respectively while the aspect ratio range from 0.43 to 0.83 with a mean value of 0.65. The shape of the seed is almost a sphere with ranges between 0.50 to 0.75, and a mean value of 0.66 ± 0.04. This shows that this seed will tend to roll when it is on a particular orientation. These properties are always considered when designing hoppers and dehulling equipment for seeds and grains.

3.1.4 Surface Area and Specific Surface Area

The surface area of prosopis africana seed is very small from 1.73 cm^2 to 2.34 cm^2 with a mean value of 1.98 cm^2 ± 0.11. The surface area of a biomaterial affects the velocity of air stream that can be used in other to separate the material from an unwanted materials in pneumatic separator or to convey seed in pneumatic conveying. The mean specific surface area is also very small (10.92 cm^2/cm^3). This implies that the mass or energy transfer rate through the surface of the material will be small.

3.1.5 Solid Volume and Bulk Volume

The solid volume of the seed range from 0.1305 cm^3 to 0.26 cm^3 with a mean value of 0.19 cm^3. The bulk volume is 50 cm^3.

3.1.6 Coefficient of Static Friction on Various Surfaces

Plywood, because of its rough surface has the highest coefficient of static friction (0.33) followed by Asbestos (0.32) and Alumminum (0.31). Surface roughness, as shown from the results, affects the coefficient of static friction. The more the roughness of these material surfaces the higher the coefficient of static friction. These values determine how a pack of seeds or grain will flow in these systems (surfaces). This is a design parameter needed in the design of agricultural machine hoppers and other conveying equipment

3.1.7 Angle of Repose

Using the emptying method, the angle of repose of prosopis africana is 22.5^o. The values range from 21.58^o and 22.72^0 with a standard deviation of ± 0.37. This property help to determine the minimum slope of flow in self emptying bin and minimum slop flow in a hopper.

3.1.8 Solid Mass and Thousand Unit Mass of Seeds

The seed has a mean solid mass of 0.17 g which ranges from 0.06 g to 0.23 g. The mean value of the 1000 unit mass of the seed is 16.15 g with ranges of values between 15.64 g and 16.15 g.

3.2 Mechanical Properties

Bio-yield force, rupture force, compressive strength, deformation at rupture and total strain energy: Prosopis africana seed length has the highest bio-yield force (162.54 N) when compared with the width (161.28 N) and Thickness (116.55 N). The rupture force for the seed is the same for both the seed length and width with a value of 175.14 N while the value for the thickness is 129.15 N and ranges from 97.65 N to 185 N. This implies that the seed is stronger across the length and width but weaker across the thickness. It will require a less force to crack the seed across the thickness than across the length and width. The mean compressive strength for the seed across the length is 0.88 N/mm^2 with ranges of 0.72 N/mm^2 to 0.95 N/mm^2. The value across the width is the same with that across the length with ranges of 0.68 N/mm^2 and 1.03 N/mm^2.

The compressive strength of the seed across the thickness ranges between 0.49N/mm^2 to 0.94 N/mm^2 with a mean value of 0.65 N/mm^2. The deformation at rupture is 2.6 mm for length, 2.28 mm for width and 2.48 mm for thickness with ranges of the length, width, and thickness as 1.75 mm to 3.75 mm, 1.75 mm to 2.75 mm and 1.75 mm to 3.25 mm respectively. The total strain energy for breaking the seed is 425.41 J across the length, 396.24 J across the width and 315.11 across the thickness with ranges of 248.06 J to 639.45 J, 292.16 J to 487.31 J and 244.13 J to 491.4 J, 292.16 to 487.31 J and 244.13 J to 491.4 J for the length, width and thickness, respectively. The force- deformation curve for the seed across the length, width and thickness are presented in Figure 4, 5 and 6 respectively.

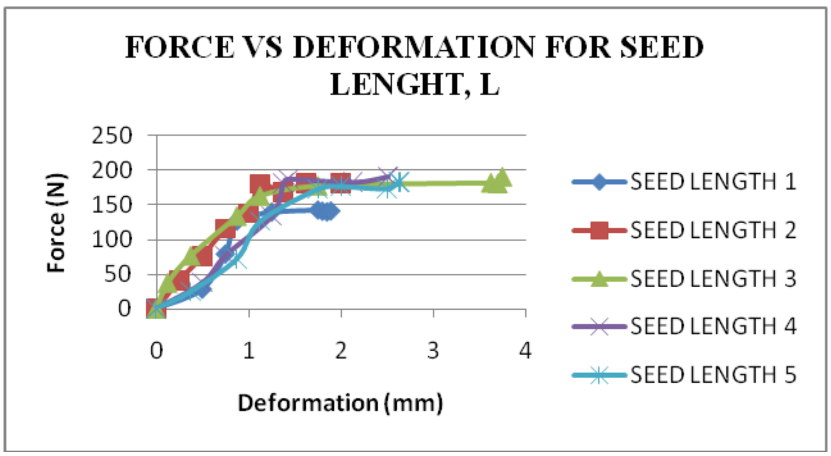

Figure 4. Force vs Deformation Curve for Prosopis Africana Seed Length, L

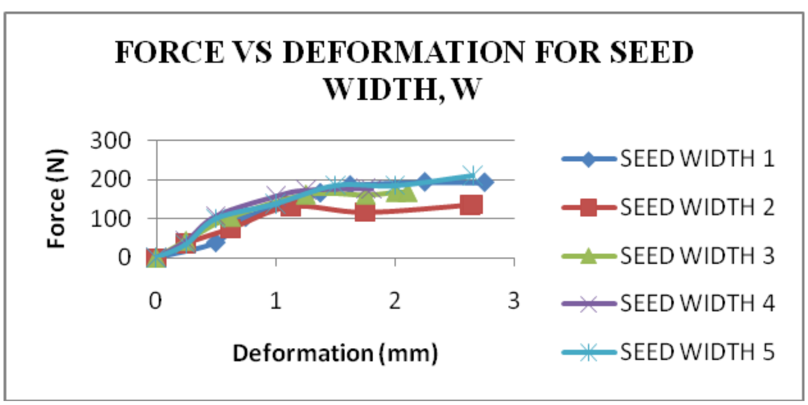

Figure 5. Force vs Deformation Curve for Prosopis Africana Seed Width, W

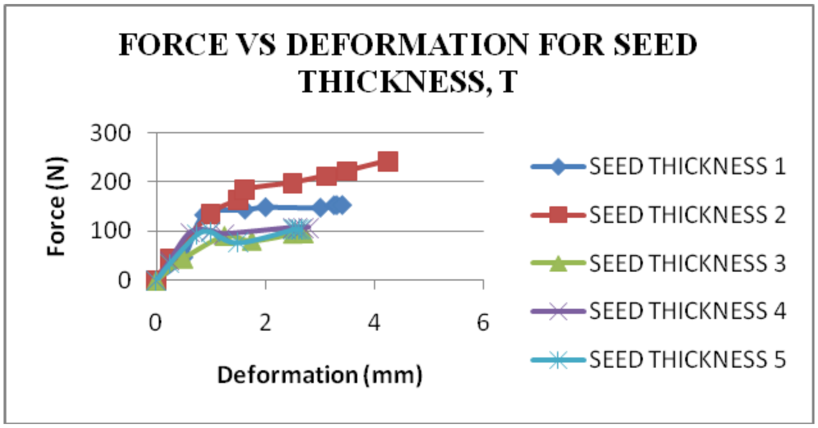

Figure 6. Force vs Deformation Curve for Prosopis Africana Seed Thickness, T

4. CONCLUSIONS

Some engineering properties (physical and mechanical) of Prosopis Africana (Okpeye) seed were determined. These properties are needed for the design of systems for postharvest operations. The physical properties determined were the dimensions, sphericity, surface area, specific surface area, volume, mass, density, coefficient of static friction on three different material surfaces, porosity and angle of repose. The mechanical properties investigated were the force of deformation, compressive strength, deformation and total strain energy, all across the various dimensions.

Dimensions for Prosopis africana seed (Okpeye) ranges from 0.42cm to 0.96cm while the sphericity (0.66) indicated that the material was close to a sphere and will tend to roll when placed on a particular orientation. The surface area, specific surface area, solid volume, bulk volume, solid mass, solid density, bulk density and 1000 unit mass were determined as 1.98 cm^2, 10.92 cm^2/cm^3, 0.19 cm^3, 50 cm^3, 0.17 g, 0.94 g/cm^3, 0.84 g/cm^3 and 16.15 g respectively. The densities showed that the seed will float in water. This makes it possible to separate from materials that are denser than water such as sand and stone. The coefficient of static friction for the three different material surfaces studied showed that Plywood offered the most resistance to flow (0.33), followed by Asbestos (0.32) and Aluminium (0.31).these values are needed in the design of agricultural machine hopper and other conveying equipment. The porosity of the seed is small (13.13 %). Due to this, drying would be slow. High powered fan is needed to pass cold air through the pore spaces during aeration. Natural aeration would be difficult and an unlikely choice. The angle of repose, moisture content wet and dry basis were 22.5^o, 5.63 % and 6.00 % respectively. The force needed to crack the seed were found to be highest across the length(162.54 N) and least across the thickness(116.55 N) while the force needed to rupture the seed were found to be highest across both the length and width(175.14N) and least across the thickness(129.14 N). The compressive strength was maximum across both the length and width (0.88 N/mm^2) and minimum across the thickness (0.65 N/mm^2). The total strain energy was maximum across the length (425.41 J) and minimum across the thickness while the deformation at rupture was maximum across the length (2.6 mm) but minimum across the width (2.276 mm).

REFERENCES

Asoiro F U and Ani A O. 2011. Determination of some physical properties of African yam beans, Pacific Journal of Science and Technology. 12(1):374-380.

Agboola, D.A. 2005. Prosopis Africana (mimosaceae): Stem, roots and seeds in the economy of the savanna areas of Nigeria. Econom. Bot., 58: S34-S42.

Akaaimo, D.I. and A.O. Raji. 2009. Some Physical and Engineering Properties of Prosopis africana seed. Biosystems Engineering, 95 (2), 197–205.

Akinnagbe, A and Oni, O. 2007. Quantitative variations in the growth of progeny seedlings of *Prosopis africana* (Guill., Perrott. And Rich.) Plus trees in Nigeria. African Journal of Biotechnology Vol. 6(4) pp. 359-363, 19 February 2007.

Aremu, M. O; Olonisakin, A; Atolaye, B. O. and Ogbu, C. F.2006. Some nutritional and functional studies of Prosopis Africana. EJEAF Chem, 5 (6) pp.1640-1648.

Barminas J T; Marina H M; Ali J. 1998. Nutrient content of Prosopis africana seeds. Plant Foods for Human Nutrition, 52(4), 325–328. Biosyst. Eng. 86 (2), 191–198.

Calisir S; Marakoglu T; Ogut H; Ozturk O. 2005. Physical properties of rapeseed (Brassica napus oleifera L.). Journal of Food Engineering, 69, 61–66.

Carman K 1996. Some physical properties of lentil seeds. Journal of Agricultural Engineering Research, 63, 87–92.

Chandrasekar V; Viswanathan R .1999. Physical and thermal properties of coffee. Journal of Agricultural Engineering Research, 73(2), 227–234.

Deshpande S D; Bal S; Ojha T P .1993. Physical properties of soybean. Journal of Agricultural Engineering Research, 56(2), 89–98.

Dutta S K; Nema V K; Bhardwaj R K .1988. Physical properties of gram. Journal of Agricultural Engineering Research, 39(4), 259–268.

Esref, I. and U. Halil, 2007. Moisture-dependent physical properties of white speckled red kidney bean grains. J. Food. Eng., 82: 209-216.

FAO. 2003. Non-Wood Forest products and Nutrition. Food and Agricultural Organisation of the United Nations, Food and Nutrition Division Publication.

Ghasemi Varnamkhasti, M., H. Mobli, A. Jafari, S. Rafiee, M. Heidary Soltanabadi and K. Kheiralipour, 2007. Some Engineering Properties of Paddy (var. Sazandegi). Int. J. Agric and Biol., 5: 763-766.

Gupta R K; Das S K 1997. Physical properties of sunflower seeds. Journal of Agricultural Engineering Research, 66, 1–8.

Haciseferogullaria H; Gezer I B; Bahtiyarca Y C; Menges H O.2003. Determination of some chemical and physical properties of sakiz faba bean (Vicia faba L. Var. major). Journal of Food Engineering, 60, 475–479.

Heidarbeigi K, H. Ahmadi, K. Kheiralipour and A. Tabatabaeefar. *2008.* Some Physical and Mechanical Properties of Iranian Wild Pistachio (*Pistachio mutica L.*). American-Eurasian J. Agric. & Environ. Sci., 3 (4): 521-525.

Joshi, D.C., S.K. Das, and R.K. Mukherjee. 1993. “Physical Properties of Pumpkin Seeds”. *Journal of Agricultural Engineering Research*. 54:219– 229.

Journal of Food Engineering, 60, 475–479.

Keay, R.W.J., C.F.A. Onochie and D.P. Stanfield, 1964. The Nigerian trees Vol II. Federal Forestry Reseach. Ibadan, pp: S113-S114.

Kerry, B., 2008. Phytotherapy for Periodontal disease and improved oral hygiene (Phytotherapy Review and Commentary) http://www.mediherb.com.

Kolapo A.L.; M.B. Okunade ; J.A. Adejumobi and M.O. Ogundiya. 2009. Phytochemical Composition and Antimicrobial Activity of *Prosopis africana* Against Some Selected Oral Pathogens. World Journal of Agricultural Sciences 5 (1): 90-93, 2009.

Konak M; Arman K C; Aydin C (2002). Physical Properties of Chick Pea Seeds. Biosystems Engineering, 82(1), 73–78.

Lvin, J.B., 1970. Analytical evaluation of pressures of granular materials on silo walls. Powder Tech, 4: 280-285.

Mohsenin, N.N., 1986. Physical Properties of Plant and Animal Materials, seconded. Gordon and Breach Science Publishers, New York.

Nimkar P M; Chattopadhyaya P K .2001. Some physical properties of green gram. Journal of Agricultural Engineering Research, 80(2), 183–189.

Oje K and Ugbor E C .1991. Some physical properties of oil bean seed. Journal of Agricultural Engineering Research, 50(4), 305–313.

Olajide, J.O, B.I.O. Adepomowaye, and E.Y Otunola. 2000. "Some Physical Properties of Shea Kernel". *Journal of Agric, Engr. Res.* 76:419-421.
Omafuvbe, B.O; S.H. Abiose and O.O. Adaraloye. 1999. The production of 'Kpaye' – a fermented condiment from *Prosopis africana* (Guill and Perr) Taub. Seeds. International Journal of Food Microbiology 51, 183–186.
Omobuwajo. O.T., A.E. Akande and A.L. Sann, 1999. Selected physical, mechanical and aerodynamic properties African Breadfruit (Treculia Africana) seeds. J. Food. Eng., 40: 241-244.
Oyeyiola G P. 1999. Fermentation of Ogiri http://www. Biologie.uni-hambood.de/b-online/ibi99/ibc/abstracts5028. html. HTML-Version made July 1999 by Kurt Stuber.
Paksoy, M. and C. Aydin, 2004. Some physicalproperties of edible squash (*Cucurbita pepo* L.) seeds. J. Food Eng., 65: 225-231.
Parde. S.R., A. Johal, D.S. Jayas and N.D.G. White, 2003. Physical properties of buckwheat cultivars. Canadian Bio-systems. Eng, Technical Note.
Pliestic, S., N. Dobricevic, D. Filipovic, and Z. Gospodaric. 2006. Physical Properties of Filbert Nut and Kernel. *Journal of Biosystems Engineering*. 93(2):173-178.
Sacilik, K., Ozturk, R and Keskin, R., 2003. Some physical properties of hemp seed.Biosystems Engineering, 86 (2),191-198
Shepherd H; Bhardwaj R K .1986. Moisture-dependent physical properties of pigeon pea. Journal of Agricultural Engineering Research, 35(4), 227–234.
Shkelqim K and Joachim M. 2010. Determination of physical, mechanical and chemical properties of seeds and kernels of Jatropha curcas L. Industrial Crops and Products 32 (2010) 129–138.
Singh K K; Goswami T K .1996. Physical properties of cumin seed. Journal of Agricultural Engineering Research, 64, 93–98.
Singh, D. and E.B. Moysey, 1985. Grain bin wall pressures. Theoretical and experimental. Canadian Agric. Eng., 27: 43-48.
Sreenarayanan V V; Viswanathan R; Subramanian V .1988. Physical and thermal properties of soybean. Journal of Agricultural Engineering, 25(4), 76–82.
Suthar S H; Das S K (1996). Some physical properties of karingda [Citrullus lanatus (Thumb) Mansf] seeds. Journal of Agricultural Engineering Research, 65, 15–22.
Vilche C; Gely M; Santalla E 2003. Physical properties of quinoa seeds. Biosystems Engineering, 86(1), 59–65.
Visvanathan R; Palanisamy P T; Gothandapani L; Sreenarayanan V V (1996). Physical properties of neem nut. Journal of Agricultural Engineering Research, 63, 19–26.
Vogt, K. A.1995. Field guide to the identification, propagation and uses of common trees and shrubs of dry land Sudan. SOS, SAHEL International (1995).
Von May dell, H. J.1986. Trees and Shrubs of the Sahel – their characteristics and uses. GTZ6MBH, Esuborn (1986).
World Agroforestry Centre(WAC). 2008. Agroforestree Database. http://www.worldagroforestrycentre.org/ sites/treedbs/aft/speciesPrinterFriendly.asp?Id=1346. Accessed on November 27, 2003.

EMPIRICAL MODELS FOR PREDICTION OF NUTRITIONAL PARAMETERS OF STORED BANANAS

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ABSTRACT

A study was conducted to develop empirical models to predict nutritional parameters of stored bananas. Three sets of four different types of passive evaporative cooling structures made of two different materials; clay and aluminium were designed and constructed as part of the study. One set consisted of four separate cooling chambers. Two cooling chambers were made with aluminium container (cylindrical and rectangular shapes) and the other two were made of clay container (cylindrical and rectangular). These four containers were separately inserted inside a bigger clay pot inter- spaced with clay soil of 5 cm (to form tin-in-pot, pot-in-pot, tin-in-wall and wall-in wall) with the outside structure wrapped with jute sack. The other two sets followed the same pattern with interspacing of 7 cm and 10 cm respectively. The set with 7 cm interspace served as the control in which the interspace soil and the jute sacks were constantly wetted at intervals of between 2 to 4 hours depending on the rate of evaporation with water at room temperature. The other two sets (5 cm and 10 cm interspaced soil) were constantly wetted with salt solution (Table salt (Nacl)) at the same interval to keep the soil in moist condition. Freshly harvested matured bananas were used for the experiment and the temperature, relative humidity and decay were monitored daily. The weight, vitamin A, vitamin C, vitamin E, lycopene, bacterial and fungal counts of these produce were determined at interval of two days for a period of 10 days. Mathematical models (using essential regression software package) were developed to predict the weight, vitamin A, vitamin C, and vitamin E and lycopene contents of the stored banana at various conditions considered in the study. The existence and sufficiency of the regression models given in the equations were also examined using the analysis of variance (ANOVA) of the multiple regression models. The models were found to be at 5% level of significant. The results of the pair-wise shows that there is no significance difference between the mean of observed and the predicted for all the models developed. The R_{adj}^2 value obtained were 89.00%, 54.34%, 58.22% and 56.40% for vitamin A, vitamin C, vitamin E and lycopene contents respectively for the stored bananas.

KEYWORDS: Prediction, models, empirical, banana, nutritional, storage.

1. INTRODUCTION

Banana (*Musa sapientium*) is the common name for herbaceous plants of the genus Musa and for the fruit they produce. They are native to tropical South and Southeast Asia. Today, they are cultivated throughout the tropics (FAO, 2005). Bananas are excellent sources of vitamin B_6 and contain moderate amounts of vitamin C, vitamin A manganese, calcium, iron, phosphorous and potassium (Southgate, 1969). Along with other fruits and vegetables, consumption of bananas may be associated with a reduced risk of colorectal cancer (Deneo-pellegrini *et al.*, 1996) and in women, breast cancer (Zhang, 2009) and renal cell carcinoma (Rashidkhani *et al.*, 2005). Banana fruits can also be used in the treatment of intestinal disorder, constipation, diarrhea, dysentery, arthritis, gout, allergies, kidney disorders, anemia, tuberculosis, urinary disorders, overweight, menstrual disorders, bums and wounds (PBGEA, 2010).

The optimum conditions for ripening bananas are at temperatures of 20 – 21^{o}C and 90% relative humidity. As the fruit ripens, sugar content increases while starch content decreases. Green bananas can be stored for up to seven days at room temperature or up to 20 days under refrigeration. Neither green nor ripe bananas should be stored at temperatures lower than 58 ^{o}F. Ethylene gas can be applied to bananas to start the ripening process and to assure evenness of ripening. Bananas also produce ethylene gas naturally. During the ripening process, pulp temperatures should range from 58 to 64 degrees F, relative humidity should be controlled, and there should be adequate air circulation to ensure high quality fruit (Chia, 1981; Huggins *et al.*, 1990).

Preventing microbial growth is one major practice of improving the storability of fresh agricultural produce. Microorganisms such as bacteria, yeasts, molds, and viruses are ubiquitous and are widely encountered in air, water, soil, living organisms, and unprocessed food items, and cause off-flavours and odours, slime production, changes in the texture and appearances, and the eventual spoilage of foods. They can be transferred to food products through the soil, handling, tools or through the atmosphere. It is therefore prudent to preserve foods by preventing microbial growth. It can be achieved through temperature and relative humidity control, elimination of excess water, harvest handling, preventing moisture loss and sanitation. Geeson, 1983; Salunkhe, 1974; Salunkhe and Kadam, 1998; Weichmann, 1987; ITC, 2002; Wilson *et al.*, 1995; Sharma and Singh, 2000; Kader, 2002; Wilson *et al.*, 1995).

Predictive modelling is the process by which a model is created or chosen to try to best predict the probability of an outcome. A predictive model was made from a number of predictors, which were variable factors that were likely to influence future behaviour or results on banana storage The development of this type of model is typically data driven (empirical/ inductive models) and requires minimal knowledge of the products or processes involved and it involves converting model inputs into outputs (Tijskens *et al.*, 2001).

Process modeling as described by NIST/SEMATECH(2009) is the concise description of the total variation in one quantity say, y, by partitioning it into a deterministic component of one or more other quantities such as $x_1, x_2, \ldots,$ and a random component that follows a particular distribution.

The general form of process model is given by;

$$y = f(\vec{x} : \vec{B}) + e \quad (2.1)$$

Where y *is the response variable,*

$f(\vec{x} : \vec{B})$ *is the mathematical model and,*

e *is the random or unexplained variation.*

The response variable y, is the quantity that varies in a way that we hope to be able to summarize and exploit via the modeling process. Generally it is known that the variation of the response variable is systematically related to the values of the one or more variable before the modeling process is begun, although testing the existence and nature of this dependence is part of the modeling process itself.

The objective of this study was to develop empirical models developed from various data generated from the evaporative cooling structures.

2. MATERIALS AND METHODS

2.1 Experimental Procedure

The experiment was carried out in Minna, Niger state, Nigeria and the samples of bananas were sourced from Garatu Market. The fresh bananas were stored inside the three sets of four different types of passive evaporative cooling structures for a period of 10 days. 30 samples of fresh bananas were stored in each structure. Two cooling chambers were made with aluminum container (cylindrical and square shapes) and the other two were made of clay container (cylindrical and square). These four containers were separately inserted inside a bigger clay pot inter- spaced with clay soil of 5 cm (to form tin-in-pot, pot-in-pot, tin-in-wall and wall-in wall) with the outside structure wrapped with jute sack. The other two sets followed the same pattern with interspacing of 7 cm and 10 cm respectively. The set with 7 cm interspace served as the control in which the interspace soil and the jute sacks were constantly wetted at intervals of between 2 to 4 hours depending on the rate of evaporation with water at room temperature. The other two sets (5 cm and 10 cm interspaced soil) were constantly wetted with salt solution (Table salt (Nacl)) at the same interval to keep the soil in moist condition. Freshly harvested matured bananas were used for the experiment and the temperature, relative humidity and decay were monitored daily. The weight, vitamin A, vitamin C, vitamin E, lycopene, bacterial and fungal counts of these produce were determined at interval of two days for a period of 10 days. Mathematical models (using essential regression software package) were developed to predict the weight, vitamin A, vitamin C, and vitamin E and lycopene contents of the stored banana at various conditions considered in the study.

2.1 Determination of Temperature and Relative Humidity

The temperature and relative humidity of stored tomatoes in the two structures were taken daily using a digital thermometer and a relative humidity measuring instrument (Testo 625 Compact instrument). at 8.00am, 12 noon and 6.00pm and their average taken and compared with the average ambient temperature.

2.2 Microbial Analysis and Soil Bulk Density

The total fungal and bacterial plate counts were determined using the methods of Collins *et al., (2004).* The bulk density was determined by core method in line with AOAC (1979).

2.3 Nutritional Parameters

Nutritional Analysis for vitamin A of the orange samples was carried out in the Central Laboratory of NationalCereals Research Institute, Badeggi, Nigeria using AOAC (1995) methods of analysis. .

2.4 Preparation of Salt Solution

About 15000 parts/millions (ppm) solution of sodium chloride (Nacl) was prepared by dissolving 225g of Nacl in 15 litres of water at room temperature and 450g of Nacl in 30 litres of water at room temperature for keeping the four structures in moist condition in the 5 cm and 10 cm soil inter-space respectively. The four structures in the 7 cm soil inter space were kept in moist condition using 20 litres of water.

3. RESULTS AND DISCUSSION OF RESULTS

The data from the experiment is as presented in Table 1.

3.1 Model Equations for Stored Bananas

$$VIT\_A = 8.60E\text{-}01 + 4.75E\text{-}03TRF - 7.87E\text{-}02TF^2 + 2.98E\text{-}01\lambda^2\gamma - 2.81E\text{-}01\lambda\gamma F,\ R_{adj}^2 = 89.00\% \quad \text{(Equation 1)}$$

$$VIT\_C = 2.81E{+}01 - 8.07E\text{-}04R^2B,\ R_{adj}^2 = 54.34\% \quad \text{(Equation 2)}$$

$$VIT\_E = 2.07E{+}00 + 1.94E\text{-}02SF^2,\ R_{adj}^2 = 58.22\% \quad \text{(Equation 3)}$$

$$LP = 2.07E{+}00 + 1.71E\text{-}02\gamma F\sigma - 3.41E\text{-}01\gamma FB,\ R_{adj}^2 = 56.40\% \quad \text{(Equation 4)}$$

T=temperature, R=Relative Humidity, S=Soil Inter-space, λ=Storage Structure (1=Tin in pot or Pot in pot, 2=Tin in wall or wall in wall), γ=Material Component (1=Aluminium component, 2=Clay component), F=Fungal Count, σ=Bacterial Count, M=Soil Moisture Content, B=Bulk Density.

Table 1: Experimental Data for Stored Bananas

S/No	Fruit	SI	SS	M	T	RH	FC	BC	SMC	BD	WT	VIT_A	VIT_C	VIT_E	LP	MC
1	3	1	1	1	26.60	76.90	1.40	24.00	68.40	0.88	243.02	8.76	25.52	1.90	2.16	12.00
2	3	1	1	1	26.10	74.20	2.60	26.00	72.60	0.96	221.06	10.24	23.76	1.80	2.42	15.40
3	3	1	1	1	26.70	77.70	1.90	23.00	87.40	1.04	228.34	10.78	24.42	1.80	2.54	16.16
4	3	1	1	1	26.20	75.90	2.40	24.00	88.40	0.89	211.15	12.42	22.84	2.60	2.42	16.32
5	3	1	1	1	26.60	77.70	2.10	26.00	79.80	1.14	182.43	12.40	22.54	2.30	1.74	17.55
6	3	1	1	2	26.60	77.00	1.40	21.00	68.40	0.88	232.06	10.32	23.40	2.30	2.32	18.20
7	3	1	1	2	26.00	74.10	1.20	22.00	72.60	0.96	212.73	9.48	24.04	2.10	2.16	16.78
8	3	1	1	2	26.70	77.70	2.40	24.00	87.40	1.04	224.62	11.42	22.06	1.90	2.72	19.24
9	3	1	1	2	26.40	75.90	1.60	23.00	88.40	0.89	213.39	12.12	24.54	2.50	2.62	18.54
10	3	1	1	2	26.70	77.80	1.60	24.00	79.80	1.14	196.65	11.14	23.36	2.20	2.42	17.24
11	3	1	2	1	26.90	76.10	1.60	23.00	68.40	0.88	242.07	11.18	22.54	2.20	2.23	15.33
12	3	1	2	1	26.40	74.20	1.90	24.00	72.60	0.96	223.65	10.52	23.88	1.90	2.31	16.12
13	3	1	2	1	26.80	75.20	1.40	22.00	87.40	1.04	233.73	9.96	23.52	2.60	1.75	19.04
14	3	1	2	1	26.60	73.60	2.00	23.00	88.40	0.89	221.76	11.21	32.66	2.80	1.76	15.36
15	3	1	2	1	26.80	75.20	1.90	24.00	79.80	1.14	202.83	12.06	23.14	2.20	2.22	16.74
16	3	1	2	2	26.80	76.20	1.40	23.00	68.40	0.88	225.41	10.62	24.12	1.60	2.22	17.06
17	3	1	2	2	26.30	74.20	1.80	24.00	72.60	0.96	203.62	12.42	24.02	2.40	2.32	16.50
18	3	1	2	2	26.90	75.10	2.60	26.00	87.40	1.04	214.31	10.36	22.42	2.80	2.66	21.01
19	3	1	2	2	26.60	73.80	2.20	23.00	88.40	0.89	202.76	11.26	21.54	1.90	2.32	16.16
20	3	1	2	2	26.90	75.10	1.30	23.00	79.80	1.14	185.75	10.74	22.78	1.80	2.19	17.82
21	3	2	1	1	26.50	76.60	1.20	23.00	74.60	0.92	255.16	8.82	24.60	2.00	2.18	19.00
22	3	2	1	1	25.70	74.30	2.40	25.00	88.72	0.89	227.66	9.78	24.12	2.00	2.39	16.24

23	3	2	1	1	26.60	77.40	2.80	26.00	84.56	0.98	244.37	11.24	23.34	2.40	2.66	18.44
24	3	2	1	1	26.20	75.50	1.80	23.00	89.20	1.08	232.17	13.54	22.96	2.40	2.33	17.41
25	3	2	1	1	26.70	76.20	2.30	23.00	82.20	0.89	209.47	11.98	22.62	2.40	1.98	16.28
26	3	2	1	2	26.50	76.70	1.80	23.00	74.60	0.92	214.09	9.86	23.36	2.10	2.24	17.40
27	3	2	1	2	25.60	74.30	1.60	21.00	88.72	0.89	2193.97	10.12	23.72	2.30	2.32	16.00
28	3	2	1	2	26.80	77.30	1.80	24.00	84.56	0.98	206.62	10.88	23.52	2.30	2.18	18.62
29	3	2	1	2	26.20	75.30	2.40	24.00	89.20	1.08	191.43	10.74	23.22	2.40	1.96	17.58
30	3	2	1	2	26.60	76.30	1.40	23.00	82.20	0.89	167.64	10.74	23.18	2.40	2.39	16.36
31	3	2	2	1	26.60	75.90	1.80	18.00	74.60	0.92	236.61	11.24	23.36	1.90	2.17	15.33
32	3	2	2	1	25.20	76.20	1.60	23.00	88.72	0.89	213.55	9.86	24.16	2.10	2.23	18.40
33	3	2	2	1	26.70	75.80	1.60	21.00	84.56	0.98	226.96	10.36	22.72	1.80	2.92	20.42
34	3	2	2	1	26.30	74.30	2.20	22.00	89.20	1.08	215.61	10.50	23.68	1.80	1.86	16.24
35	3	2	2	1	26.30	75.80	1.60	23.00	82.20	0.89	194.37	11.98	23.08	2.60	2.33	15.96
36	3	2	2	2	26.50	76.10	1.20	23.00	74.60	0.92	261.63	10.48	24.56	1.90	2.34	15.00
37	3	2	2	2	25.20	75.80	2.20	23.00	88.72	0.89	241.64	11.78	23.92	2.10	2.18	16.00
38	3	2	2	2	26.80	76.10	2.30	23.00	84.56	0.98	256.33	11.26	23.62	1.90	2.78	20.04
39	3	2	2	2	26.30	75.20	2.20	22.00	89.20	1.08	246.65	10.86	22.32	2.40	1.98	15.52
40	3	2	2	2	26.40	76.30	1.80	24.00	82.20	0.89	228.95	11.52	22.92	2.00	2.20	16.38
41	3	3	1	1	26.60	76.30	1.30	23.00	78.83	0.98	208.61	8.18	24.66	2.10	2.18	16.00
42	3	3	1	1	25.50	74.30	1.60	24.00	76.40	1.02	193.92	9.88	23.88	1.90	2.36	17.40
43	3	3	1	1	26.60	77.20	1.80	25.00	78.56	0.88	212.53	11.76	24.52	2.30	2.72	18.24
44	3	3	1	1	26.10	75.50	1.80	21.00	78.72	0.94	208.62	12.76	23.06	2.60	2.31	15.50
45	3	3	1	1	26.60	77.10	2.40	25.00	76.40	0.98	196.63	12.04	22.66	2.20	2.01	16.79
46	3	3	1	2	26.50	76.40	1.60	22.00	78.83	0.98	269.67	10.16	23.42	2.20	2.36	16.30

47	3	3	1	2	25.40	74.70	2.00	23.00	76.40	1.02	231.97	9.86	23.84	2.20	2.30	18.42
48	3	3	1	2	26.70	77.20	2.20	22.00	78.56	0.88	252.32	11.06	24.32	2.40	1.98	17.52
49	3	3	1	2	26.20	75.60	1.90	22.00	78.72	0.94	232.73	10.60	23.50	2.30	1.98	17.24
50	3	3	1	2	26.70	77.20	1.60	24.00	76.40	0.98	208.14	11.10	23.27	2.60	2.29	18.26
51	3	3	2	1	26.50	76.20	1.60	20.00	78.83	0.98	243.51	11.16	23.24	2.10	1.30	17.00
52	3	3	2	1	25.30	75.40	2.40	22.00	76.40	1.02	220.15	10.56	23.18	2.60	2.17	19.20
53	3	3	2	1	26.80	75.90	1.80	24.00	78.56	0.88	239.76	11.04	21.88	2.40	2.35	18.16
54	3	3	2	1	26.30	74.90	1.90	24.00	78.72	0.94	227.61	11.46	24.22	2.60	1.87	15.80
55	3	3	2	1	26.80	75.80	2.00	24.00	76.40	0.98	207.57	12.04	23.20	2.00	2.34	16.12
56	3	3	2	2	26.50	76.10	1.30	24.00	78.83	0.98	245.83	10.74	24.36	1.80	2.25	15.00
57	3	3	2	2	25.20	75.30	2.30	24.00	76.40	1.02	217.66	11.58	24.16	2.60	2.23	17.40
58	3	3	2	2	26.70	76.10	2.80	23.00	78.56	0.88	226.36	10.98	23.72	2.60	2.99	19.74
59	3	3	2	2	26.20	75.10	2.10	21.00	78.72	0.94	198.45	11.22	21.76	2.20	2.06	16.14
60	3	3	2	2	26.70	76.10	1.20	23.00	76.40	0.98	169.57	10.86	23.06	2.20	2.20	15.88

T=temperature, Rh=Relative Humidity, FC=Fungal Count, BC=Bacterial Count, SMC=Soil Moisture Content, BD=Bulk Density. SI=Soil Inter-space (1, 2 & 3 represent 5 cm, 7 cm and 10 cm respectively), SS= Storage Structures (1 represents tin-in-pot and pot-in-pot which are cylindrical in shape while 2 represents tin-in-wall & wall-in-wall which are rectangular in shape), M=Material Component for the Storage Structures (1represents tin component made of aluminium material while 2 represents pot /wall components made of clay material). 3= banana fruit

From the essential regression analysis, 256 model equations were generated under each fruit and vegetables out of which the best was selected for weight, vitamin A, vitamin C, vitamin E and lycopene contents of stored bananas based on their R_{adj}^2 as shown in equation 1 to 4. The existence and sufficiency of the regression models given in the equations above were also examined using the analysis of variance (ANOVA) of the multiple regression models shown in Tables 2. The analysis was carried out using essential regression computer software package. Regression models are sometime examined or tested with Analysis of Variance (ANOVA). This is because ANOVA tests the acceptability of the model from a statistical perspective. The four models developed for banana above (equation 1 to 4.) were selected as the best performing models based on their respective values of R_{adj}^2 Also the analysis of variance table (Tables 2) which tests the acceptability of the model from a statistical perspective was seen to be significant at 5% for all the selected models.

Table 2: Analysis of Variance of the Multiple Regressions on the Nutritional Parameters as Function of Stored Banana

Variable	*Source*	*Df*	*SS*	*MS*	*F*	*F Signif.*
VIT_A	Regression	4	23.01	5.753	9.291	0.001*
	Residual	55	34.06	0.619		
	Total	59	57.07			
VIT_C	Regression	1	8.653	8.653	4.512	0.037*
	Residual	58	111.24	1.918		
	Total	59	119.89			
VIT_E	Regression	1	0.482	0.482	6.298	0.014*
	Residual	58	4.440	0.07655		
	Total	59	4.922			
LYP	Regression	2	0.808	0.404	5.516	0.0065*
	Residual	57	4.174	0.07323		
	Total	59	4.982			

**significant at 5% level*

3.2 Model Validation

By substituting different values of predictor variables/ factors (materials, temperature, relative humidity, storage structures, fungal and bacterial counts etc) into the model equations, the expected values of weight, vitamin A, vitamin C, vitamin E and lycopene contents of stored bananas were predicted. The predicted and measured (observed) values were plotted as shown in figures 1 to 4 for stored bananas. The graphs suggest a very close relationship between the observed and the predicted-an indication of a good fit. Further analysis was done using a paired sample t-test using SPSS 16.0 computer software package. The results are presented in table 3. The results of the pair-wise shows that there is no significance difference between the mean of observed and the predicted for all the models developed. This implies that all the models developed are adequate and can be used to predict optimum values of the nutritional parameters.

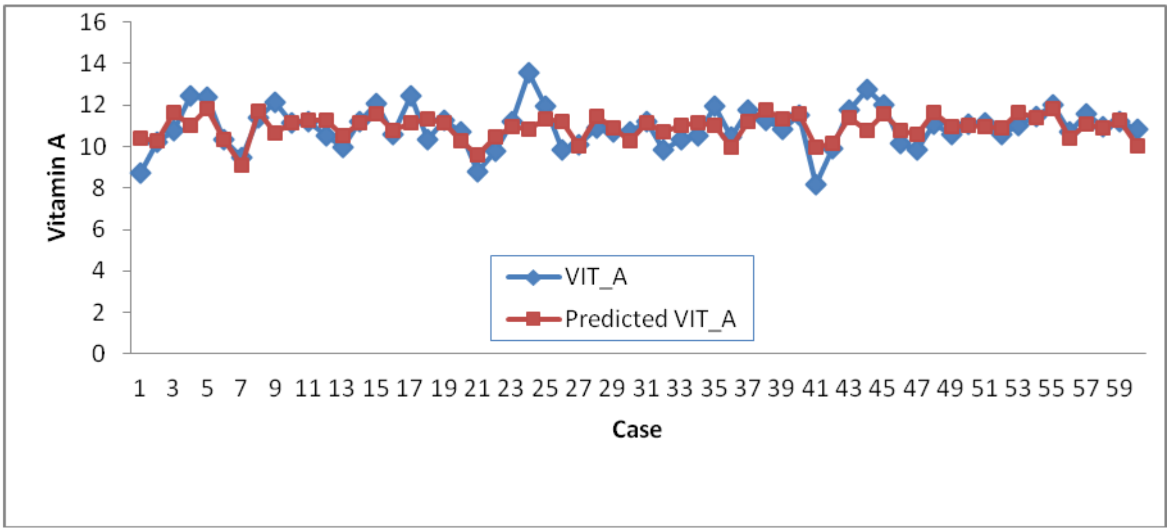

Figure 1: Predicted and observed values for vitamin A of stored banana

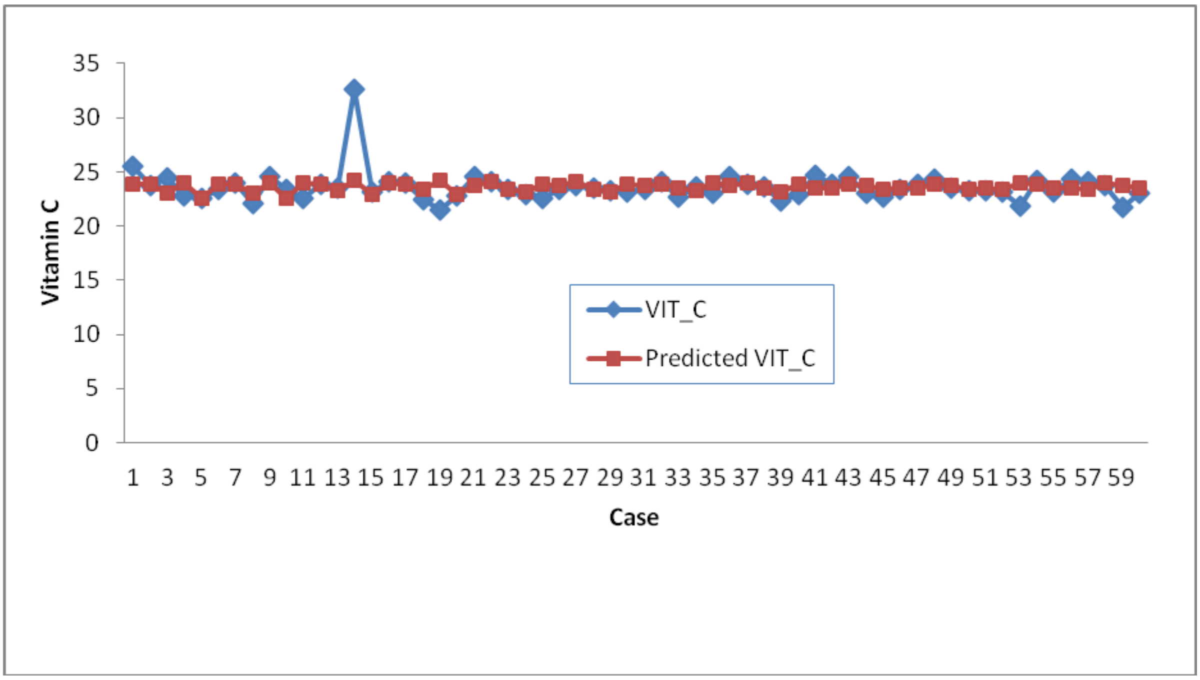

Figure 2: Predicted and Observed Values for Vitamin C of Stored Banana

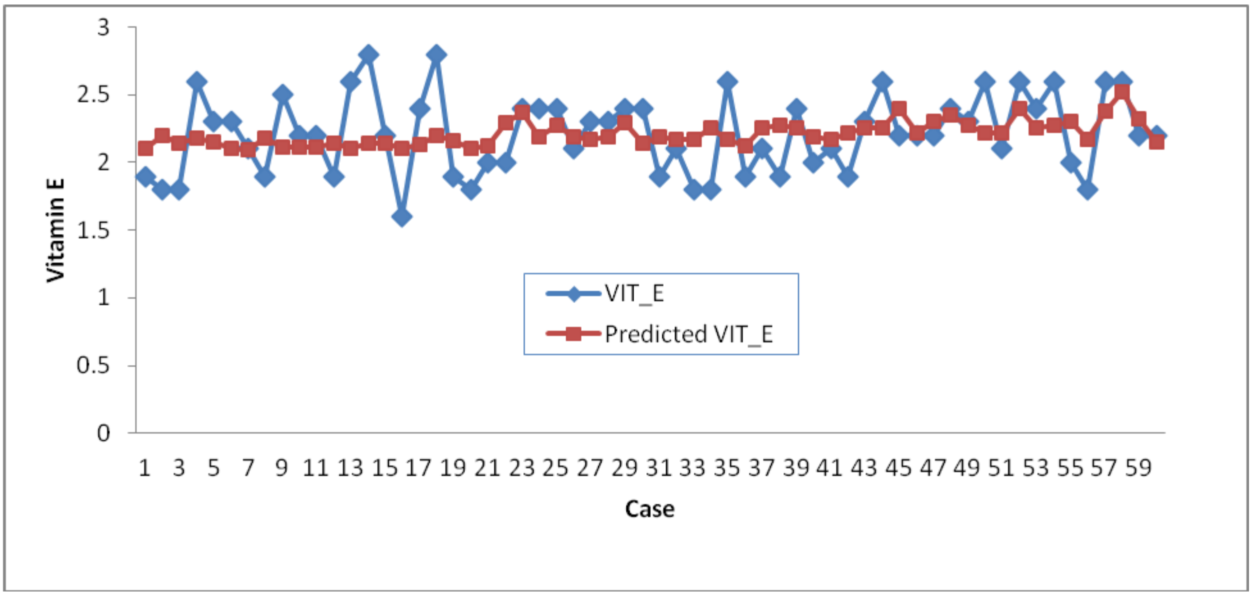

Figure 3: Predicted and Observed Values for Vitamin E of Stored Banana

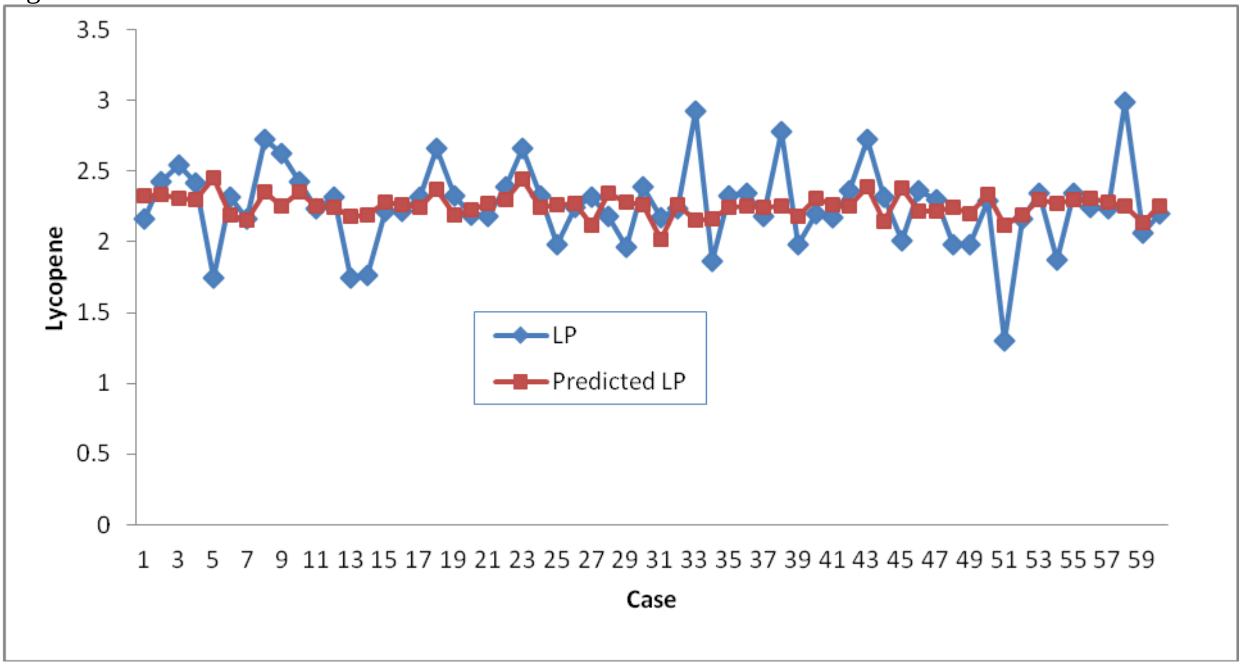

Figure 4: Predicted and observed values for lycopene of stored banana

Table 3: Pair-wise Test Comparing Observed and Predicted Values of Measured Parameters in Stored Bananas

Pair sample	Mean	Std. Error Mean	T	Df	Sig. (2-tailed)	Correlation
observed- predicted[a]	0.00012	0.10271	0.000	59	0.999	0.588
observed- predicted[b]	0.00000	0.17722	0.001	59	1.000	0.270
observed- predicted[c]	-0.00003	0.03541	0.000	59	0.999	0.313
observed- predicted[d]	0.00003	0.03607	0.001	59	0.999	0.275

a=Vitamin A., b=Vitamin C, c=Vitamin E, d=Lycopene,

4. CONCLUSION

An empirical model based on the measured parameters on the field was developed to provide objective guidance on the nutritional values of stored bananas inside the passive evaporative cooling structures. The four models developed for banana above (equation 1 to 4.) were selected as the best performing models based on their respective values of adjusted coefficient of determination which were seen to be significantly higher Also the analysis of variance which tests the acceptability of the model from a statistical perspective was seen to be significant at 1% for all the selected models. The verification of the models was done using pair wise t-test. The mathematical models developed are reasonably accurate to predict the storability of banana in passive evaporative cooling structures. Also, the model performance was found to be satisfactory and show good predictability.

REFERENCES

AOAC 1979. Association of Official Analytical Chemistry. Approved Method of Analysis.

AOAC 1995. Association of Official Analytical Chemist in Official Method of Analysis. 15th Edition. Washington DC, USA Pp 537-544.

Chia, C. L. 1981. Bananas Commodity Fact Sheet BA-3(A) Fruit. Hawaii Cooperative Extension Service, CTAHR, University of Hawaii.

Collins, C. H., Lyne, PM., Grange, JM and Falkinham, J. O. 2004. Collins and Lynes Microbiological Methods, 8th Edition. Amold Publishers.

Deneo-pellegrini, H, De Stefani, E and Ronco, A. 1996. Vegetables, Fruits and Risk of Colorectal Cancer: A Case-Control Study from Uruguay. Nutrition and Cancer journal, 25(3): 297-304.

Food and Agriculture Organization 2005. Retrieved 12/09/2006 Geeson, JD (1983) Brassicas. In: C. Dennis (ed) Postharvest Pathology of Fruits and Vegetables, Acad. Press, NY, pp. 125-156.

Huggins, C. A, Kevin M, Yokoyama, K W, Stuart T and Chia, C L 1990. Banana Economic Fact Sheet #11. Department of Agricultural and Resource Economics, CTAHR, University of Hawaii. International Trade Centre 2000. Export Packaging Bulletin. No 2.

Kader, A. A. 2002. Quality Parameters of Fresh-cut Fruits and vegetables Products. In: Lamikanra O, editor. Fresh-cut Fruits and Vegetables. Boca Raton, Fla: CRC Press LLC. Pp 11-20.

Pilipino Banana Growers and Exporters Association. 2010. News Bulletin.

Rashidkhani, B, Linblad P. and Wolk, A 2005. Fruits, Vegetables and Risk of Renal Cell Carcinoma: A prospective Study of Swedish Women. International Journal of Cancer, 113 (3): 451-5.

Salunkhe, D. K. 1974. Development in Technology of Storage and Handling of Fresh Fruits and Vegetables. Cri Rev. Food Technology. 15-54Pp.

Salunkhe, D. K. and Kadam, S. S. 1998. Handbook of Vegetable Science and Technology: Production, Composition, Storage and Processing. New York: Marcel Dekker.

Sharma, R. M. and Singh, R. R. 2000. Harvesting, Postharvest Handling and Physiology of Fruits and Vegetables. In: Verma, L.R., Joshi, V.K. Editors. Postharvest Technology of Fruits and Vegetables. Vol. 1. Handling, Processing, Fermentation and Waste management. Tagore Garden, New delhi: Indus publishing Co. pp 94-147.

Southgate, DAT. 1969. Determination of Carbohydrates in Foods (ii). Unavailable Carbohydrates. Journal of Science of Food and Agriculture. 20, 331-5

Tijskens, L. M. M, Hertog, M. L. A. T. M, and Nicolai, B. M. 2001. *Food Process Modelling.* Published by Woodhead Publishing Limited, England. 510pp.

Weichmann, J. 1987. Postharvest Physiology of Vegetables, Marcel Dekker, Inc., New York, NY

Wilson, L. G, Boyette, M. D. and Estes, E. A. 1995. Postharvest Handling and Cooling of Fresh Fruits, Vegetables and Flowers for Small Farms. Leaflets 800–804. North Carolina Cooperative Extension Service. 17 p. Accessed on-line at: http://www.foodsafety.org/nc/nc1055.htm

Zhang, C. X. 2009. Greater Vegetable and Fruit Intake is Associated with a Lower Risk of Breast Cancer among Chinese Women. International Journal of Cancer 125 (1): 181-8.

GRAPHICAL ANALYSES OF GROUNDWATER CONTRIBUTION TO RIVER FLOWS IN PARTS OF SOUTHWESTERN NIGERIA

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ABSTRACT

Groundwater contribution to river channel flows often accounts for a significant proportion of total flow, especially during the dry season. Quantity of this baseflow at the dry season determines reliability of the river for most water supplies.

Discharge data of daily flow rate of some rivers for upward of 6 years from 16 gauge stations within Benin-Owena Drainage Basin, southwestern Nigeria, were subjected to quantitative flow analyses. The Drainage Basin extends over 36,000km^2. Hydrograph separation into direct runoff and baseflow components was carried out. The total baseflow in the channel for each year as well as total channel flow and direct runoff were calculated. Spatial distribution of each of these flows was plotted as discharge map and correlated with the underlying geology.

The results showed that 15 out of the 16 river channels have baseflow contribution. High baseflow (up to 641 x 10^{9}m^3/yr) was found in areas underlain by the highly permeable coastal plain sands and the mangrove/deltaic swamps while low baseflow (0 – 53.1 x 10^{9}m^3/yr) characterized areas underlain by crystalline rocks. Generally, the baseflow increases seaward along flow direction and its value overcomes the direct run-off value from the area about the middle of the drainage basin. This downplayed effect of geology on baseflow and suggested cumulative discharge over distance as the major factor determining quantity of baseflow along drainage path.

KEYWORDS: Baseflow, hydrograph, runoff, groundwater, drainage basin.

1. INTRODUCTION

Provision of accurate estimate of groundwater contribution to river flow is important to anticipate possible low flow periods and to evaluate aquifer renewal rates. Groundwater contribution to river flow, generally called baseflow, often accounts for a significant proportion of total flow rate, especially during the dry season. Baseflow must be estimated to find a compromise between basin development and maintenance of river ecology (Smakhtin, 2007).

Conceptually, a river catchment can be perceived as a series of interlinked reservoirs, each of which has components of recharge, storage and discharge (Smakhtin, 2001). In regional scale aquifers, groundwater contributions to river flow is often considered to be the recharge and therefore influenced by climate, geology and topography (Toth, 1963). Landuse, soil type and hydrostratigraphy are also important local scale factors determining the volumes of water which can infiltrate, percolate through the unsaturated zone, reach the water table and eventually discharge into rivers (Cherkauer and Ansari, 2005). Since baseflow represents the discharge of aquifers and recharge to river flow, there is a need to differentiate the influent streams from effluent streams. An influent stream is one which has a negative baseflow i.e. the stream feeds the groundwater instead of receiving from it e.g. irrigation channels. This type of stream is ephemeral and dries up during dry season.

An effluent stream on the other hand is one with baseflow, i.e. the stream is being fed by groundwater and this type of stream is perennial, with a low dry season flow.

Hydrograph separation techniques (Chapman, 1991; Sloto and Crouse, 1996; Eckhardt, 2005) are often used to quantify aquifer contribution to river flow at the outlet of a watershed and are probably the most commonly used techniques for baseflow estimation.

In this study, hydrograph separation is used to provide estimate of baseflow in the Benin-Owena Drainage Basin.

2. MATERIALS AND METHODS

2.1 The Study Area

The study area is the Benin-Owena Drainage Basin in Southwestern Nigeria and lies between latitude 5^oN to 8^oN and longitude 4^o to 7^oE (Fig. 1). The River Basin extends over $36,000km^2$ and covers four states of the country which include Ondo, Ekiti, Edo and Delta states (Fig. 2). The rain forest vegetation characterizes the northwestern parts while the swamp/mangrove forest covers the remaining parts of the Drainage Basin. The crystalline rocks of the Basement Complex (which consist of undifferentiated gneiss-migmatite, undifferentiated metasediments and older granites) underlies the Northwestern part and some areas in the Northeastern part of the Basin while the remaining parts are jointly underlain by segments of sedimentary formations of Anambra and Niger Delta Basins along with the Coastal Plain Sands (Fig. 3). The general flow direction within the basin is from North to South.

Fig. 1: Map of Southern Nigeria showing the Study Area (after Macmillan Nigeria, 2010).

1. River Ogbese Aduloju
2. River Ogbese at Ogbese
3. River Owena
4. River Onyami
5. River Ojo
6. River Edion
7. River Owan
8. River Ofosu
9. River Oha
10. River Osse
11. River ikpoba
12. River Okhunwan
13. River Ossiomo (Abudu)
14. River Ossiomo (Ologbo)
15. River Adofi
16. River Ethiope near Abraka

Fig. 2: Drainage Map of the Study Area Showing Gauge Stations (after BORDDA, 1989)

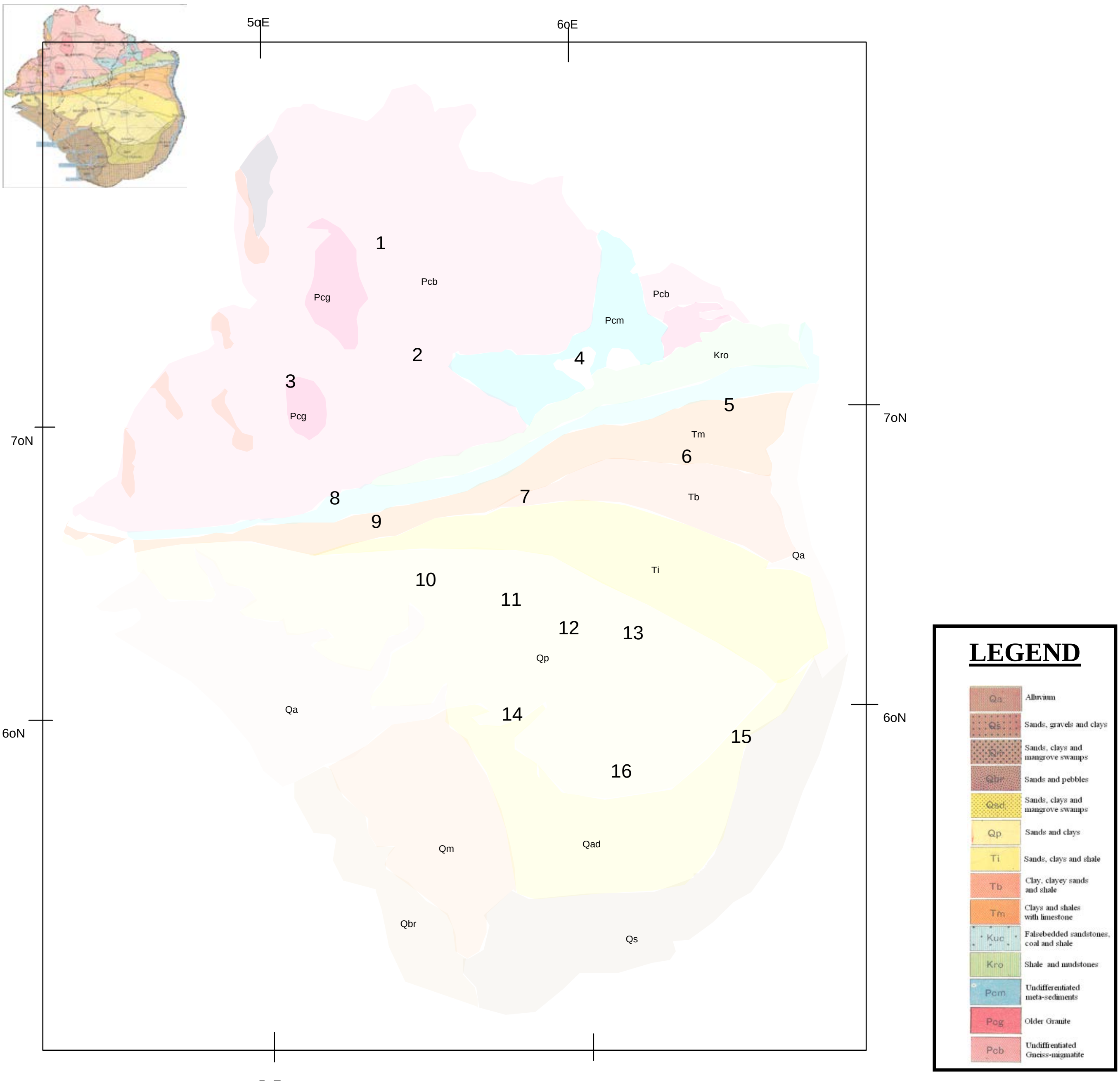

Fig. 3: Geological Map of the Study Area (after GSN, 1984)

2.2 Data Analysis

Many digital and graphical methods have been developed to separate baseflow from total streamflow (Gonzales *et al*., 2009). The advantages of hydrograph separation techniques are that they are easily implemented and they provide a rapid estimate of groundwater contribution to river flow especially during low flow periods, when groundwater essentially provides the only contribution to the river flow. Baseflow separation techniques use the time-series record of stream flow to derive the baseflow signature.

In this study, discharge data of daily flow rate of 16 rivers from 1989 to 1994 for 16 gauge stations (Fig.4) within Benin-Owena Drainage Basin were subjected to hydrograph analysis (Fig. 5 & 6). GRAPHER, a graphic software package was used for the hydrograph separation into Direct Runoff and Baseflow components. This separation method defines the points where the baseflow intersects the rising and falling limbs of the quickflow response and assumes streamflow subsequent to these points to be entirely baseflow within a defined hydrologic season.

The graphical separation method employs:

a.) The constant discharge method – This method assumed that baseflow is constant during the storm hydrograph (Linsley *et al*, 1958). The minimum streamflow immediately prior to the rising limb or beginning of the storm hydrograph is used as the constant value; and

b.) The constant slope method – This method connects the start of the rising limb with the inflection point on the receding limb. This assumes an instant response in baseflow to the rainfall event.

Fig.4: Typical Gauge Station used in the Drainage Basin

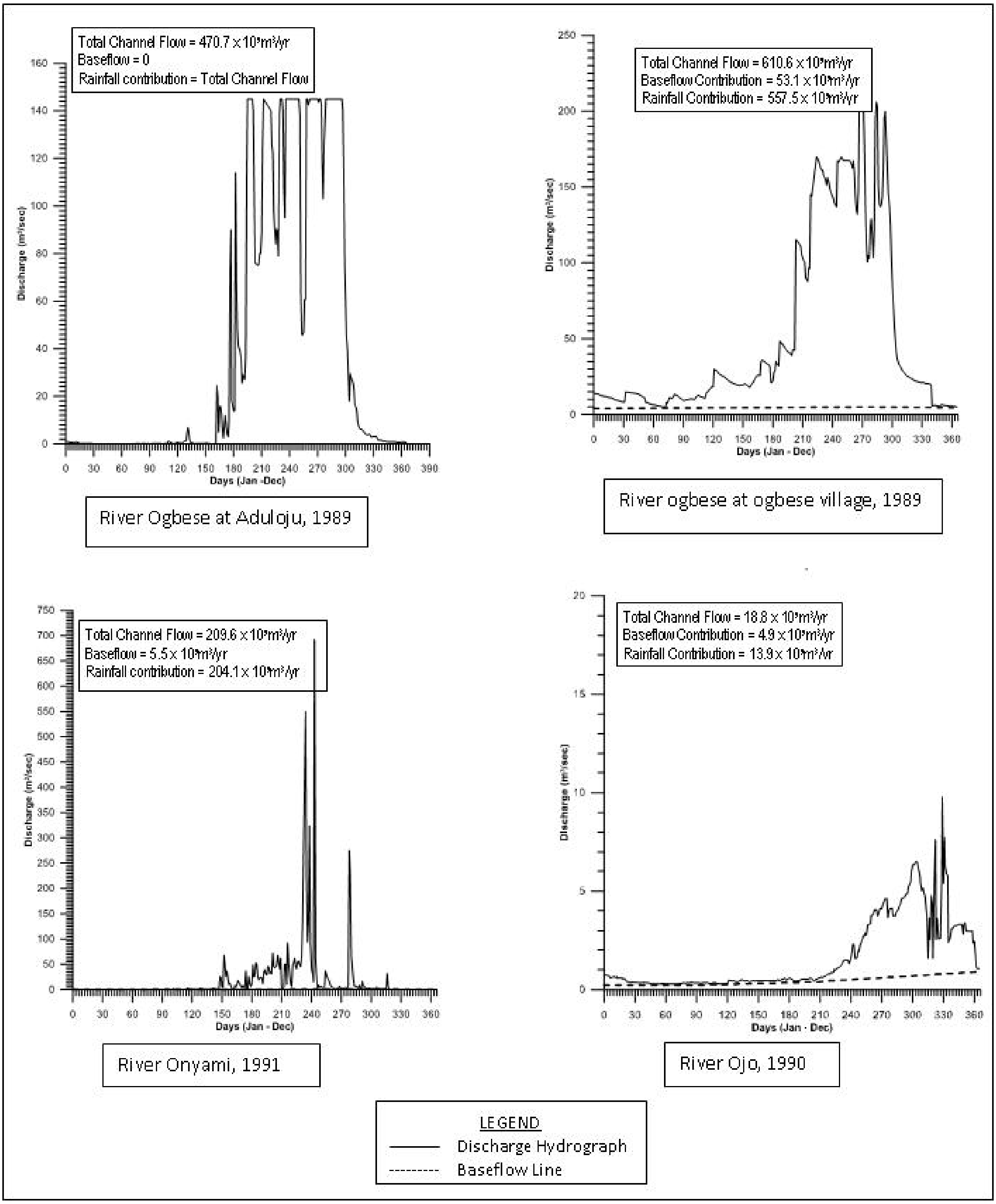

Fig. 5: Typical Hydrograph plots showing the Direct Runoff and Baseflow components.

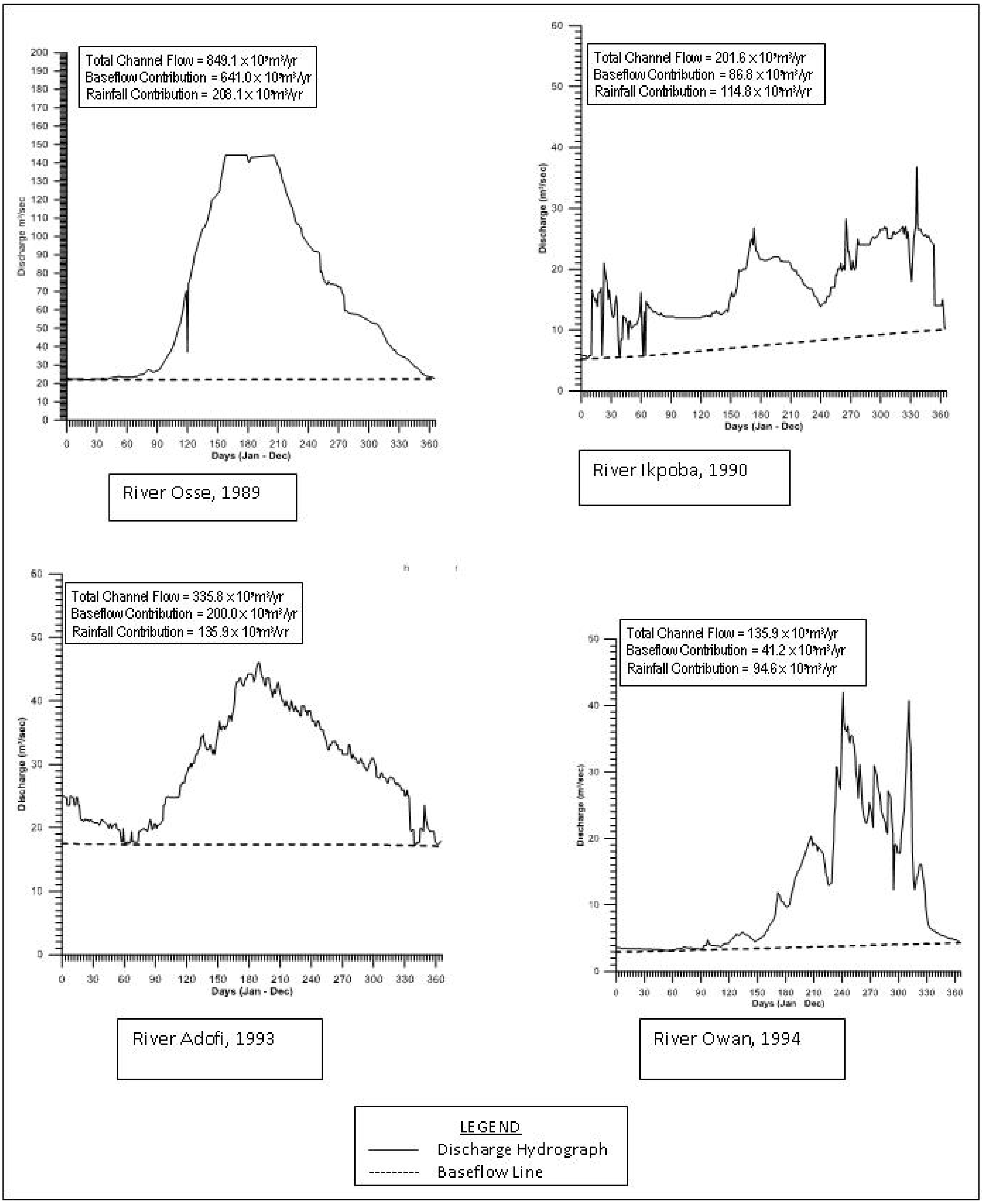

Fig. 6: Typical Hydrograph plots showing the Direct Runoff and Baseflow components

3. RESULTS AND DISCUSSION

The results of the hydrograph separation into Direct Runoff and Baseflow components as well as the Total Channel flow in each of the 16 rivers from the 16 gauge stations are presented in Table 1 while the maps showing spatial distribution of baseflow in the rivers from 1989 to 1994 are presented in Figures 7 to 12.

The results showed that 15 out of the 16 river channels receive groundwater contributions. The only river with no groundwater contribution, River Ogbese at Aduloju, is a losing stream or an influent

stream which gives seasonal flow caused by rainfall and interflow. Of all the channels with baseflow, Ofosu river consistently has the lowest groundwater contribution of between 1.5 and 2.2 x $10^9 m^3$/yr.
Baseflow is generally higher (up to 641 x $10^9 m^3$/yr) in areas underlain by the highly permeable Coastal Plain Sands and Mangrove/Deltaic Swamps while lower values of baseflow (0 – 53.1 x $10^9 m^3$/yr) characterize areas underlain by crystalline rocks and areas underlain by the sedimentary formations of Anambra Basin at the Northeastern part. It is observed that baseflow increases downstream in seaward direction and its value generally overcomes the direct runoff value from the area around the middle of the Drainage Basin (Fig. 7 to 12). This increase along flow direction suggested that cumulative discharge over distance is the major factor determining the quantity of baseflow along drainage path and that the baseflow is much less influenced by the underlying geology within the Drainage Basin.

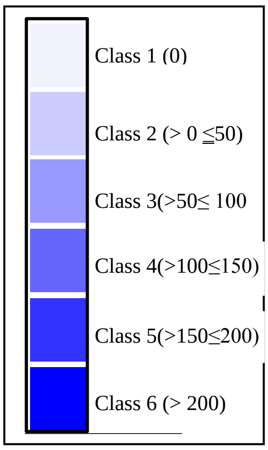

Fig. 7: Spatial Distribution of Baseflow in 1989

Table 1: Total Channel Flow, Baseflow and Direct Runoff Values in the Study Area.

TCF – Total Channel Flow BF – Baseflow DR – Direct Runoff

FLOW (x $10^9 m^3/yr$)																			
RIVERS		1989			1990			1991			1992			1993			1994		
		TCF	BF	DR	TCF	BF	DR	TCF	BF	DR	TCF	BF	DR	TCF	BF	DR	TCF	BF	DR
1	Ogbese Aduloju	470.7	0	470.7	426.5	0	426.5	453.0	0	453.0	277.1	0	277.1						
2	Ogbese at ogbese	610.6	53.1	557.5															
3	Owena	70.5	10.4	60.1													76.7	10.2	66.5
4	Onyami	103.7	9.6	94.1	89.4	9.8	79.7	209.6	5.5	204.1	80.7	9.4	71.3	90.9	7.7	83.3	252.2	15.9	236.2
5	Ojo	28.0	4.8	23.1	18.8	4.9	13.9	48.1	10.2	37.9	18.2	7.5	10.7						
6	Edion	217.4	12.3	205.1	175.3	9.2	166.0	386.3	12.8	373.6									
7	Owan	151.4	34.4	117.0	136.9	50.3	86.6	161.4	46.2	115.1	127.9	56.9	71.0	92.6	37.1	55.5	135.9	41.2	94.6
8	Ofosu	100.8	2.2	98.6	92.5	1.5	91.0	158.0	1.7	156.2									
9	Oha				22.6	7.8	14.7	20.6	3.4	17.2	15.7	4.0	11.7	11.6	3.2	8.3			
10	Osse	849.1	641.0	208.1	709.5	252.2	457.3	1052.5	235.9	816.6	1002.1	437.6	564.5	772.0	342.8	429.2	787.5	255.8	531.7
11	Ikpoba				201.6	86.8	114.8							324.1	260.6	63.5	363.5	269.6	93.9
12	Okhunwan				68.0	43.2	24.7	85.5	46.8	38.6	100.1	63.5	36.8	94.9	72.6	22.3	130.7	78.8	51.9
13	Ossiomo(Abudu)				221.6	140.9	80.7	326.2	141.1	185.1	392.8	146.0	246.8	375.3	195.5	179.8	414.2	222.7	191.5
14	Ossiomo (Ologbo)	244.8	183.1	61.7	271.5	202.1	69.4	294.3	220.3	74.0	257.9	197.5	60.5	365.0	294.8	70.2	421.3	331.2	90.0
15	Adofi							294.3	220.7	73.6	258.0	194.0	63.9						
16	Ethiope near Abraka				262.5	116.2	146.3	346.0	224.0	122.0	341.6	215.9	125.6	335.8	200.0	135.9	354.4	213.9	140.5

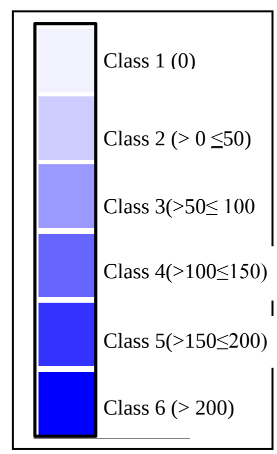

Fig. 8: Spatial Distribution of Baseflow in 1990

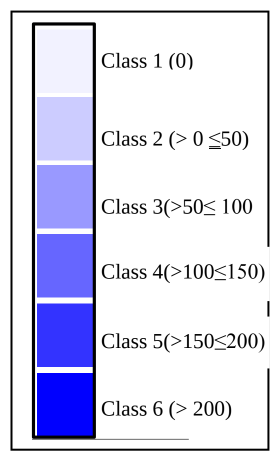

Fig. 9: Spatial Distribution of Baseflow in 1991.

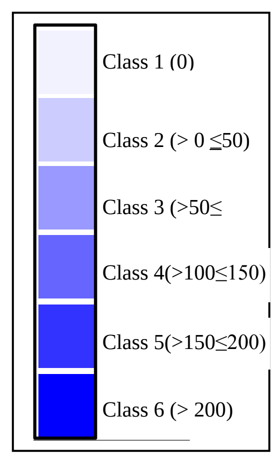

Fig. 10: Spatial Distribution of Baseflow in 1992

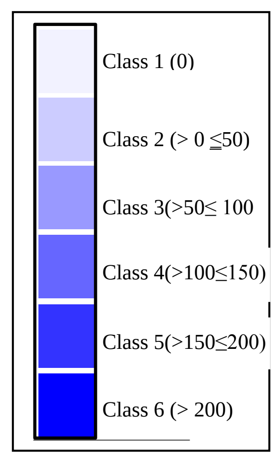

Fig. 11: Spatial Distribution of Baseflow in 1993

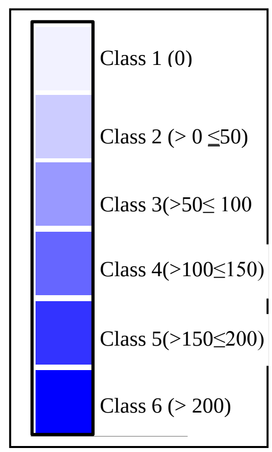

Fig. 12: Spatial Distribution of Baseflow in 1994.

4. CONCLUSIONS

The work shows that hydrograph separation provides estimates of groundwater contribution to river channels. The Benin-Owena Drainage Basin receives substantial groundwater contributions annually and the channel flows are mostly effluent. The underlying geology has insignificant effect on the groundwater contribution as baseflow generally increases seaward along flow direction irrespective of the underlying rock types within the Basin. Despite the limited quantity of certified data available for use in this study and the missing gaps in record, the results obtained are still useful in water resources development planning.

REFERENCES

Benin-Owena River Basin Development Authority. 1989. Hydrological year book. A publication of the Federal Ministry of Water Resources, Abuja, Nigeria. 206p.

Chapman, T. G. 1991. Comment on “Evaluation of automated techniques for baseflow and recession analyses” by R. J. Nathan and T. A. McMahon, Water Resour. Res., 27, 1783 – 1784.

Cherkauer, D. S. and Ansari, S. A. 2005. Estimating groundwater recharge from topography, hydrogeology, and land cover, Groundwater, 43(1), 102 – 112.

Eckhardt K. 2005. How to construct recursive digital filters for baseflow separation, Hydrol. Process., 19, 507 – 515.

GSN. 1994. Geological map of Nigeria. Geological Survey of Nigeria.

Gonzales, A. L., Nonner, J., Heijkers, J., and Uhlenbrook, S. 2009. Comparison of different base flow separation methods in a lowland catchment, Hydrol. Earth Syst. Sci., 13, 2055 – 2068, doi:10.5194/hess-13-2055-2009.

Linsley R. K., Kohler M. A., Paulhus J. l. H., Wallace J. S. 1958. Hydrology for engineers. McGraw Hill, New York.

Macmillan Nigeria. 2010. Secondary Atlas. 136p.

Offodile M. E. 2002. Groundwater study and development in Nigeria, 2nd Ed., 201 – 244.

Sloto, R. A. and Crouse, M. Y. 1996. HYSEP: A computer program for streamflow hydrograph separation and analysis; United States Geological Survey, Water-Resources Investigations, Report 96 – 4040, 46 pp..

Smakhtin, V. 2007. Environmental flows: a call for hydrology, Hydrol. Process., 21, 701 – 703.

Smakhtin, V. 2001. Low flow hydrology: a review, J. Hydrol., 240, 147 – 186.

Tòth, J. 1963. A theoretical analysis of groundwater flow in small drainage basins, J. Geophys. Res., 68(16), 4795 – 4812.

EVALUATION OF IMPACT OF LAND-USE CHANGE IN THE EBONYI RIVER WATERSHED, SOUTH-EASTERN NIGERIA, USING SWAT

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ABSTRACT

Soil and Water Assessment Tool (SWAT) was applied on a watershed (3,765 km^2) in south-eastern Nigeria, to predict streamflow and sediment discharge from the Ebonyi River Watershed using globally available data downloaded from the internet. Digital elevation, land-use and soil maps of the study area from global databases and historical weather data measured locally were used. SWAT model was setup to use the MapWindow GIS interface. The model predicted an average daily streamflow and sediment discharge of 24.32 m^3/s and 341.31 metric tonnes, respectively, at the watershed outlet for the case of no land-use change. The major land-use of the study area (savanna) was then altered to grassland and row-crop agriculture to simulate six land-use change scenarios, representing combinations of decreasing grassland (93.76% - 0.09%) and increasing agricultural land (0.09% - 93.76%). Other model inputs were kept constant and experimental runs were performed to obtain streamflow and sediment discharges for a one-year period in daily time steps.

Results show that expansion of agricultural land to about 19% of the watershed area increased average daily streamflow and sediment discharge to about 29% and 44%, respectively. A further increase of streamflow and sediment discharge to about 52% and 79% respectively, was simulated for expansion of agricultural land to 56%. Also, about 72% and 99% increase were obtained for streamflow and sediment discharge, respectively, when agricultural land was expanded to 94% of the watershed area. Generally, as more of the watershed is allocated to row-crop agriculture, streamflow and sediment discharge increased and the measure of increase reflected watershed characteristics and conditions.

KEYWORDS: Map, window, land-use, streamflow, sediment discharge, SWAT, Ebonyi river.

1. INTRODUCTION

Natural watershed systems maintain a balance between precipitation, runoff, infiltration and evapotranspiration, completing the natural hydrologic cycle. Today, land-use changes as a result of human activities (deforestation, commercial agriculture, animal husbandry and urbanisation) have altered this hydrologic balance particularly in small catchments (Cao et al., 2009). Deforestation activities account for the largest percentage of land-use change occurring on the planet (Calder, 2000), resulting to increases in annual streamflow and stormflow volumes in temperate, humid and dry tropical areas (Wilk, 2002). The severity of these problems is more pronounced in arid or semi-arid regions, where high rainfall intensities of short duration on grazing lands and rain-fed farms land have accelerated soil erosion (Omani et al., 2007).

Physically-based, distributed hydrological models such as the Soil and Water Assessment Tool (SWAT) (Arnold et al., 1995) are increasingly being used to simulate complex water resource systems including the impacts of land-use on water resources in river basins during past decades (Xu et al., 2009). The Soil and Water Assessment Tool (SWAT) model was originally developed by the United States Department of Agriculture Research Service (USDA-ARS) to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large ungauged basins (Arnold et al., 1995). Its key strength lies in its ability to predict the relative impacts of changes in land-use on water quantity and quality

(Govender and Everson, 2005), and providing a scientific basis for water resources planning and management, as well as measures to control water and soil erosion (Xu et al., 2009). The SWAT model has been applied in various studies to evaluate watershed response to land-use changes; Fohrer et al. (2001) used hypothetical scenarios to support the development of sustainable land-use concepts, while Heuvelmans et al. (2004) also used hypothetical scenarios to assess implications of land-use impact on hydrology. Pikounis et al. (2003) studied hydrological effects of land-use in Greece which resulted in an increase in discharge during wet months and a decrease during dry periods.

In this study, streamflow and sediment discharge from Ebonyi River Watershed is simulated for different scenarios of land-use change using SWAT.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is the River Ebonyi watershed (3,764km^2) located on the western border of the Cross River Plains, headed by the Udi-Nsukka Escarpment (Fig. 1). Geographically, the River Ebonyi catchment is situated between latitudes 5º78'N and 6º50'N and longitudes 7 º47'E and 8 º00'E. It is situated in the transition zone between the Guinea-Congolian wetter-type forest and Guinea savannah eco-climatological zones with elevation ranging between 105m and 565 m above sea level (Campling et al., 2002). The mean annual temperature is 23ºC and the mean annual rainfall is 1577 mm with the peak rainfall period between mid-August and mid-September (Campling et al., 2000).

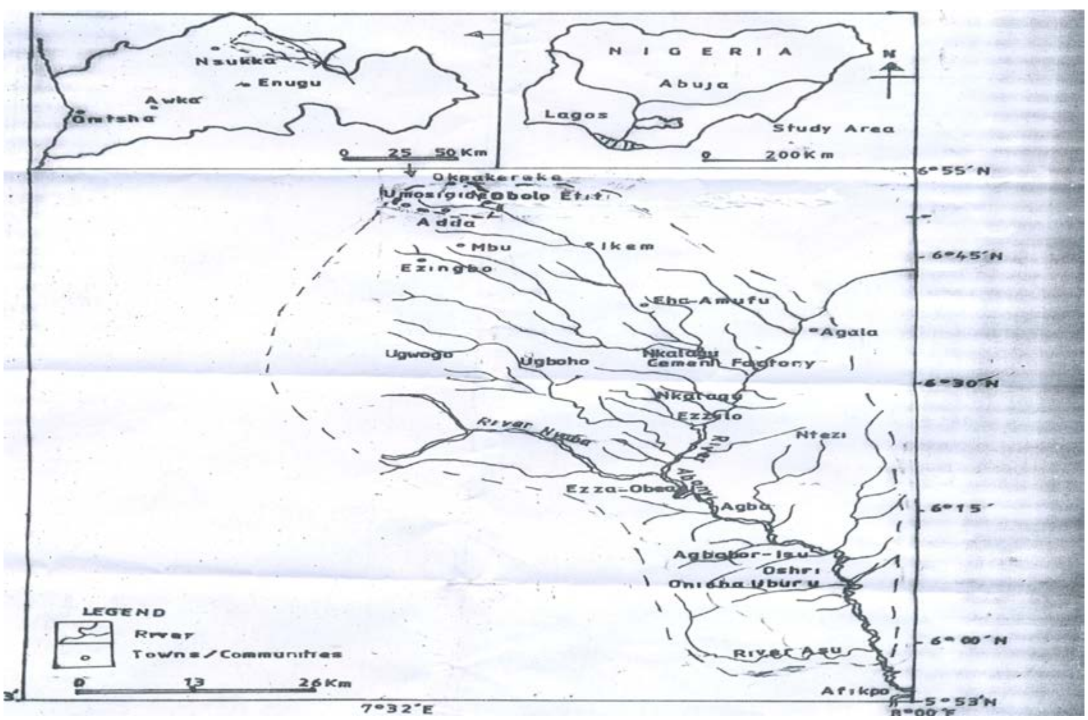

Fig. 1: Location of River Ebonyi Watershed

2.2 Modelling Approach

The Soil and Water Assessment Tool (SWAT), a river basin model, was developed initially by Jeff Arnold for the USDA Agricultural Research Service (ARS) in the early 1990s in Texas A & M University, Texas but is now being applied across the world (Neitsch et al., 2005). The SWAT2005 version used in this study is continuous, spatially distributed, and designed to simulate water, sediment, nutrient and pesticide transport at a catchment scale, on a daily time scale (Setegn et al., 2008). It has eight major components – hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, and agricultural management (Borah and Bera, 2003). A watershed is divided into sub-basins that are spatially related to one another and, further, into hydrological response units (HRUs), which are homogenous units that posses unique land-use/land-cover and soil attributes and which account for the complexity of the landscapes within the sub-basins (Githui et al., 2009). Alternatively, a watershed may be divided into only sub-watersheds that are characterized by dominant land-use, soil type, and management (Gassman et al., 2007). Flow and sediment loadings from each HRU in a sub-basin are summed up and routed through channels to the watershed outlets (Arnold et al., 2001). SWAT was interfaced with a geographical information system (GIS). MapWindow – SWAT (MWSWAT) is an interface between SWAT and the open source GIS MapWindow, and is specifically designed to use freely available GIS data for anywhere in the world, as well as local data when available (George and Leon, 2009).

The hydrologic cycle as simulated by SWAT is based on the water balance equation (Setegn et al., 2008):

$$SWt = SW_{\circ} + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right) \quad \text{.......................................1}$$

where: SW_t = final soil water content (mm water); $SW_{\circ}$ = initial soil water content in day i (mm water); t = time (days); R_{day} = amount of precipitation in day i (mm water); Q_{surf} = amount of surface runoff in day i (mm water); E_a = amount of evapotranspiration in day i (mm water); W_{seep} = amount of water entering the vadose zone from the soil profile in day i (mm water); Q_{gw} = amount of return flow in day i(mm water). In this study, SWAT 2005 (Neitsch et al., 2005) model used the Soil Conservation Service (SCS) curve number method to calculate surface runoff (SCS, 1972) and estimated sediment yield using the Modified Universal Soil Loss Equation (MUSLE) (William, 1975). Also, channel sediment routing was calculated using the stream power equation (Bagnold, 1977) while the variable storage coefficient method (William, 1969) was used to calculate flow routing.

2.3 Model Input

The data used were obtained in the following manner:

a) Digital elevation model (DEM) - a 90 m by 90 m resolution DEM was downloaded from Shuttle Radar Topographic Mission (SRTM, 2004) website on 1st September, 2010. The DEM was used to delineate the watershed as shown in Fig. 2.

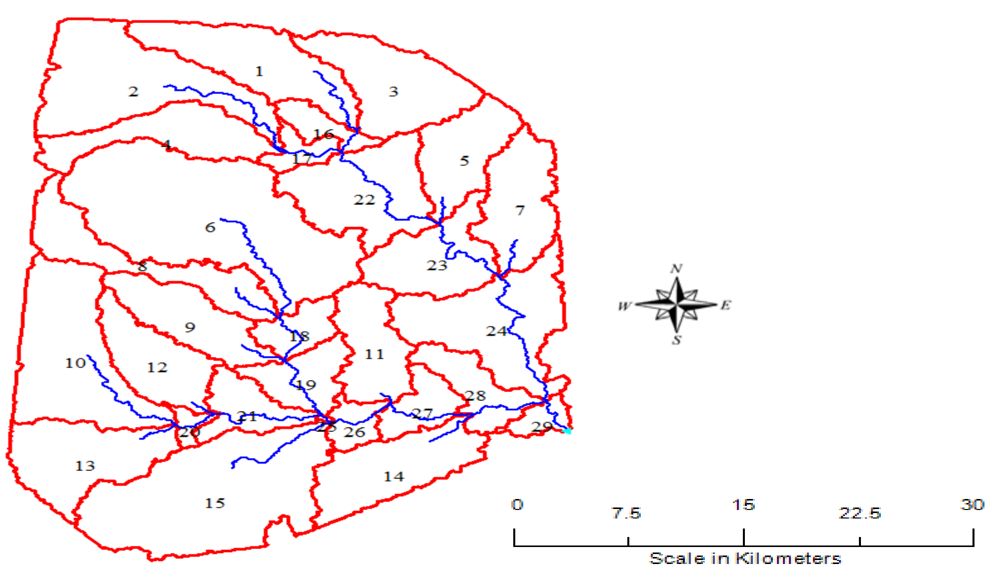

Fig. 2: The Ebonyi River Watershed as Delineated in the Study

b) Land-use Data – obtained from the University of Maryland Global Land Cover Classification (Hensen et al., 1998) at 1km spatial resolution.
c) Soil data - obtained from the Digital Soil Map of the World and Derived Soil properties CD-ROM (FAO, 2003) at a scale of 1:5000000.
d) Weather Data - SWAT requires daily weather data that can either be read from a measured data set or generated by the weather generator component of the model. Daily rainfall and temperature data for Nsukka (6º87'N, 7º43'E, 442m), from 1973 to 1982 was obtained from the Agrometeorological Station, University of Nigeria Nsukka (UNN) and used for this study. Also, breakpoint rainfall data for Nsukka for 2009 was obtained from the Centre for basic Space Studies, UNN and used as input for the weather generator model for filling gaps due to missing data and to determine other weather parameters.

2.4 SWAT Model Implementation

The model setup involved the following steps: (1) watershed delineation; (2) Hydrologic response unit (HRU) definition; and (3) Data input and model execution.

The required spatial datasets (DEM, land-use and soil) were projected to the same projection called UTM Zone 32N, which is the transverse mercator projection parameter for Nigeria using MapWindow GIS 4.7.5. A shapefile of the study watershed was created and imported into the MapWindow-SWAT (MWSWAT) interface. The digital elevation model was used to delineate the watershed into twenty-nine (29) sub-watersheds using a threshold area of 100 km^2. The land-use and soil maps were loaded into the MWSWAT interface and related to land-use and soil classes in the SWAT database to determine the area of each land/soil category simulated within each sub-watershed. An intermediate slope band of 5% was selected and the DEM was used for slope classification. In this study, HRUs were formed based on a particular combination of land-use, soil and slope. A minimal percentage of 5% land-use, 5% soil and 5% slope were selected as the threshold level for HRU definition, which resulted to 96 HRUs in the whole basin. Land-uses which will be eliminated during HRU definition were however exempted. Distribution of land-use types in the study area are as presented in Table 1 for the control Scenario (Scenario 0). Ten years of daily temperature and rainfall data were obtained from the Agrometeorological Station, University of Nigeria, Nsukka, and a weather generator file was created (consist of statistical weather parameters). These were inputted into the model and a simulation run in daily time steps for a one-year period was performed. Model results were obtained at the watershed outlet.

Table 1: Distribution of Land-Use Type for the Control Land-use Scenario (Scenario 0)

Land-use Types	Area (ha)	Watershed (%)
Savanna (SAVA)	353313.26	93.85
Cropland/woodland mosaic (CRWO)	3117.14	0.83
Dry land, cropland and pasture (CRDY)	19481.82	5.18
Evergreen broadleaf forest (FOEB)	163.48	0.04
Residential medium density (URMD)	370.98	0.10

2.5 Land-use Change Scenarios

The Savanna land-use type which covers about 93% of the watershed area was split into Grassland (GRSS) and Agriculture-Row Crop (AGRR) land uses, using the 'Split Land-use' option in the MWSWAT interface. Six land-use scenarios were created to represent combinations of decreasing grassland (93.76% - 0.09%) and increasing agricultural land (0.09% - 93.76%) as in Table 2. Other model inputs (DEM, soil and weather data) were kept constant, while the different scenarios of land-use change were investigated. Model runs were performed for Scenarios 1 to 6, and average streamflow and sediment discharge were obtained at the watershed outlet for a 1-year period.

Table 2: Areal Coverage of Land-Use Change Scenarios in Percent of Watershed Area

Scenario	SAVA		CRWO	CRDY	FOEB	URMD
0	93.85		0.83	5.18	0.04	0.10
	GRSS	**AGRR**	0.83	5.18	0.04	0.10
1	93.76	0.09	0.83	5.18	0.04	0.10
2	75.08	18.77	0.83	5.18	0.04	0.10
3	56.31	37.54	0.83	5.18	0.04	0.10
4	37.54	56.31	0.83	5.18	0.04	0.10
5	18.77	75.08	0.83	5.18	0.04	0.10
6	0.09	93.76	0.83	5.18	0.04	0.10

3. RESULTS AND DISCUSSION

3.1 Simulated Streamflow and Sediment Discharge

Results for the control simulation (Scenario 0) processed for average weekly streamflow and sediment discharges at the watershed outlet are shown in Figures 3(a) and 3(b), respectively. It was observed from Fig. 3 that both average weekly streamflow and sediment yield discharges followed the same pattern (high in rainy season and low in dry season) as sediment discharge is sensitive to changes in streamflow. Thus higher amounts of suspended sediment were found to be transported when the watershed was hydrologically more active. Similar distributions for discharge and sediment yield were observed in studies by Xu et al. (2009) and Lana-Renault et al (2010).

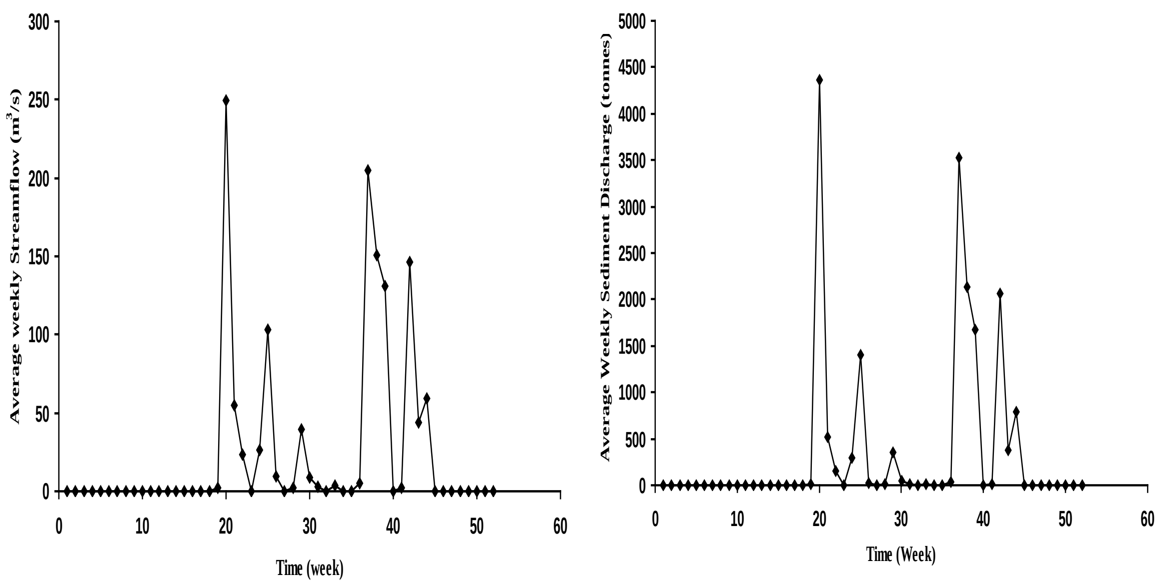

Fig. 3: (a) Average Weekly Streamflow (b) Average Weekly Sediment Discharge

3.2 Land-Use Scenarios

Similarly, model results for Scenarios 1 (best-case scenario) to 6 (worst-case scenario), processed for average weekly streamflow and sediment discharges are plotted in Figures 4 and 5. These results were compared to the results from the control simulation (Scenario 0) and it was observed that all land-use scenarios followed the same pattern with increases in streamflow (Fig. 4) and sediment discharge (Fig. 5) as more of the watershed area is allotted to row-crop agriculture. Previous studies (Pikounis et al., 2003; Govender and Everson, 2005, Githui et al, 2009, Renault-Lana et al., 2010,) clearly show the strong impact that agricultural land-use have on runoff discharge and sediment yield.

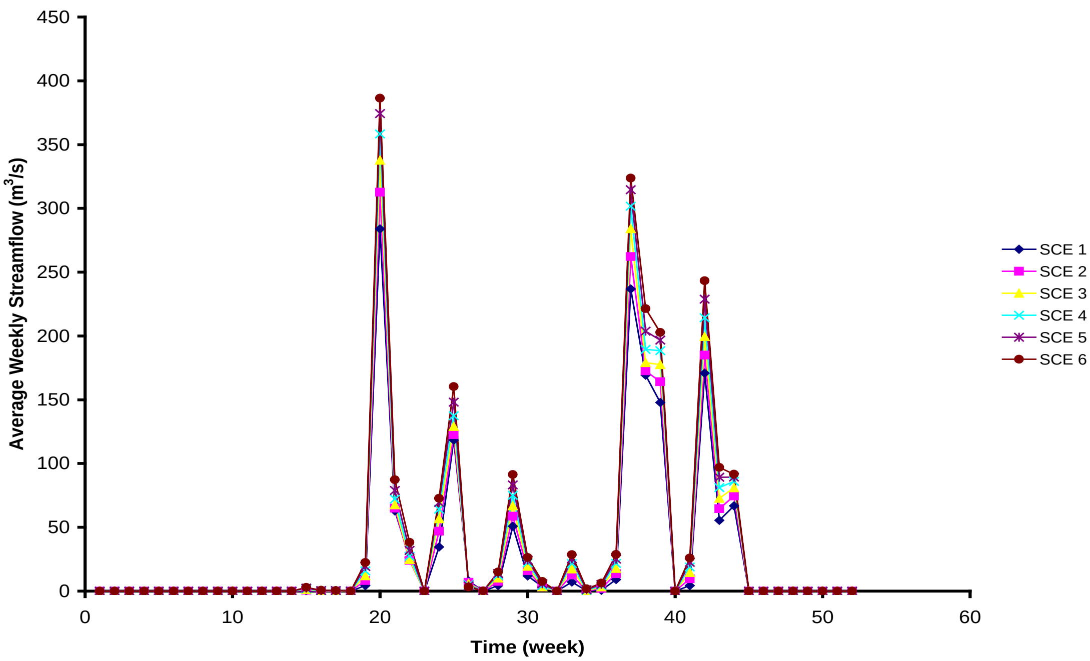

Fig. 4: Average Weekly Streamflow for Land-Use Scenarios 1 to 6

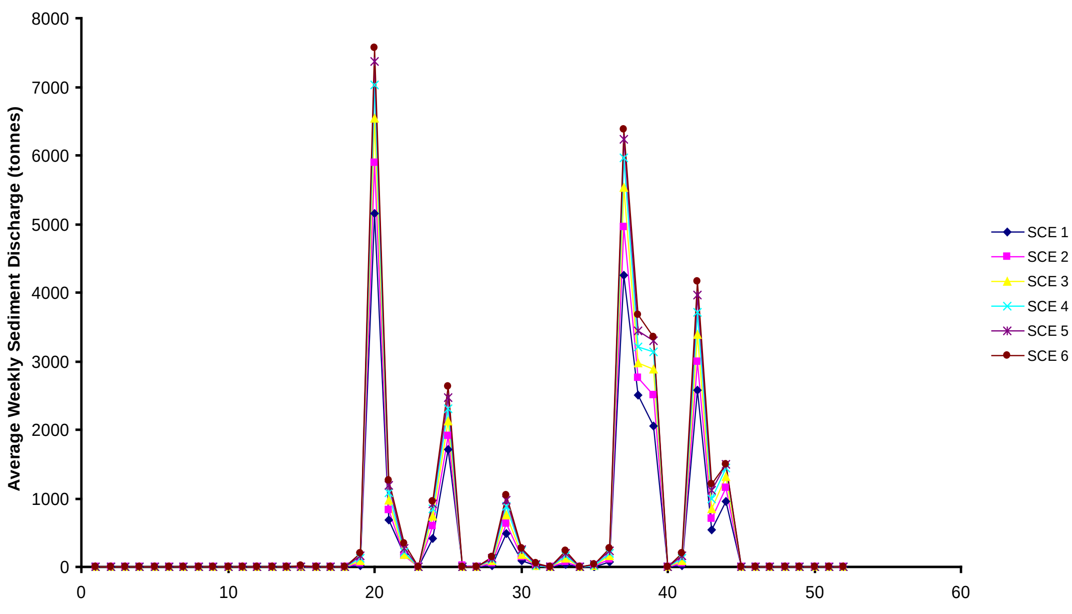

Fig. 5: Average Weekly Sediment Discharge for Land-Use Scenarios 1 to 6

Comparisons between simulated average daily streamflow rates from the control land-use scenario (Scenario 0) and that from the six land-use change scenarios show that the average daily streamflow increased by 16.53% for scenario 1, 28.82% for scenario 2, 40.63% for scenario 3, 51.81% for scenario 4, 62.38% for scenario 5 and 72.41% for scenario 6. Consequently, average daily sediment discharge increased by 22.53% for scenario 1, 43.94% for scenario 2, 63.25% for scenario 3, 78.92% for scenario 4, 90.87% for scenario 5 and 99.52% for scenario 6. This study has clearly shown that an increase in agricultural land area from 0.1% to 94% will increase discharge and sediment yield from about 17% - 72% and 23% - 99% respectively in Ebonyi River Watershed. This increase in runoff due to increase in agricultural land area is in line with a study by Githui et al. (2009) which predicted a change in runoff from about 55 – 68% as agricultural land area increased from about 40 – 64%.

From Figures 4 and 5, scenario 6 (worst-case scenario) yielded the most streamflow and sediment respectively and were observed to be higher during the wet months and lower during the dry months. Removal of vegetative cover, especially grass, would generally increase average surface runoff. Row-crop agriculture is also known to leave the soil bare for a longer period of time, particularly during periods of crop planting and early growth stages. Therefore, as more of the watershed is converted to row-crop agriculture, the rates of overland flow increase leading to higher runoff rates. This results to increased detachment and transportation of sediments. Also, ridging which characterizes row-crop agriculture creates a very loose and porous upper soil condition which facilitates soil erosion.

Generally, the average daily streamflow and sediment discharge increases from the best-case scenario (Scenario 1) to the worst-case scenario (Scenario 6) for the study area as shown in Table 3. Observed results shows the tendency for flooding and land degradation (soil erosion) to occur if a greater land area of the study area is put to unsustainable agricultural practice.

Table 3: Average Daily Streamflow and Sediment Discharge for all Scenarios

Scenario	Streamflow (m^3/s)	Sediment Discharge (tonnes)
0	24.32	341.31
1	28.34	418.22
2	31.33	491.29
3	34.20	557.20
4	36.92	610.66
5	39.49	651.46
6	41.93	680.98

4. CONCLUSIONS

The need to provide food and shelter to the ever increasing world population has led to alterations in our natural watershed systems, affecting the hydrologic balance. The capability of MapWindow GIS in using freely available global, spatial data (DEM, land-use and soil) from online sources, and interfaced with the Soil and Water Assessment Tool has been tested in this study to evaluate the impacts of land-use change on streamflow and sediment discharge from the Ebonyi River watershed.

Digital elevation, land-use and soil maps of the study area from global databases and historical weather data measured locally were inputs into the model and a one year simulation run in daily time steps performed. The major land-use (Savannah) of the study area was split into different combinations of agricultural land and grassland to create six (6) land-use scenarios, and model experimental run was performed with other inputs held constant.

Study results show that streamflow discharge and sediment yield follows the same pattern, with peaks during rainy season. Also, model results for the different land-use scenarios clearly show that expansion of row-crop agricultural land area in the Ebonyi River watershed impacted significantly on streamflow discharge and sediment yield at the watershed outlet with higher amounts occurring during wet months. Thus, a shift in land-use from grassland to unsustainable agricultural practices in the future will have significant impact on the hydrological system of the study area resulting in extreme runoff and soil erosion during wet months. Result from this type of study serves as a useful guide on water resources, water quality and related environmental hazard issues.

REFERENCES

Arnold, J. G., William, J.R. & Maidment, D. R. 1995. Continuous-Time Water and Sediment-Routing Model for Large Basins. Journal of Hydraulic Engineering, 121 (2): 171 - 183

Arnold, J. G., Allen, P. M. & Morgan, D. S. 2001. Hydrologic Model for Design & Constructed Wetlands. Wetland 21 (2): 167-178.

Bagnold, R. A. 1977. Bedload Transport in Natural Rivers. Water Resour. Res. 13: 303 – 312.

Borah, D. K. and Bera, M. 2003. SWAT Model Background and Application Reviews. ASAE Annual International Meeting, Las Vegas, Nevada, USA. July 27- 30 Paper Number: 032054.

Calder, I. R. 2000. Land-use Impacts on Water Resources. Land-use and Water Resources Research (1): 2.1-2.14

Campling, P., Gobin, A. and Feyen, J. 2000. Temporal and Spatial Rainfall Analysis Across a Tropical Catchment. Hydrological Processes 15(3): 359 – 375.

Campling, P., Gobin, Q., Beven, K. and Feyen, J. 2002. Rainfall-Runoff Modelling of a Humid Tropical Catchment: The TOPMODEL Approach. Hydrological Processes (16): 231 – 253.

Cao. W., Bowder, W. B. & Davie, T. 2009. Modelling Impacts of Land Cover Change on Critical Water Resources in the Motueka River Catchment, New Zealand. Water Resources Management (25): 137-151.

FAO 2003. Digital Soil Map of the World and Derived Soil Properties http://www.fao.org/catalog/what_new-e.htm.

Fohrer, N., Haverkamp, S., Eckhardt, K., & Frede, H.G. 2001. Hydrologic Response to Land-use Changes on the Catchment Scale. Phys. Chem. Earth (B) (7 – 8): 577 - 582

Gassman, P. W., Reyes, M. R., Green, C. H. and Arnold, J. G. 2007. The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Directions. Transactions of the ASABE 50(4): 1211-1250.

George, C. & Leon, L. F. 2009. WaterBase: Open Source Software for Integrated Water Resources Management. SWAT-SEA Conference. Chiang Mai, China.

Githui, F., Mutua, F., Bauwens, W. 2009. Estimating the Impacts of Land-Cover Change on Runoff Using the Soil and Water Assessment Tool (SWAT): Case Study of Nzois Catchment, Kenya. Hydrological Sciences Journal 54 (5): 898-908.

Govender, M. & Everson, C. S. 2005. Modelling Streamflow from Two Small South African Experiment Catchment Using the SWAT Model. Hydrol. Process (19): 683-692.

Hensen, M., Defries, R. Townshend, J. & Sohlberg, R. 1998. IKm Land Cover Classification Derived from AVHRR. http://www.glef.umiacs.umd.edu/data/landcover

Heuvelmans, G., Muys, B. & Feyen, J. 2004. Evaluation of Hydrological Model Parameter Transferability for Simulating the Impacts of Land Use on Catchment Hydrology. Phys. Chem. Earth Parts A/B/C 29 (11 – 12), 739 – 747.

Lana-Renault, N., Regues, D., Nadal-Romero, E., Serrano-Muela, M. P. and Garcia-Ruiz, J. M. 2010. Streamflow Response and Sediment Yield After Farmland Abandonment: Results from a Small Experimental Catchment in the Central Spanish Pyrenees. Pirineous, 165: 97 - 114

Neitsch, S. L., Arnold, J. G., Kiniry, J. R. & Williams, J. R. 2005. Soil and Water Assessment Tool, Theoretical Documentation: Version 2005. Temple, TX. USDA Agricultural Research Service and Texas A & M Blackland Research Centre.

Omani, N., Tajrishy, M. & Abrishamchi, A. 2007. Modelling of a River Basin Using SWAT Model and SUFI-2. 4th SWAT International Conference, Delft, Netherlands. July 4-6

Pikounis, M., Varanou, E., Baltas, E., Dassaklis, A. & Mimikou, M. 2003. Application of the SWAT Model in the Pinios River Basin under different land-use Scenarios. Global Nest: the Int. J. 5(2); 71 – 79.

Setegn, S. G., Srinivasan, R. & Dargahi, B. 2008. Hydrological Modelling in the Lake Tana Basin, Ethiopia Using SWAT Model. The Open Hydrology Journal (2): 49-62

SRTM 2004. DEM Data from International Centre for Tropical Agriculture (CIAT), Available from the CGIAR-CSI Shuttle Radar Topographic Mission 90m. http://www.srtm.csi.cgiar.org

USDA Soil Conservation Service 1972. National Engineering Handbook Section 4 Hydrology, Chapters 4 -10.

Wilk, J. 2002. Hydrological Impacts of Forest Conversion to Agriculture and Local Perceptions in a Large River Basin in Northeast Thailand. 12th ISCO Conference, Beijing, China.

William, J. R. 1969. Flood Routing with Variable Travel Time or Variable Storage Coefficient. Trans. ASAE 12 (1): 100-103.

William, J. R. 1975. Sediment Routing from Agricultural Watersheds. Water Resour. Bull. 11(5): 965 – 974.

Xu, Z. X., Pang, J. P., Liu, C. M. & Li, J. Y. 2009. Assessment of Runoff and Sediment Yield in the Miyun Reservoir Catchment by Using SWAT Model. Hydrol. Process. (23): 3619-3630

INFLUENCE OF DIFFERENT SOIL FERTILITY MANAGEMENT ON WATER, RADIATION USE EFFICIENCIES AND YIELD COMPONENTS OF GREENHOUSE GROWN *ORYZA SATIVA*

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ABSTRACT

A greenhouse experiment was conducted under the humid rainforest climate of Akure, Nigeria to determine the water and radiation use efficiencies, and biomass yield of *Oryza sativa*.L, variety Farro-46, under four different soil fertility managements. The treatments were: liquid NPK fertilizer applications at rate 2.5 L ha^{-1}, 0.20 ton ha^{-1} of poultry manure, 0.20 ton ha^{-1} organo-mineral fertilizer, and zero fertilizer application (control). The four treatments were replicated nine times to make a total of thirty six samples. The crop was planted in sandy loam soil contained in cylindrical buckets (22 cm diameter and 30 cm high). The highest seasonal water use efficiency (WUE) value during the experiment occurred in treatment samples under poultry manure with a value of 154.27 (±4.41) kg mm^{-1} ha^{-1} and least value 62.98 (±1.74) kg mm^{-1} ha^{-1} was observed in the control treatment samples (C). The mean difference of water use efficiencies between samples under control treatment and samples under poultry manure treatment was highly significant at the $p \leq 0.05$ level. The radiation use efficiency of *rice* was highest (0.222±0.05 g MJ^{-1}) in poultry manure treated samples. Measured plant parameters showed the greatest grain and biomass yields of 4.27(±0.98) and 6.31(±0.29) ton ha^{-1}, respectively were observed in samples under poultry manure treatment. The mean plant height at 84 days after sowing (DAS) was 53.06 cm, 58.20 cm, 57.45 cm, 56.60 cm under the control, poultry manure, organo-mineral and NPK fertilizer treatments, respectively, while the mean leaf areas during the 84 DAS were 49.5, 91.82, 43.0, and 42.7 cm^2 and corresponding leaf area index values were 0.36, 0.66, 0.31 and 0.31 in treatment plots under control, poultry manure, NPK fertilizer and organo-mineral fertilizer, respectively. The total wet biomass yields at the 12 DAS were 5.19 (±0.89) tonha^{-1}, 6.31 (±4.29), 5.77 (±1.76) and 3.80 (±0.58) in samples under NPK fertilizer, poultry manure, organo-mineral and control, treatments, respectively. The poultry manure and organo-mineral fertilizer applied improved the chemical properties of the soil and consequently a significant increase in the biomass yield of rice.

KEYWORDS: *Oryza sativa*, yield, water use efficiency, radiation use, rice, soil fertility.

1. INTRODUCTION

Rice is the world’s most important staple food and feeds more than two billion people in Asia and hundreds of millions in Africa and Latin America (Ladha *et al*., 1997). It is by far the most economically important food crop in many developing countries (FAO, 1995a). The potential production of rice in Nigeria is estimated at 4.6 to 4.9 million hectares. However, only about 1.7 million hectares of this land is presently being cropped to rice which is far below the production capacities of other countries of the world. There are a number of factors contributing to this yield gap, including poor soil fertility. In fact there is no other alternative for higher productivity, than to use balance plant nutrition, crop improvement and cultural management strategies (Ahmad, 1992).

The optimum use of fertilizer nutrient, particularly nitrogen plays an important role in boosting the yields (Mandal *et al.,* 1999). It is a fact that the use of nitrogenous and phosphatic fertilizers above the optimum levels at the different phenological stages of the crop instead of giving yield advantage may reduce the same (Bajwa and Rehman, 1998). Different varieties may have varying responses to N and P fertilizers depending on their agronomic traits. The application of nitrogen and phosphorous fertilizer either in excess or less than optimum rate affects both yield and quality to a remarkable extent (Manzoor *et al.*, 2006). Hence proper management of crop nutrition is of immense importance. Rice grain yield was recorded highest in case the N application ranged between 90-250 kg ha^{-1} (Bali *et al.*, 1995). However, the application of chemical fertilizers is costly and gradually lead to the environmental problems. Organic residue recycling is becoming an increasingly important aspect of environmentally sound sustainable agriculture. Nowadays, agriculture production based on organic applications is growing in interest and the demands for the resulting products are increasing (Azad *et al*., 1995).

Therefore, the effective use of organic materials in rice farming is also likely to be promoted. The application of organic materials is fundamentally important in that they supply various kinds of plant nutrients including micronutrients, improve soil physical and chemical properties and hence nutrient holding and buffering capacity, and consequently enhance microbial activities (Suzuki, 1997). In addition, organic matter continuously releases N as plant need it. N is the most limiting nutrient in irrigated rice systems, but P and K deficiencies are also the constraints increasing yield for consecutive planting of rice (Rafey *et al*., 1989). Therefore, use of livestock wastes in agricultural soils has been an increasing interest due to the possibility of recycling valuable components such as organic matter, N, P and K (Suzuki, 1997). An advantage of farm application of organic wastes is that they usually provide a number of nutritive elements to crops with little added cost (Myint *et al*., 2010).

In Nigeria, rice is widely grown in swampy areas, which are very limited and far below rice demand by the populace (Akanji, 1995). Little attention is still being given to upland rice production in Nigeria perhaps as a result of low yields following inadequate technology for its production (Ayotade and Fagade, 1986; Singh *et al.*, 1997). One of such inadequate technology is that most recommended rates of fertilizers are based on results of studies conducted in different agro-ecologies where soils and climatic conditions are not quite similar. Moreover, the inability of the farmers to know the most adaptable varieties for a given agro-ecology is also a serious factor. Against this background, it has become important to conduct a study on the effects of different fertilization on the yield of rice in Akure agro-ecology zone of Nigeria (Tanaka, 1964).

The rice used in this study was the Farro-46 variety, which is very popular with farmers for its high yield potential and wide adaptability. However, there is little available research information related to the influence of water use and radiation efficiencies on yield response under different N application. Therefore, the research was aimed at determining the consumptive use, radiation and water use efficiencies, and dry matter yield of rice grown under different N sources.

2 MATERIALS AND METHODS

2.1 Description of the Study Area

The field experiment was conducted in the greenhouse of the Agricultural Engineering Department, Federal University of Technology, Akure between June and August, 2011. The site is located in Akure (latitude 7^o14'N and longitude 5^o08'E) which lies within the humid sub-tropical region of Nigeria. Akure lies in the rain forest zone with a mean annual rainfall of between 1,300 – 1,600 mm and with an average temperature of 27°C. This climate is influenced by the monsoons originating from the South Atlantic Ocean, which is brought into the country by the (maritime tropical) MT airmass. The Tropical rainforest has a very small temperature range; the temperature ranges are almost constant throughout the year. The southern part of Nigeria, experiences heavy and abundant rainfall, the storms are usually conventional in making, due to the region proximity to the equatorial belt. The relative humidity ranges between 85 and 100% during the rainy season and less than 60% during the dry season period. Akure is about 351 m above the sea level. Akure is an area of about 2,303 km^2 situated within the western upland area (Fasinmirin and Oguntuase, 2008).

2.2 Treatment and Experimental Procedures

Rice seeds (*Oryza sativa* L.) of variety Farro-46 were established in rubber buckets of diameter 22 cm and depth 30 cm filled with sandy loam soil of the crop, soil and pest management (CSP) department (crop museum), characterized with mean electrical conductivity (EC) of 1.7 x 10^2 µmhos, pH of 5.9, organic matter content of 2.72%; and N, P, K, effective CEC values of 0.12 %, 2.40 mg kg^{-1} and 0.17 Cmol kg^{-1} and 2.96 Cmol kg^{-1}, respectively. The base of the buckets was perforated to allow drainage of water from the buckets. The soil was sieved with 3 mm diameter sieves so as to improve water penetration and good root development. The experiment comprised of three different fertilizer applications and a control which was replicated three times as shown in Table 1.

Table 1: Different fertilizer treatments of soils

Code		Definition
T1	-	NPK fertilizer application
T2	-	Poultry manure application
T3	-	Organo-mineral application
T4	-	Zero fertilization application

Rice seeds variety "Farro-46" was obtained from Institute of Agricultural Research and Training (IAR&T), Ibadan. Seeds were planted at rate of 1.2kg ha^{-1} on Thursday 2nd June 2011 and plant stands were thinned down to one plant per bucket at two (2) weeks after planting.

Organic manure treatments i.e poultry manure and organo-mineral was applied as single application pre-sowing at a rate of 0.2 ton ha^{-1} on Wednesday 1st June, 2011 while liquid NPK fertilizer was applied three weeks after planting by spraying. The weight by volume of the liquid fertilizer shows 20 % Nitrogen, 20% Phosphate, 20% Potassium, 1.5% Magnessium (MgO), 0.15% Iron (Fe), 0.075% Manganese (Mn), 0.075% Cooper (Cu), 0.075% Zinc (Zn), 0.0315% Boron (B), 0.0012% Cobalt (Co) and 0.0012% Molybdenum (Mo). Manual weeding was carried out on weekly basis. Irrigation water was applied when soil moisture content fell below 12% corresponding to the soil moisture content at field capacity.

2.3 Climatic Variables during the Experiment

Climatic variables of the experimental site were collected. Climatic data collected include the rainfall, maximum and minimum air temperature, maximum and minimum relative humidity (RH), wind speed and their average values computed. The climatic variables are used to calculate reference crop evapotranspiration using Penman-Monteith equation (Allen *et al*., 1998). The actual crop evapotranspiration was estimated based on the different phenological stages of the crop by the multiplication of crop factor for the crop growth stage with the reference evapotranspiration, while the seasonal crop evapotranspiration was estimated by the addition of the estimated actual crop evapotranspiration of the different crop phenological stages (Allen *et al*., 1998).

2.4 Soil Physiochemical Characterization

Chemical characterization of the collected soil samples includes the analysis of organic matter, Cation Exchange Capacity (CEC) at pH 7.0 and soil pH whereas the physical characterization consisted of particle size analysis, water holding capacity, particle density, bulk density and total porosity determination. The exchangeable Potassium (K^+) was extracted with HCl solution and their levels determined by flame photometry. The cation exchange capacity (CEC) at pH 7.0 with Ammonium Acetate was determined following the procedure described by Chapman (1965). The soil pH was determined using the digital electronic pH meter.

Soil particle sizes were determined by the pipette method using the ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils. Textural classification was carried out using the USDA classification system. Soil moisture content was recorded at depths 0 -5 cm, 5 – 10 cm and 10 – 15 cm during experiment using a hand-held digital soil moisture meter - Lutron PMS-714; IP- 65 water resistance, heavy duty ranging from 0-50% moisture content with a 7.9” SS probe supplied by Lutron Electronic Enterprise Co., Ltd. The bulk density was obtained by the gravimetric soil core method described by Blake and Hartge (1986) and the particle density (Dp) was determined from the bulk density. The total porosity (Pt) was calculated from bulk density (Ds) and Dp using the equation and relationship developed by Danielson and Sutherland (1986). The organic matter content was determined using ASTM D 2974 – Standard test methods for moisture, ash, and organic matter of peat and organic soils.

2.5 Crop Data

2.5.1 Evapotranspiration (ET), Water and Radiation Use Efficiencies

Reference ET was measured using the Penman-Monteith model (FAO 56). Reference ET throughout the period of rice development was measured and the Actual ET determined by the product of reference ET and the crop factor (Kc) at the varying stages of development (FAO-56). Also, direct evapotranspiration (ET) of rice was estimated on daily basis by direct weighing of growing rice on electronic weighing balance. The difference between measurements of two consecutive days represents evapotranspiration value for the period of such measurements. Daily evapotranspiration was estimated using equation given by Kadayifci *et al.* (2005) given as:

$$ET_o = \frac{W_{i-1} - W_i}{\rho_w \ x \ A} \qquad 1$$

Where $ET_{(0)i}$ is the evapotranspiration (mm), W_{i-1} and W_i are weights (kg) of the bucket at day *i*-1 and *I* respectively, ρ_w is the gravimetric water content (g/cm^3), and A is the surface area (m^2) of the bucket (Kadayifci *et al*, 2005). The water use efficiency (WUE) of the crop was estimated from the relationship of the crop evapotranspiration and the biomass yield of rice as shown in equation 2

$$WUE = \frac{Biomass\ yield\ (kg\ ha^{-1})}{Evapotranspiration\ (mm)} \qquad 2$$

The fraction of intercepted radiation (Fi) was estimated from LAI using the exponential attenuation equation (Monteith and Elston, 1983).

$$Fi = 1- \exp(-K \times LAI) \qquad 3$$

where K is extinction coefficient for total solar radiation The coefficient is equal to 0.306 (Monteith ,1977). The PAR was assumed to be equal to one half of the total incident radiation Szcich (1974). Multiplying these totals by the appropriate estimates of Fi gave an estimate of the amount of radiation intercepted by a crop canopy (Sa) where

$$Sa = Fi \times Si \qquad 4$$

where Si is the total amount of incident PAR. The radiation utilization efficiency was then defined following the relationship in equation 5 as given by Ahmad *et al.* (2008)

$$RUE = \frac{Biomass\ yield\ (kg\ ha^{-1})}{\Sigma S_a} \qquad 5$$

2.6 Agronomic Parameters

Plant height was measured weekly from the 2nd week to the 12th week while leaf area and leaf area index were measured during the 4th, 5th, 6th and 8th week after planting. The height of plant was measured from the soil surface to the apex of the plant. The leaf area was measured using the approximate method tracing leaf samples on graph paper to measure the number squares therein, which represents the leaf area. From this measurement, leaf surface area (cm^2) and leaf area index was estimated by the following relationship (Watson, 1947).

$$\text{Leaf Area Index (LAI)} = \frac{\text{Total surface area of plant}}{\text{Soil surface area covered by the plant}} \qquad 6$$

2.7 Statistical Analysis

Crop data obtained from the experiment were subjected to statistical analysis. The mean of biomass yield was computed and analysis of variance (ANOVA) was performed on the crop data obtained from the four treatments.

3. RESULTS AND DISCUSSION

3.1 Climatic Condition during Experiment

The mean air temperature and relative humidity of the greenhouse during the period of experiment is presented in Table 2. There were fluctuations in the mean air temperature and relative humidity and observed values did not follow specific pattern from the first 1st week after planting (1WAP) to the 13WAP.

Highest mean maximum relative humidity, RH (94.3%) occurred at the 9WAP (1st week of August) and the RH value was accompanied by the lowest mean air temperature (26.2 °C). The lowest minimum RH (71.8%) was observed at the 1WAP, with characteristically warm air temperature of 32.3 °C, which was typical of the period of the onset of heavy rainfall. The highest mean air temperature (34.4 °C) was observed during the 13WAP (period of short dry spell, when rainfall ceases). However, mean relative humidity value of 83.35% was recorded during the second week of July (6WAP), a period of low solar radiation and few hours of sunshine.

Table 2. Mean Air Temperature and Rel. Humidity in the Greenhouse

Month	Date	Mean air temperature (°C)	Mean maximum relative humidity (%)	Mean minimum relative humidity (%)
June	1WAP	32.3	81.2	53.1
	2WAP	30.2	89.0	68.8
	3WAP	29.3	73.6	62.7
	4WAP	26.6	81.5	71.2
July	5WAP	27.6	79.0	68.9
	6WAP	27.1	88.8	77.9
	7WAP	26.8	83.5	73.0
	8WAP	33.7	80.2	75.0
July -August	9WAP	26.2	94.3	64.0
	10WAP	29.6	78.6	70.4
	11WAP	30.4	77.2	68.6
	12WAP	30.9	78.5	70.3
August – September	13WAP	34.4	71.8	64.0

Generally, the pattern of climate is such that at the inception of full wet season in June, the mean air temperature dropped to a low value of 26.8 °C. The mean air temperature however rose gradually till it reached its maximum value (34.4 °C) in the month of September, just before the inception of another peak rainfall period.

3.2 Physicochemical Properties of the Soil used for the Experiment

The properties of the soil before planting are shown in Tables 3. The result of particulate analysis of the soil showed a sandy clay loam classification (Soil Survey Staff, 1999). The top soil forms mainly the agricultural layer required for the cultivation of most cereals. The top soil average carbon content falls within the range (0.6 - 1.2%) given by Young (1976) as desirable for tropical crop production. The high organic matter content of treatment plots may be due to the fact that the sampled points were not frequently cultivated and primary carbon production is high (Fasinmirin and Oguntuase, 2008). The organic matter accumulation may also be due to continuous plant growth on the soil collected for the experiment. The highest mean soil pH falls within the acidic range (5.56) before planting was done. This value fell within the limit 6.5 considered ideal for good availability of plant nutrients in the mineral soils (Foth and Ellis, 1997). The bulk density of the experimental site ranged from 1.26 – 1.33 g cm^{-3} within the first 0.15 m depth of soil.

Table 3: Data of the physicochemical properties of the field before planting

Treatments	Sand	Clay	Silt	OMC	pH	N	P	K	Ca	Mg	C.E.C
	(%)	(%)	(%)	(%)			(%)	(PPM)	(cmol/kg)	(PPM)	(cmol/kg)
	(cmol/kg)										
NPK	20.30	70.40	10.30	2.10	5.56	1.30	16.85	0.53	0.55	2.50	1.81
Poultry manure	20.12	69.75	10.13	2.15	5.46	1.50	17.05	0.55	0.56	2.65	1.74
Organo-Mineral	21.35	69.21	9.44	2.42	5.38	1.46	14.67	0.62	0.58	2.72	1.83
Control	21.49	68.16	10.30	2.25	5.34	1.40	16.93	0.58	0.60	2.70	1.71

3.3 Water and Radiation Use Efficiencies

The water and radiation use efficiencies of rice at the end of the experiment (50 DAP) is presented in the Table 4. The highest and lowest values of water use efficiency (WUE) were 154.27 (±1.86) and 62.98 (±0.32) kg mm^{-1} ha^{-1} under poultry manure and control treatments, respectively, while the highest and lowest values of radiation use efficiency (RUE) were 0.222 g MJ^{-1} and 0.098 g MJ^{-1} under poultry manure and NPK treatments, respectively (Table 4). The difference in WUE among treatments was highly significant at the 5% level of probability (Table 5). The high value of WUE observed in plots under poultry manure treatments during the 50 DAP may be due to the effective utilization of moisture and nutrient for greater yield (Fasinmirin and Olufayo, 2009). The lower RUE in the NPK treatment may be due to the orientation of the greenhouse which may have caused reduced total incident radiation (TIR) to the treatment. The mean difference of RUE between the sample pots under poultry manure and organo-mineral treatments are not significant at 5% probability level (Table 6).

Table 4: Mean water use efficiency (WUE) and Radiation use efficiency (RUE) at 50 DAP

Treatments	WUE (kg mm^{-1} ha^{-1})	RUE (g MJ^{-1})
NPK fertilized plots	85.30(±3.44)	0.098(±0.01)
Poultry manure plots	154.27(±4.41)	0.222(±0.05)
Organo-Mineral plots	111.32(±6.09)	0.204(±0.06)
Control (zero fertilizer)	62.98 (±1.74)	0.103(±0.01)

Table 5. Mean comparison of WUE among treatments (Tukey test)

(i) Treatment	(j) Treatments	Mean Difference (i – j)
1	2	68.96*
1	3	26.02*
1	4	22.32*
2	3	42.95*
2	4	91.28*
3	4	48.34*

*The mean difference is significant at the 0.05 level

Table 6. Mean comparison of RUE among treatments (Tukey test)

(ii) Treatment	(j) Treatments	Mean Difference (i – j)
1	2	0.13*
1	3	0.11*
1	4	0.01
2	3	0.02
2	4	0.12*
3	4	0.10*

*The mean difference is significant at the 0.05 level

3.4 Agronomic Measurements

3.4.1 Plant Height

Table 7 shows the mean plant height between one and six weeks after planting (WAP). The plant height was highest in the plots under poultry manure treatment than in the treatment plots that received fertilizer, urea and the control treatment The mean plant height under NPK fertilizer, poultry manure, organo-mineral and zero fertilizer (control) were 42.60 (±20.1) cm, 46.13 (±1.92) cm, 42.70 (±0.76) cm, and 41.20 (±1.18) cm, respectively at the 4 WAP. The highest plant growth in soil under poultry manure treatment may have been caused by the improvement of soil properties such as organic matter increase, improved water holding capacity, enhanced cation exchange capacity (CEC) and increased micro-organism activities in the soil. Similar observation was made by De Jong (1983), who reported increased soil moisture retention upon increase in soil organic matter content in disturbed soil. Rice plant under poultry manure treatment consistently showed greater height than the other three treatments from the 3 WAP to the 6 WAP.

Table 7: Mean Plant Height (cm) of rice

Treatments	Plant Height in cm				
	1WAP	2WAP	3WAP	4WAP	6WAP
NPK	6.70(±0.78)	15.24(±1.67)	23.66(±1.09)	42.6(±2.01)	46.60(±0.97)
Poultry Manure	6.82(±0.12)	14.58(±1.53)	33.17(±2.12)	46.13(±1.92)	48.20(±0.45)
Organo-Mineral	5.75(±2.17)	13.40(±1.67)	22.88(±1.89)	42.70(±0.76)	47.45(±1.79)
Control	7.25(±0.21)	14.98(±0.52)	27.91(±2.27)	41.20(±1.18)	43.06(±1.86)

3.4.2 Biomass Yield

The values of biomass yield in the various treatments are shown in Table 8 at 50 DAP. Biomass yield was increased as a result of the fertilizer applied. The total wet biomass yield for the four fertilizer application treatments differed significantly. There was significant difference between the mean yields of treatments with fertilizer and the control. The mean of the total wet grain yield at 84 DAP are 2.68 ton ha^{-1} under the control treatment, 4.27 ton ha^{-1} under poultry manure treatment, 3.79 ton ha^{-1} under NPK fertilizer treatment and 3.97 ton ha^{-1} in samples under organo-mineral treatment. Samples with poultry manure treatment had the highest yield. The result also showed appreciable effect of organo-mineral fertilizer and NPK to soil fertility.

Table 8: Mean (stdev.) grain yield and biomass yield (wet) of rice at maturity

Treatments	Grain yield (ton ha^{-1})	Biomass yield (ton ha^{-1})
NPK	3.79 (±0.12)	5.19(±0.89)
Poultry Manure	4.27(±0.98)	6.31(±0.29)
Organo-Mineral	3.97(±1.47)	5.77(±1.76)
Control	2.68(±1.45)	3.80(±0.58)

3.5.3 Leaf Area and the Leaf Area Index (LAI)

Table 9 shows the values of leaf area (LA) and leaf area index (LAI) of rice during the 4th, 8th and 12th WAP. There were significant differences in the LA and the LAI among treatments at the 5% level of significance. The leaf area of rice at the 6WAP was 52.70, 91.82, 53.02 and 49.50 cm^2 in plots under NPK, poultry manure and organo-mineral applications and control treatments, respectively.

The leaf area and the leaf area index increases from the control to the poultry manure treatment, which had the highest leaf area index (0.24). The leaves of rice responded fast to manure applications with luxuriantly green surfaces. This is because of the available nutrient in the soil and moisture. This result revealed that the soil fertility condition had a significant effect on the size of the leaf developed by the rice plants. The increase in some of these agronomic characters could be attributed to some factors reported by Jun *et al.* (2007) that plants with good leaf area and increased plant height could utilize sunlight energy for photosynthesis more efficiently. Such rice varieties therefore have the potential for high yield as a result of effective utilization of sunlight which would increase the rate of photosynthesis (Oko *et al.* (2012).

Table 9: Mean leaf area and leaf area index (LAI) of rice under different fertilizer treatments

	LA (cm^2)	LAI	LA (cm^2)	LAI	LA (cm^2)	LAI
Treatments (12WAP)	(4WAP)	(4WAP)	(8WAP)	(8WAP)	(12WAP)	
NPK fertilizer	35.0	0.09(±0.01)	35.50	0.09(±0.01)	52.70	0.14(±0.02)
Poultry manure	32.5	0.08(±0.01)	45.00	0.12(±0.03)	91.82	0.24(±0.04)
Organo-mineral	21.6	0.06(±0.03)	32.50	0.08(±0.01)	53.02	0.14(±0.01)
Control	24.1	0.06(±0.02)	33.70	0.09(±0.02)	49.50	0.13(±0.03)

4. CONCLUSION

Effects of fertilizer application on rice were investigated and it was found to be very sensitive to good soil fertility condition. Biomass yield increased with poultry manure application to soil when grown under good soil moisture condition. Rice crop was very sensitive to fertility treatments as higher biomass yields were observed in treatment plots under fertilizer and organic manure applications at the different phenological stages of the crop. Total yield was well influenced in plots under poultry manure treatment than the soil plots under organo-mineral treatment. However, the control treatment plots were characteristically lowest in biomass yield comparatively with other treatment plots under fertilizer treatment.

REFERENCES

Ahmad S., Zia-Ul-Haq M., H. Ali, S.A. Shad, A. Ahmad, M. Maqsood, M.B. Khan, S. Mehmood and A. Hussain. 2008.Water and radiation use efficiencies of transplanted rice (*Oryza sativa* L.) at different plant densities and irrigation regimes under semi-arid environment Pak. J. Bot., 40(1): 199-209.

Ahmad, N. 1992. Efficient use of plant nutrients. Proc. 4th Nat. Cong. Soil Sci., p. 2-22.

Akanji, B.O. 1995. Hedonic-Price Analysis of the Demand for Grain Crops in Nigeria: The Case of Rice and Cowpea. A Ph.D Thesis Submitted to the University of Ibadan, Ibadan, Nigeria

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M., 1998. Crop Evapotranspiration. FAO Irrigation and Drainage Paper 56. Food and Agricultural Organization of the United Nations, Rome, Italy, 300pp.

Ayotade, K.A. and Fagade, S.O. 1986. Nigeria's program for wetland rice production and rice research. In: The wetlands and rice in Sub-Saharan Africa, eds. A.S.R. Juo and J.A. Lowe, p. 259, IITA, Ibadan.

Azad, A. K., Gaffer, M. A. Samanta, S. C.Kashem, M. A. and Islam, M. T. 1995. Response of BRIO rice to different levels of nitrogen and spacing. Bangladesh J. Sci. Ind. Res., 30:31-38.

Bajwa, M.I and Rehman F. 1998. Customized complete (compound) fertilizer. Proc. Seminar "Plant Nutrition Management for Sustainable Agricultural Growth" p. 155-160.

Bali, A. Siddique, S.M., Ganai, B.A., Khan, H.V., Singh, K.N. and Bali, A.S. 1995. Response of rice (*Oryza sativa*) genotypes to nitrogen levels under transplanted conditions in Kashmir valley. Indian J. Agron. 40(1): 35-37

Blake, G.R., Hartge, K.H. 1986. Bulk density. In: Klute, A. (Ed.), Methods of Soil Analysis:Physical and Mineralogical Methods,. American Society of Agronomy. Vol. 1 pp. 363–375.

Chapman, H.D. 1965. Cation-exchange capacity. *In:* C. A. Black (ed.) Methods of soil analysis Chemical and microbiological properties. Agronomy 9: 891-901.

DeJong,R.,1983. Soil water desorption curves estimated from limited data.Can.J.Soil Sci.63,697-703.

FAO 1995a. Production statistics (Food and Agriculture Organisation of the United Nation) Year Book vol.50 .71 p.

Fasinmirin J. T., and Oguntuase, A. M. 2008. Soil moisture distribution pattern in *Amaranthus cruentus* field under drip irrigation system. Afri. J. of Agri. Res., 3 (7): 486-493

Fasinmirin, J.T. and Olufayo, A.A. 2009. Yield and water use efficiency of jute mallow *Corchorus olitorius* under varying soil water management strategies. Journal of Medicinal Plants Research Vol. 3(4), pp. 186-191

Foth, H.D. and Ellis, B.G. 1997: Soil Fertility. Second Edition, pp 290. CRC Press Boca Raton, Florida.

Jun, M. A. Wen – bo, M. Dong – Feng, Y. Shing–ming, and Z. Qing – seng, 2007. Characteristics of the rice plant with heavy panicle. Agricultural Science in China 5(12), 911-918

Kadayifci, A., Tuylu, G.I., Ucar, Y., Cakmak, B. 2005. Crop water use of onion (*Allium cepa L.*) in Turkey. Agr. Water Mgt. 72:59–68.

Ladha, J.K., De Bruijn, F. J., & Malik, K. A. 1997. Introduction: Assessing opportunities for nitrogen fixation in rice – a frontier project. Plant and Soil, 194:1−10.

Mandal, B., Velk, P.L.G., and Mandal. L.N. 1999. Beneficial effects of blue-green algae and *Azolla,*excluding supplying nitrogen, on wetland rice fields: a review. Bio. Fertil. Soils, 24: 329-342.

Manzoor, Z., Awan T.H., Safdar, M.E., Ali, R.I., Ashraf, M.M. and Ahmad, M. 2006. Effect of nitrogen levels on yield and yield components of basmati. J. Agric. Res., 44(2): 115-120.

Monteith, J.L. 1977. Climate and efficiency of crop production in Britian. Phil. Trans. Royal Soc. London. B. 281: 277-294.

Monteith, J.L. and Elston, J.F. 1983. Performance and productivity of foliage in the field. In: The Growth and Functioning of Leaves (Eds.): J.E. Dale and F.L. Milthorpe. Camb. Univ. Press, Butterworths, London, pp. 499-518.

Myint, A. K., Yamakawa, T., Kajihara, Y. and Zenmyo, T. 2010. Application of different organic and mineral fertilizers on the growth, yield and nutrient accumulation of rice in a Japanese ordinary paddy field. Sci. World J., 5 (2): 47-54.

Oko, A. O., Ubi, B. E. and Efisue, A. A. 2012. A comparative study on local and newly introduced rice varieties in Ebonyi State of Nigeria based on selected agronomic characteristics. Inter. J. Agric. Fores., 2(1): 11-17

Rafey, A., Khan, P.A. and Srivastava,V.C. 1989. Effect of N on growth, yield and nutrient uptake of upla nd rice. Indian J. Agron. 34(1):133-135.

Szcich, G. 1974. Solar radiation for plant growth. *J.Appl. Ecol*., 11: 617-636.

Singh, B.N., Fagade, S., Ukwungwu, M.N., Williams, C., Jagtap, S.S., Oladimeji, O., Efisue, A. and Okhidievbie, O. 1997. Rice growing environments and biophysical constraints in different agroecological zones of Nigeria. Met. J.2(1), pp. 35-44

Soil Survey Staff. 1999. Keys to Soil Taxonomy. 8th ed. USDA, Washington D.C

Suzuki, A. 1997. Fertilization of rice in Japan. Japan FAO Association, Tokyo, Japan.

Tanaka, A., Navaser, S.A. , Garcia, C.V., Parao, , F.T. and Ramirez, E. 1964. Growth habit of the rice plant in the tropics and its effect on nitrogen response. IRRI, Los Banos, p. 80.

Watson, D.J. 1947. Comparative physiological studies on the growth of field crops. Variation
in net assimilation rate and leaf area between species and varieties and within and between years. Annals of Botany, 11: 41-76.

Young, A. 1976. Tropical soils and survey. Cambridge University Press. pp 467.

ECONOMIC BENEFIT OF LAND RECLAMATION OF MINED FLOOD PLAINS FOR AGRICULTURAL DEVELOPMENT IN NIGERIA

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ABSTRACT

The economic benefit of land reclamation was appraised in a 2-ha floodplain farm by comparing irrigation cost, land preparation charges and vegetable yield before and after reclamation. 99% of the time was saved in land preparation and 25% in irrigation with corresponding reductions of 85% and 50% as cost of land preparation and irrigation, respectively. Vegetable yield also increased by 53% as a result of increase in cropped area, convenient application of cultural operation and optimization of mechanization possibilities. A benefit cost ratio (CBR) of 1.73 was recorded, but when cost of soil replacement was added to the overall cost, the CBR reduced to 0.60, a 65% reduction in the economic benefit of the farm enterprise and a confirmation that neglect Mining operators to reclaim mined lands in conformity with the mineral Act, is negatively affecting farm enterprise returns.

KEYWORDS: Agricultural development, land scarcity, flood plain farming aggregate mining, land reclamation, economic benefit.

1. INTRODUCTION

Agricultural development is said to have occurred if there is enough food for the people and marketable surplus produced to increase the income of the farmers, increase in the production of export crops with improvement in the quality or grade of each export crop and the supply of raw materials to agriculturally based industries.

One of the problems of agricultural development in Nigeria is land constraints (Olayide, 1998). Although land appears to be the most abundant resource for agricultural production in Nigeria, these land resources are not only diversified, but appear to be virgin, and the cost of bringing such land under cultivation is prohibitive particularly in the extreme Northern and Southern areas of the country. Also, there are constraints created by competing alternative uses for land hitherto used for agricultural production. Furthermore, due to conditions created by climate, vegetation and geology, most Nigerian soil for agricultural production are of low fertility (Olayide, 1998; Udoh, 2010) and the complexities of the various land use systems in the country, make land the least available resource for agricultural production. Adama (2010) in assessing available resources for mechanization of agriculture (in some urban areas) in Nigeria listed land as the least available resource. Land availability is further compounded by ecological problems which limit the productive capacity and efficiency of farmers.

Mbajiorgu (2008) listed mining as an ecological problem. Mining cause fragmentation of land holdings which is a major obstacle to agricultural production since it does not allow the optimization possibilities for mechanization (Tan et al., 2009). In the Niger and Cross River Deltas of Nigeria where oil production is intensified and unsustainable agricultural techniques have over exploited the land, farmers take advantage of the floodplains that are present throughout the area to produce horticultural crops under irrigation (USAID, 2009). However, aggregate (gravel) mining on the floodplains has resulted in impacts and economic damage both to floodplain agriculture and environment. Udom (2010) found that between 2004 and 2009, a total of 1.34×10^6 m^3/yr of gravel was mined from the floodplains in Akwa Ibom State, Nigeria. This resulted in the degradation of 332.89 ha/yr of cultivable floodplain land due to mining operations. Increase of 207% in extent of aggregate mining within the period under study showed the progressiveness of floodplain mining.

The need for prevention of these damages in the midst of land scarcity cannot be overemphasized. Agunwamba (2001) presented a model for evaluating the benefit (B) of preventing such ecological problem, as

$$B = \Delta D + \Delta I \quad (1)$$

where,

ΔD is the value of annual economic damage prevented by these measures and, ΔI is the annual increase in income resulting from improvements in productivity. If C is the annual costs for implementation of the preventive measures; then if B is greater than C, measure is economical. If B is less than C, measure is not economical. The parameter ΔD is obtained as the difference between the damage which would take place if prevention measures are not employed (ΔD_1) and damage left after implementing the measure (ΔD_2)

$$\Delta D = \Delta D_1 - \Delta D_2 \quad (2)$$

The parameter ΔI is obtained from

$$\Delta I = \sum_{J=1}^{N} q_j\, z_i - \sum_{i=1}^{M} q_i \quad (3)$$

where,

q_i = quantity of production of i kind of quality before implementation of preventive measure
q_j = quantify of production of i kind of quality after implementation of preventive measure
and z_i = an estimate of the production of i unit cost.

Floodplain mining has become more commonly viewed as temporary land use that can be reclaimed into a new use once the suitable material has been extracted. By utilizing the proper reclamation technique, these reclaimed sites can provide new and, at times better usable croplands (Alexander and Kidd, 2009).

Mine reclamation is the process of creating useful landscapes from mined land. It includes all aspects of the work, including material placement, stabilizing, capping, re-grading and placing cover soils, re-vegetation and maintenance. Mine rehabilitation aims to minimize and mitigate the environmental effects of mining which may in the case of open pit mining involve movement of significant volumes of soil. Rehabilitation often results in open pit mines being backfilled.

In Nigeria, mining companies are required to establish a tax deductible reserve for environmental protection, mine rehabilitation and reclamation and mine closure costs (Republic of Nigeria constitution, 1999; Republic of Nigeria Mineral Act, 2007). Under the mineral and Mining Act, it is mandatory for reconnaissance permits and exploration licenses to the obtained before commencement of operation. The ministry of mines and steel development manages the solid mineral sector, administers the Minerals and Mining Act, formulate and issues policy and ensures orderly and sustainable development of mineral resources. Mining companies are therefore required to follow strictly the environmental and rehabilitation codes in order to minimize environment impacts and economic costs.

These regulations are not enforced by government in the Niger and Cross River Delta areas and, since mining operators do not reclaim mined lands, farmers therefore bear the burden of the impacts and cost of land reclamation. Consequently the farmers created fertile soils by using a combination of borrowed soil, organic manures, modern inorganic fertilizer and refuse ash to reclaim mined lands. Several studies have been undertaken to show the importance of reclaimed land for horticultural production (Ballard et al, 2001; Boudurand, 1971; Chaplin, 1978; Morse and O' Dell, 1983 and Schaller and Sulton, 2008).

Institutional incapability in enforcing the reclamation of mind lands in Nigeria was studied by Alexander and Kidd (2009). These studies have been intensive around popular solid mineral producing areas of the country but in the Niger and Cross River Deltas areas there is scanty data on these studies since much indigenous work has not seen done. Farmers also need to be empowered with facts to take informed decision on investing in reclaimed mined lands in expectation of favourable economic returns.

The objectives of this study therefore are: (i) to investigate the economic benefits of land reclamation, in terms of cost benefit analysis on floodplain farms in Akwa Ibom State, Nigeria,(ii) to investigate the effects of mining induced land fragmentation on the mechanization of floodplain agriculture and, to determine the effect of non-enforcement of the reclamation clause of the Mineral Act on floodplain farm enterprise returns.

2. MATERIALS AND METHODS

This study was undertaken in the European Union assisted Obio Akpa Small Scale Irrigation Scheme, taking some mined farms situated at the right bank of the Obio Akpa River along the Abak-Obio Akpa – Ikot Ibritam highway currently under construction. The soil of the area is sandy loam underlain by sandy clay. The soil is slightly acidic (P^H 4.9- 3.67) and has a moderately permeably structure (Udol, 2010) with bulk density of 1.42g/cm^3 , average field capacity of 25%, permanent wilting point of 11% and available moisture of 14%. A 2-hectare farm owned by 8 farmers and containing seven mines was selected for the study out of 10 hectares owned by 40 farmers affected by mining activities. Soil from spoil banks of the (CCE) Construction Company road camp site was transported into the mines whose dimensions were determined (Table1).

Table 1: Cost of Land Reclamation

Mine No.	Volume of fill (m$^{3)}$	Cost of fill material (₦)		
		Soil(₦)	Humus(₦)	Total (₦)
1.	160.0	40,000.00	21,120.00	61,120.00
2.	182.0	45,000.00	24,024.00	69,120.00
3.	84.0	21,000:00	11,088.00	32,088.00
4.	384.0	96,000: 00	50,688.00	146,688.00
5.	180.0	45,000.00	23,760.00	68,760.00
6.	126.0	31,000.00	16,132:00	48,132.00
7.	126.0	58,000:00	30,888.00	89,388.00
Total:		337,500.00	178,200.00	515, 700.00

The mines were filled and compacted. Volumes of soil needed to fill the mines were recorded on site. The total replacement cost (TRC) of the soil (lost to mining) was estimated as described by Agunwamba (2001) as, volume of soil x unit cost of fill + surface area of fill x unit cost of humus. The unit costs of replacement were obtained from Bill of Quantities of completed erosion control works at the Abak Bridge by Nesman (Nig) Ltd. The unit cost of filling with earth and covering with humus were ₦2500.00/m^3 and ₦33.00/m^3 respectively. The reclaimed land was left fallow during the rainy season until the following planting (dry) season. Two hectares of un-mined farm land were used as the control. Soil characteristics of the reclaimed land and the control were determined (Table2) before the farmers commenced their cultivation practices.

Table2: Average Percent Variation of Soil Characteristics

Soil Properties	Reclaimed Soil	Control	Percent Variation
Bulk density (gm/cm^3)	1.42	1.32	7
Field Capacity (%)	25	23	8
Wilting Point (%)	11	10	9
Available Moisture (%)	14	13	7

3. RESULTS AND DISCUSSION

Table 3 presents the effects of land reclamation on the farm enterprise.

Table.3 Land Reclamation Effects.

S/ No.	Item	Before Reclamation	After Reclamation	Control plot
1.	Land Preparation	35man day (md) @#700/md	0.26md@#3500/md	
2.	Seeding	21md@# 700md	36.7md@#700/md	
3.	Fertilizer	6md@#500/md	10.5md@ 200/md	
4.	Irrigation	193md@#300/md	145md@200/md	
5.	Weeding	13md@ ₦ 500/md	23.7md@₦500/md	
6.	Harvesting	174md@ ₦300/md	192md@₦ 300/md	
7.	Yield:			
	Waterleaf	1500kg	2700kg	293.4kg
	Fluted Pumpkin	800kg	1536.6kg	1670.2kg
	Garden Egg	500k	930kg	1010.86
	Pepper	400kg	736kg	800kg

There was appreciable saving both in land preparation and irrigation. Some 99% of the time was saved in land preparation and 25% of the time was saved for irrigation. Costs of land preparation reduced by 85%, while the cost of irrigation reduced by 50 %(Table 4)

Table 4: Cost Changes due to Land Reclamation (₦)

S/No	items	Before Reclamation	After Reclamation	Control farm	ΔD_1	ΔD_2	ΔI
1	Yield	328,000.00	603,520.00	655,969.00	327,969.00	52,449.00	275520.00
2	Land Preparation	24,500.00	3,500.00	3, 500.00	21,000.00	280.00	21,000.00
3	Irrigation	57,700.00	29,000.00	29, 000.00	28,900.00	2310.00	28,900.00
4	Income				360469.00	55039.00	308020.00

Cost of Reclamation (C) = 515700 .00 (178200).
ΔD = 305430.00
ΔI=308020.00
Benefit of Reclamation (B) = $\Delta D + \Delta I$ = 613450.00; since B (613450.00) is greater than C (515700 .00) {178200.00}, the measure is economical. Therefore, economic benefit resulting from improvements (increases) in yield and optimization of resources due to reclamation = 613,450. The above savings were due to the mechanization of the practices which until now was not possible due to fragmentation of the land by mines.

Land reclamation yielded some benefits. The annual earnings of the farmers increased by 52% since both qualitatively and quantitatively the cropland improved and the benefit of mechanization were optimized. Adequate land reduced dependence on fragmented small holdings. Only 8 farmers out of 48 benefited from land reclamation. The remaining farmers were still restricted by mining activities. The total earning of the 8 farmers was ₦475,220.00 if the farmers bear only the cost of humus placement as in this case and ₦137,720.00 if both cost of soil replacement and humus placement were borne by the farmer. If the degraded floodplain land is all reclaimed, the earnings will increase by ₦475220x48/8 = 2,851,320.00 , the difference being ₦826320.00 which is 600% increase in productivity due to land reclamation.
The reclamation measure was economical at all the costs. The benefit cost ratio of land reclamation was 1.73 (excluding cost of soil replacement), but when the cost of soil replacement is considered, the benefit

cost ratio reduced to 0.60 (Table4). This clearly shows the necessity of implementing the reclamation clause of the Minerals Act in which soil replacement is the responsibility of the operators. The transfer of this cost to the farmers reduced the farmers benefit, in this case, by 65%.The variation in yield between the reclaimed land and the control (9%). (Table3) is accounted for by the partial consolidation of the fill (Table2) which is expected to stabilize over time.

4. CONCLUSION AND RECOMMENDATION

On the basis of these findings, it could be safely concluded that land reclamation is not a controversial issue as optimal production is enhanced and economic benefit is guaranteed. It is recommended that government should enforce the reclamation clause of the Mineral Act as a panacea for land scarcity for agriculture production.

As the state (Akwa Ibom) is evolving new blueprints for sustainable development of resources through guidelines of the Millennium Development Goals (MDGs), government as well as local communities should consider new land use and land management strategies to ensure sustainability of land resources for future development. Land reclamation of degraded floodplain farms will be a sound strategy for increased production of dry season horticultural crops in the Niger and cross River Delta areas of Nigeria.

REFERENCES

Adama, J. C., 2010. Available resources for agricultural mechanization in urban areas of Nigeria. case study of Enugu State. Proceedings 10th international conference and 31st annual general meeting of Nigeria Institution of Agricultural Engineers (NIAE) Enugu, Nigeria pp12-15

Agunwamba, J. C., 2001. Economic damage and cost – benefit analysis in: Waste engineering and management tools. Immaculate Publications Ltd. Enugu. Nigeria.

Alexander, M. J., and A. O. Kidd., 2009. Farmers' capability and Institution incapability in reclaiming disturbed land on the Jos Plateau. Nigeria Journal of environment management vol.59(2) 2009.

Ballard, Donna., 2001. Use of reclaimed land economic use of surface Production. www.uvn.edu/Agexten/landrec/hort.htm.

Boudurand, D. M., 1971. Re-vegetation and economic use of surface Mined land. School of mines. West Virginia University. Morgan Town Wv.

Chaplin, C. E., 1978. Experiment on grape production on strip mined soils. Hort. Science 13(3) pp264-7

Federal Republic of Nigeria constitution 1999. Federal Government of Nigeria

Federal Republic of Nigeria Mineral Act 2007 Federal Government of Nigeria

Hensley, D. L., and G. R. Brown., 1981. Performance of blackberries on disturbed sites. Hort. Science 16(3) pp280.

Mbajiorgu, C. C., 2008. Ecological problems identification within Watersheds in Nigeria. Journal of Agricultural Engineering and Technology 16(1)pp93-107

Morse, R and C. O'Dell., 1983. Cultivation of mine soils for cultivation of vegetable crops. Proc. 1883 Symposium on surface mining Hydrology, sedimentology and reclamation. Nov28-Dec 2 pp 163-168

Olayide, S. O., 1998. Nigeria small farmer's problems and prospects in integrated rural development. C.A.R.D. Ibadan. Schaller, F. W., and P. Sulton, 2008. Reclamation of drastically disturbed Land. Am. Soc. Agron. Madison. WI.

Tan, Shuhao, Nico Heerink and Futian Qu., 2009. Land fragmentation and its Driving forces in China. Land use policy. Vol.23(3) pp272-285.

Udoh, B. T., 2010. Soils and land potential assessment in Akwa Ibom State: A Geographical Perspective. Eds Etop J. Usoro and Phillip AKpan. Immaculate Publication Limited. Enugu Nigeria.

Udom, I. J., 2010. Agro-environmental and economic dimensions of aggregate mining from stream channels and floodplains. International Journal of Economic and Development issues. Vol.6(1) pp68-78

USAID, 2009 USAID land tenure net/…/Nigeria

STABILIZATION EFFECTS OF GROUNDNUT HUSK ASH AND CEMENT ON CLAY BLOCKS FOR LOW-COST HOUSING

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ABSTRACT

Clay is one of the earth materials that are commonly used for rural housing in most developing countries including Nigeria. Due to its high swelling and shrinkage potentials and consequent severe cracks suffered by walls built of this soil material, stabilization is needed to improve its quality for building constructions. This study measures the properties of clay blocks treated with the groundnut husk ash (GHA) and cement at different blending mixes. The various engineering properties established include particle size distribution, consistency limits, compaction characteristics, water absorption and compressive strength. The results of the study show that the soil textural class is silt clay and is of medium plasticity. The plasticity index (PI), linear shrinkage (LS) and water absorption (WA) decrease with increase in the GHA and cement contents thereby reducing the swelling potential of the soil. At specific cement content, there is decreasing trend of PI, LS and WA with increase in GHA contents. The compressive strength of stabilized blocks however increases with the increase in the GHA and cement contents. At specific cement content, the compressive strength of the treated clay blocks maintained an increasing trend with increase in the GHA contents. The compaction characteristics study show that the Maximum dry density increases with increase in cement but decreases with the increase in GHA contents.

KEYWORDS: Clay blocks, groundnut husk ash, cement, stabilization, low cost-buildings.

1. INTRODUCTION

The sharp rise in the price of materials for building construction has been a source of concern in the building industries, especially if the construction site is not in close proximity to place of procurement. In developing countries, including Nigeria, the research efforts are continued to be directed towards evolving alternative material to substitute the high costly ones for construction of buildings and other rural infrastructures. Clay material is one of the oldest materials used for building constructions but its main weakness as a building material lies in its low resistance to water. According to FAO (1988) tropical rains of any intensity can damage unprotected walls. Walls built of unstabilised soil will swell on taking up water and shrink on drying. This results in severe cracking and collapse of the structure. The quality of any inorganic soil as building material can be improved remarkably with the addition of the stabilizer in a suitable proportion (Ola, 1997; Oriola, 2010; Olarewaju et al, 2011). The major objective of soil stabilization is to increase the soil's resistance to destructive weather conditions and it is achieved by mechanical and chemical methods as documented by Olarewaju et al, (2011).

Many types of material have been used for soil stabilization. Several studies have been reported in literature on soil stabilization using different materials (Ola, 1997; Olarewaju et al, 2011; Nwakonobi and Ogbonnaya, 2002; Olarewaju, 2004; Nwakonobi and Osadebe, 2008; Oriola, 2010). The potentials and effects of different type of pozzolanic materials such as fly-ash, rice husk ash and ash of other organic materials have also been reported by Alhassan, (2008). Over the times, cement and lime are the two main materials used for stabilizing soils. These materials have rapidly increased in price due to the sharp increase in the cost of energy since 1970s (Neville, 2000). Groundnut husk is an abundant agricultural waste constituting a disposable problem in the environment. It is an agricultural waste obtained from milling of groundnut. In 2002, about 2,699,000 Mt of groundnut were produced in Nigeria which makes it the 3rd largest producer of groundnut in the world (Oriola, 2010). Meanwhile, the ash from groundnut husk has been categorized under pozzolana (Alabadan et.al, 2006). The X- ray diffraction analysis indicates that the groundnut husk ash is composed mainly of 54% silicates and 39% aluminates with traces of other elements which compare favourably with the chemical composition of other pozzolanic ash (Elinwa, and Awari, 2003). The use of groundnut husk ash in building construction to eliminate its waste disposal problem formed the major issue of this study. The groundnut husk ash can therefore reacts with free lime librated during cement hydration to form secondary cementitious compound. Alabadan, (2006) reported that a measure of success was achieved in their study where groundnut husk ash was used in concrete as a partial replacement material for cement. This study investigates the suitability of groundnut husk ash in enhancing the properties of clay-cement blocks for the construction of low-cost buildings and other rural infrastructures.

2. MATERIALS AND METHOD

The groundnut shell used was procured as a waste material and the ash gotten by burning the groundnut husk in the open air under normal ambient temperature. The ash was passed through sieve opening of 425 μm. The Portland cement was procured from the depot while the clay material sample was dug from Otukpo in Benue State, Nigeria at a depth of about 1.5 m using the method of disturbed sampling.

2.1 Testing Methods

Standard soil classification tests were carried out based on the British standards, BS 1377: (1990). The summary of the test results are presented in Table 1. The clay was first air-dried, then crushed and ground into powder form. Only the portion passing 63 μm was used in preparing the test specimens. The fine clay powder was to ensure sufficient plasticity for a uniform mix when added with other component of the mixture. The soil material was then blended with the stabilizers at different percentage mix proportions of 2%, 4%, 6%, 8%, 10% for cement; 2%, 4%, 6%, 8%, and10% for groundnut husk ash. The batching was such that all the mix ratios of groundnut husk ash were tested against each of the cement ratio for all the properties determined. A total of 50 test specimens were prepared for each property determined with the two replications used. The stabilized and unstabilized clay blocks were tested for linear shrinkage, water absorption and compressive strength.

Water absorption test was performed by 'cold water sprinkling'. The block specimens' cube of size 100mm x 100mm x 100mm for water absorption tests were preconditioned by drying in the oven until constant mass was attained. Each test specimen after cooling to room temperature and the initial weight being noted was sprinkled with cold water until it was properly soaked and then was wiped of any trace of water before the final weight was taken. The water absorption was calculated using the following expression:

$$Water\ absorption\ (\%) = \frac{weight\ of\ wet\ block - weight\ of\ dry\ block}{weight\ of\ dry\ block} \times 100\% \quad (1)$$

The test specimens for compressive strength were prepared at optimum moisture content (OPC). The compressive strength was determined in accordance with the specification of the standard organization of Nigeria (1997). The block specimens' size of 100mm x 100mm x 100mm were prepared and cured for a standard period of 28 days. The specimens were compressed to failure at a constant loading rate using ELE 1500 compressing testing machine. The compressive strength was calculated from the following equation:

$$Compressive\ strength\ (MN/M^2) = \frac{maximun\ load\ (MN)}{cross\ sectional\ area\ (m^2)} \quad (2)$$

3. RESULTS AND DISCUSSION

3.1 Properties of Untreated Clay and Groundnut Husk Ash

The properties of the untreated clay material as established are presented in Table 1

Table 1: Physical properties of untreated clay

property	Index value
Grade	Clay of medium plasticity
Liquid limit, %	38
Plastic limit, %	18
Plastic index, %	20
Linear shrinkage, %	15.7
Specific gravity, %	2.48
Cay block's density, Kg/m^3	1.60
Optimum moisture content, %	20.1
Maximum Dry Density, Kg/m^3	1.11
Water absorption of unstabilized block, %	37
Compressive strength of unstabilized block, KN/m^2	2.0

The particle size distribution analysis indicates the grading of the soil as clay, 48.08%; silt, 46.64%; sand, 5.28%. From the triangular classification chart adopted from (Head, 1992), the untreated soil sample was classified as silt clay. Following the results obtained for the consistency limits, the untreated soil sample can also be classified as Clay of medium plasticity using plasticity chart adopted from (Head, 1992). The soil with linear shrinkage higher than 10% the more the stabilizer has to be used (FAO, 1988). The otukpo clay therefore requires some form of stabilization to be suitable for building construction. Its plastic limit index values show that it has less swelling and shrinkage potentials which may completely be overcome by addition of stabilizers. The X-ray diffraction analysis of groundnut husk ash by Elinwa and Awari (2003) as shown on Table 2 indicates that it possesses high silicon and alumina contents to act as pozzolana which help in forming cementitious compounds with cement hydration reaction products. The physical properties such as specific gravity and loose bulk density of groundnut husk ash have also been determined to be 2.41 and 435kg/m^3 respectively (Elinwa and Awari, 2003).

Table 2: Chemical analysis of groundnut husk Ash as adopted from [9].

Constituent	Composition (%)
SiO_2	54.03
Al_2O_3	39.81
Fe_2O_3	4.35
CaO	1.70
MgO	0.004
MnO	0.10
Na_2	0.85
K_2O	0.17
P_2O_2	1.44
SO_3	0.09

3.2 Properties of Groundnut Husk Ash - Cement Treated Clay

Consistency limits: The variation of plasticity index (PI), linear shrinkage (LS), and water absorption (WA) with groundnut husk ash (GHA) and cement are shown in Figs.1, 2 and 3 respectively. The PI, LS and WA decrease with increase in both GHA and cement contents. There is sharp decrease in PI at 6% of

GHA and cement content. This indicates reduction in the swelling and shrinkage potentials of clay soil by the stabilizers and the consequent elimination of cracks in earth building. Reduction in LS with the increasing stabilizers' contents could be attributed to the pozzolonic reactions forming cementation compound leading to reduced soil movement. The reduction achieved in water absorption is as a result of bonding resulting from the pozzolonic reaction with cement hydration products. Thus the stabilizers bring about imperviousness in the soil materials which are in line with the study by (Moh, 1962).

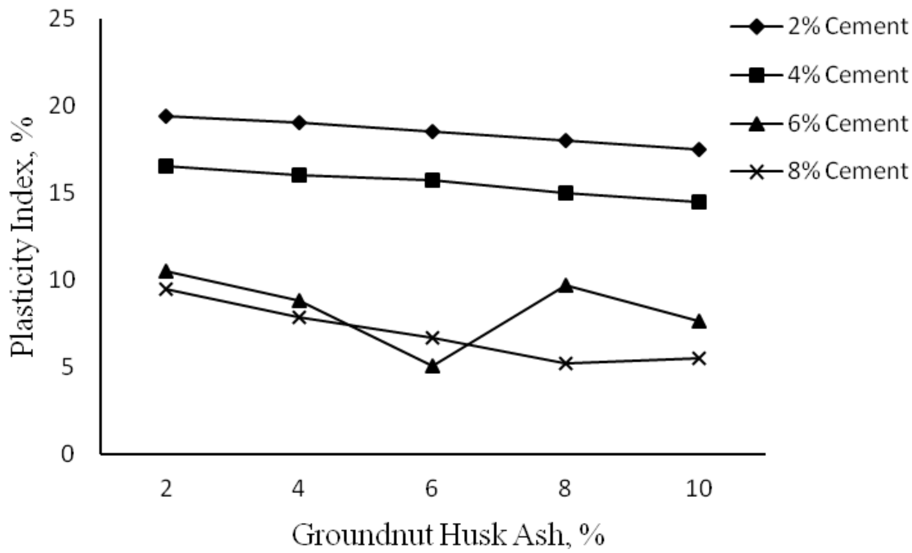

Fig.1. The variation of Plasticity Index with GHA and cement

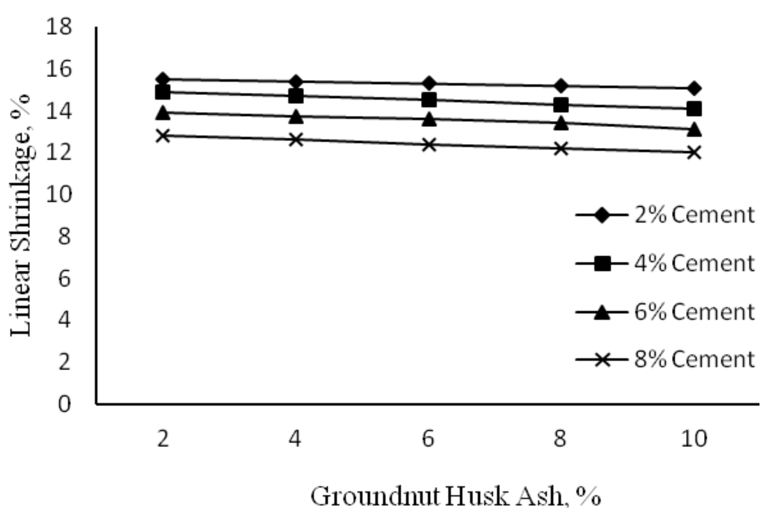

Fig. 2. Variation of Linear shrinkage with GHA and cement

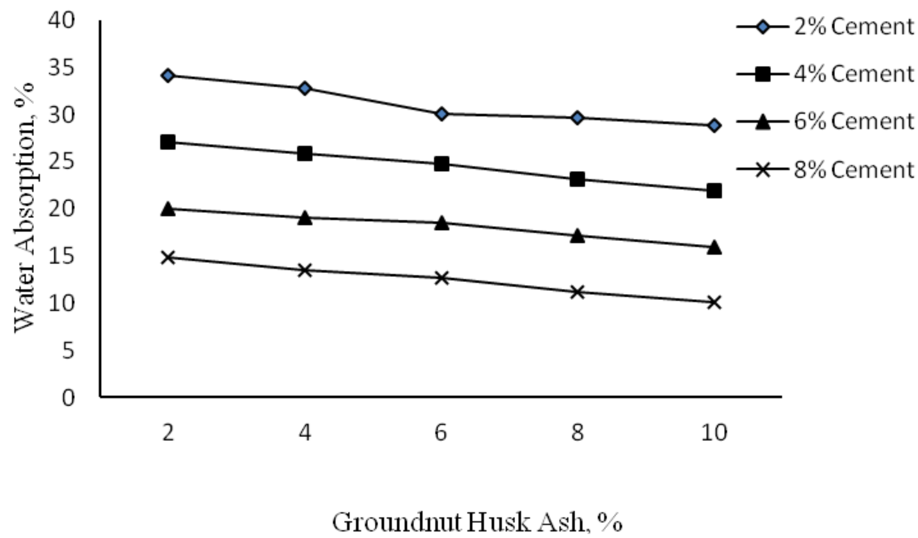

Fig. 3. Variation of Water absorption with GHA and cement

Compaction Characteristics: The variation of optimum moisture content (OMC) and maximum dry density (MDD) are shown in Figs. 4 and 5 respectively. The OMC increases with increase in cement content. This increasing trend could be as a result of more water being required for the hydration of cement. The OMC, at specific cement content, increases with the increase in GHA content. This could be due to additional water required for pozzolanic reaction which is more slowly than that of cement (FAO, 1988). More water was also needed to compact soil-cement GHA mixtures (Osinubi, 1999).

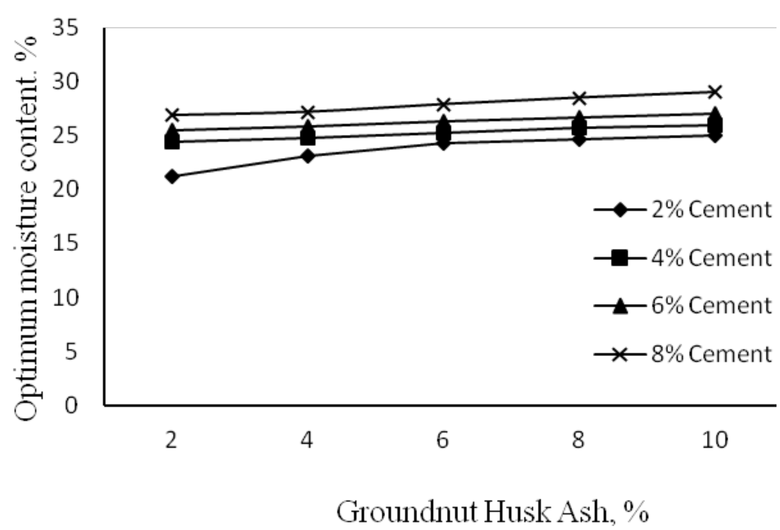

Fig. 4. Variation of OMC with GHA and cement

The MDD increases with increase in cement contents. The increase in MDD with increase in cement can be attributed to the specific gravity of cement (3.15) which is relatively higher than that of clay (2.48). At specific cement content, MDD decrease with the increase in GHA content. The decrease in MDD with increasing GHA is because its specific gravity (2.41) is relatively lower than that of soil and cement (Ola 1975; Osinubi and Katte, 1997).

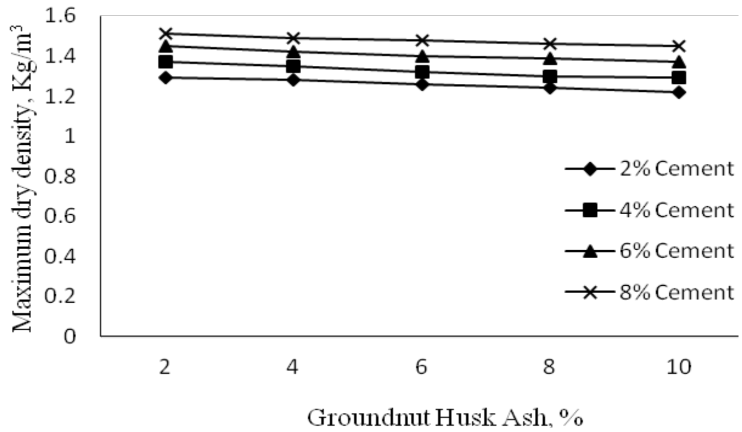

Fig. 5. Variation of MDD with GHA and cement

Compressive Strength and Weight characteristics: The Compressive strength is the main test recommended for the determination of the required amount of additive to be used in stabilization of soil (Singh and Singh, 1991). It is the test most accepted for quality control in materials for building constructions. The variation of the compressive strength with cement and GHA is shown in Fig. 6. The results of the test which was only studied at standard curing period of 28 days indicate that the compressive strength of the cement-GHA blocks increase with the increase in the cement content. It also shows that at specific cement content the strength increases with the increasing GHA contents. The maximum strength value (10KN/m^2) obtained with the addition of cement-GHA as stabilizers is an enhancement compared with the strength value (2KN/m^2) of the unstabilized clay bocks. The improvement in the compressive strength due to increase in GHA must have resulted from the pozollanic reaction between the lime librated from the hydration reaction of cement and the GHA to form secondary cementitious compound (Osinubi and Medubi, 1997).

The specific weight variation with GHA and cement is shown in Fig.7. The results indicate that the specific weight increases with the increase in cement contents but decreases with the increasing GHA contents. The decreasing trend with GHA could well be attributed to the specific gravity of GHA which is relatively lower than that of soil and cement. Light weight improvement can therefore be obtained with the GHA at the proportion where the other mixture properties are enhanced.

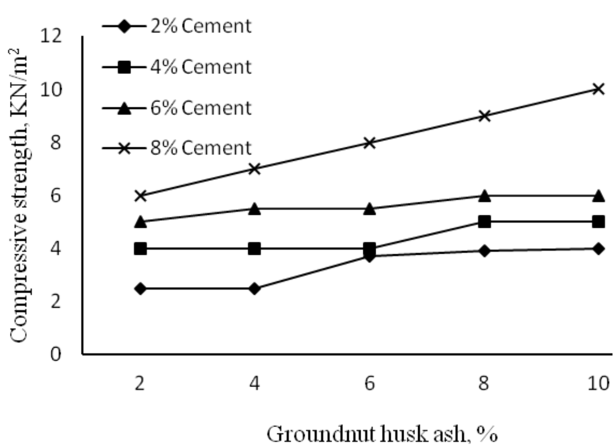

Fig. 6. Variation of Compressive strength with GHA and cement

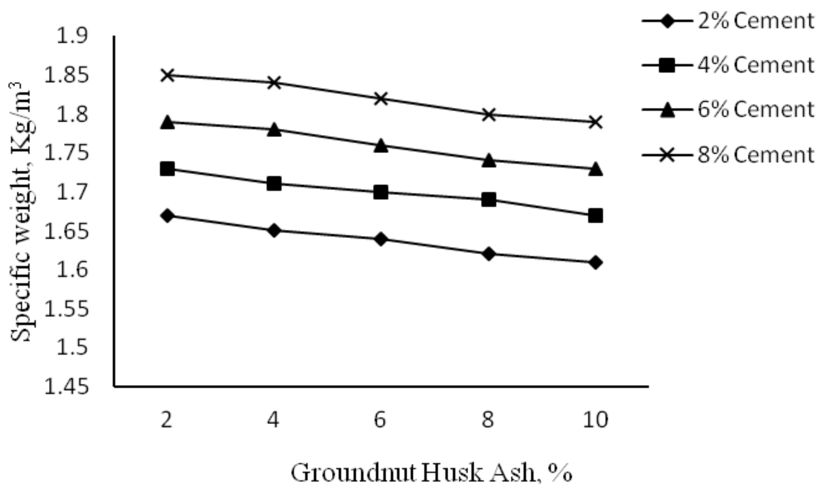

Fig. 7. Variation of Specific weight with GHA and Cement

4. CONCLUSION

The clay like every other soil possesses all the weaknesses that make it unfit for building construction. It needs stabilization to enhance its properties. The experimental study carried out indicates that groundnut husk ash and cement in combination are suitable materials that can be used to treat and improve the engineering properties of clay. The plasticity index of the clay material was reduced down to 5.1% at the blending mix of 6% GHA and 6% cement as stabilizers. The strength properties increase with the increasing GHA and cement contents which are the indication of the pozzolanic reaction between GHA and librated free lime from cement hydration reaction forming cementation compound that cause further bonding and imperviousness in blocks. The GHA can therefore be used as a pozzolana to partially replace cement in soil-cement block production, particularly in places where it is in abundance and poses waste disposal problems.

REFERENCES

Alabadan, B. A. 2006. The potential of Groundnut shell ash as concrete additive. Agric. Eng. Intl., CIGR ejournal, Vol. VIII.

Alhassan, M. 2008. Potentials of Rice Husk Ash for Soil Stabilization. A. U. J. T., 11(4), 246-250.

FAO. 1988. Farm structures in tropical Climates. A textbook for structural Engineering and Design, In: Lennart P, Bengtsson J, Whitaker J. Food and Agricultural Organization of the United Nations, Rome.

BSI 1990. Methods of testing soil for civil engineering purposes, (B.S.1377). British Standards Institute, London, England.

Elinwa, A. U, Awari, A. 2003. Groundnut husk Concrete, Nigerian J. Eng. Mgt., 2 (1), 8- 15.

Head, K. H. 1992. Manual of Soil Laboratory Testing. Soil classification and compaction tests, Vol.1, 2nd ed. Rentech Press Ltd. London.

Moh, Z.C. 1962. Soil stabilization with cement and Sodium additives. J. Soil Mech. & Foundation Div., 88(6), 81-106.

Neville, A.M. 2000, Properties of Concrete. 4th Edition, Pearson Education Asia Ltd, Malaysia.

Nwakonobi, T. U, Ogbonnaya, J. M. 2002. Evaluation of Clay-Terrazzo waste mixture as lining material in Irrigation Channels. J. Kwameh, Nkrumah University of Science and Technology, Kumasi; 22 (1, 2&3), 59-65.

Nwakonobi, T. U. Osadebe, N.N. 2008. Optimization Model for Mix proportioning of Clay-Rice husk-Cement Mixture for Animal Buildings. Agric. Eng. Int., CIGR-Ejournal; Vol. X.

Ola S. A. 1975. Stabilization of Nigeria lateritic soils with cement, bitumen and lime, Proceeding of 6th Regional Conference for Africa on Soil Mechanics and Foundation Engineering. Durban, South Africa.

Ola, S. A. 1997. The potentials of lime stabilization of lateritic soil. Eng. Geol., (11), 305-317.

Olarewaju, A. J. 2004. Soil Stabilization. M.Eng Seminar on Course Title: Advanced Soil Mechanics (CVE 821), Civil Engineering Department, Federal University of Technology, Akure, Ondo State, Nigeria.

Olarewaju, A. J, Balogun, M. O, Akinlolu, S.O. 2011. Suitability of Eggshell Stabilized Lateritic Soil as Subgrade Material for Road Construction. EJGE, 16, 899-908.

Osinubi, K. J.; and Katte, V.Y. 1997. Effect of elapsed time after mixing on grain size and plasticity characteristics; soil lime mixes. Nigeria Soc. Enging. Tech. Trans. 32(4): 65-76.

Osinubi K. J., Medubi A. B. 1997. Evaluation of cement and phosphatic waste admixture on tropical black clay for road foundation, Structural Engineering Analysis and Modeling, SEAM4 (2): 297-307.

Osinubi K. J. 1999. Evaluation of admixture stabilization of Nigeria black cotton soil, Nigeria Society of Engineers (NSE) Technical Transaction, Nigeria; 1999, 34(3): 88-96.

Oriola, F and Moses, G. 2010. Groundnut Shell Ash Stabilization of
Black Cotton Soil. EJGE Vol. 15 [2010], Bund. E, 415-428

Singh G., Singh J. 1991. Highway Engineering. Standard Publishers Distributors, Nai, Sarak, India, p. 608-610.

AN APPRAISAL OF THE CONSTRUCTION AND MAINTENANCE OF FARM STRUCTURES IN THE TROPICS: A CASE STUDY OF POULTRY HOUSING

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ABSTRACT

A survey of poultry housing design, construction and maintenance practices in Enugu state was undertaken. Interviews, observations and site assessment were used in the study of 50 poultry farms randomly selected in Nsukka agro-ecological zone. Investigation shows that the common poultry structures existing in the area were those constructed with wood, corrugated roofing sheet and masonry bricks. Most of these structures were not properly ventilated, space requirements were not considered in their design and woods used for construction were not treated. Structural defects occur mainly in the roof, walls and foundation of the poultry house. These include cracks, leakage, termite infestation and rot. Annual maintenance cost ranges from N2,000 to N10,000. The farmers were not making profit under such conditions since their output were low as result of the high operating cost. Hence, the need for technical improvement on the design and construction materials used for poultry housing.

KEYWORDS: Poultry, housing, construction, defects, maintenance, cost.

1. INTRODUCTION

For poultry birds to express their full genetic potential, certain basic requirements must be provided. These include environment, good management, balanced rations and adequate housing. These facilities can be provided through adequate capital base, which is lacking in Nigeria. High cost of building materials, inadequate extension and training facilities has been the bane to adequate housing of poultry in Nigeria. (Alabi and Aruna, 2005)

Livestock production constitutes an important component of the agricultural economy in developing countries and it is an instrument for socio-economic change, improved income and quality of rural life in Nigeria (Okumadewa, 1999). The importance of poultry to the national economy cannot be overemphasized. In livestock production, poultry occupies a prominent position in providing animal protein as it accounts for 25% of local meat production in Nigeria (Okunlola and Olofinsawe, 2007). An earlier report by Okonkwo and Akubuo (2001) shows that about ten (10) percent of the Nigerian population are engaged in poultry production, mostly on subsistence and small or medium-sized farms.

It is highly desirable but hardly feasible to produce buildings that are maintenance-free, although much can be done at the design stage to reduce the amount of subsequent maintenance work. All elements of buildings deteriorate at a greater or lesser rate depending on the materials, methods of construction, environmental conditions and the purpose for which the building is erected. Most of the structures used to house poultry in Nigeria do not meet the basic requirements for poultry housing. Often times adequate space requirements needed for proper growth are not considered in the housing design. A good poultry house protects the birds from the harsh climate (weather), predators, injury and theft (Clauer 2009). Poultry require a dry, draft-free house. This can be accomplished by building a relatively draft free house with windows and/or doors which can be opened for ventilation when necessary (Plamondon, 2009). This study is important because increased production and productivity in the poultry industry are direct consequences of efficiency of production resulting from efficiency of input combinations, disposed under improved technology.

The objective of this study is to determine the various types of structures used for poultry production in Enugu State at the local level. The specific objectives are to (i) assess the socio – economic characteristics of the poultry producer in the study area (ii) determine the type of construction materials used and their major defects, and (iii) Proffer possible suggestion for improvement

2. MATERIALS AND METHODS

2.1 Study Area

The study was carreied out in Nsukka agro-ecological zone. The Local Government Areas (LGAs) that is within Nsukka agro-ecological zone include Nsukka, Igbo-Eze North, Igbo-Eze South, Udenu and Igbo-Etiti. The Nsukka agro-ecological zone has an area of approximately 9,050 km². As of 2007, the Zone had an estimated population of 309,633. Towns that fall within the zone include Nsukka, Opi, Ovoko, Enugu Ezike and Obollo-Afor, Ede-Oballa, Uzo Uwani and Mkpologwu. The zone is mainly composed of agrarian communities as agriculture is the main occupation of the people. Food crops such as cassava, yam, maize, rice, vegetable are grown in the area. Livestock produced include pig, sheep, goat and poultry.

2.2 Methodology

Preliminary investigations were carried out on the types of poultry structures in Nsukka agro-ecological zone. Random sampling technique was followed to arrive at a total of 50 poultry farms in the zone, 10 from each of the five LGAs. Interview schedule was used to gather information from respondents. Visual observations were also undertaken. The interviews and observations assissted in the determination of the following:

a. The personal and socio-economic characteristics of the farmers.
b. Types of construction materials, size and age of structure;
c. Design requirement for the poultry structures
d. Types, causes and location of defects, and
e. Maintenance methods and annual costs.

Descriptive statistics were used in the data analysis.

3. RESULTS AND DISCUSSION

3.1 Personal and Socio-Economic Characteristics of Poultry Farmers

Table 1 presents the personal and socio-economic characteristics of the interviewed poultry famers in the study area. This showed that majority of the farmers were female (64%). The fact that majority of the poultry keepers were women is consistent with 56% estimated by Sonaiya, (1995). Table 1 also showed that the respondents wee relatively young, with majority falling between the ages of 21 to 40 years (56%). The table also indicates that most of the farmers were small scale producers with many of the farms having a holding capacity of less than 500 birds (76%). Illiteracy is heavily regarded as a major limitation to receptive to technology adoption in the study area as only 14% of the farmers had tertiary education. Higher level of education would have enable respondents to access relevant information that would have stimulated their production.

Table 1. Frequency Distribution of Respondents by Personal and Socio-economic Characteristics (N=50)

Personal and Socio-economic characteristics			Personal and Socio-economic characteristics		
Age	Frequency	%	Holding type	Frequency	%
< 21	3	6	Rented	7	14
21-40	28	56	Leased	1	2
41-60	12	24	Owned	42	84
>60	7	14			
Sex	Frequency	%	Major occupation	Frequency	%
Male	16	36	Poultry farming	4	8

Female	32	64	Others	46	92
Marital Status	Frequency	%	Number of birds	Frequency	%
Single	12	24	<500	38	76
Married	17	34	501-1000	8	16
Divorced	5	10	1001-2000	4	8
Widowed	16	32	>2000	0	0
Educational Status	Frequency	%	Types of bird kept	Frequency	%
No formal education	15	30	Layers	15	30
Adult education	2	4	Broilers/cockerels	21	42
Primary education	8	16	All types	14	28
Secondary education	17	34			
Tertiary education	7	14			

3.2 Types of Poultry Structures in the Study Area

The result of the preliminary investigation shows that the major types of poultry houses in the LGA were poultry houses constructed with wood, corrugated roofing sheet and masonry bricks.

3.2.1 Poultry Houses Constructed with Wood

These type of poultry houses were either fixed or moveable. They come in different sizes, depending on the economy of the farmer. The shape were either square or rectangular. The height ranges from 2 – 4 meters. The roof is usually constructed with corrugated roofing sheet. The floor and wall in some cases are made of wood. They were generally not well ventilated, predator proof or well lighted. The cost of construction ranged between N4,000 – N20, 000. The movable type is shown in Fig. 1.

Fig. 1: Moveable Wooden Poultry House

3.2.2 *Poultry Houses Constructed with Corrugated Roofing Sheet*

These type of structures were constructed of wooden posts and corrugated roofing sheets were used as the walls as shown in Fig. 2. They were either rectangular or square shaped. The height, ranged from 2 – 4 meters. The roofs were also made of corrugated roofing sheets. The cost of construction was found to ranged between N10,000 – N20,000.

Fig. 2: Poultry house constructed with corrugated roofing sheet

3.2.3 *Poultry Houses Constructed with Block Masonry*

These typesof poultry houses were usually made of sandcrete block. While some were constructed with openings on the wall, others had dwarf walls fitted wire guaze for proper ventilation. They also come in different sizes. The shapes were square or rectangular. The height ranged from 4 – 6 meters. The roofs were usually constructed with corrugated roofing sheet. They were generally not well ventilated, predator proof or well lighted. The cost of construction ranges between N20,000 – N50, 000. The type of poultry house is shown in plate 3.

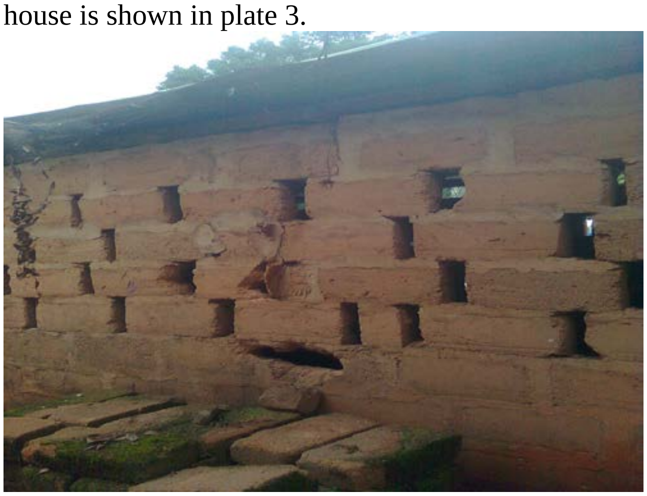

Fig. 3: Poultry house constructed with block masonry

3.3 Type of Construction Material and Age of Poultry Structure in the Study Area

Table 2 shows the distribution of poultry houses in the study area according to the type of construction material used and the age of the structure. Table 2 indicates that majority of the poultry houses (54%) were constructed with wood. Also most of the poultry buildings were new as 70% of the houses were less than 5 years.

Table 2. Frequently Distribution of Poultry Houses by Type of Construction Material and Age of Structure (N=50)

Main construction material	Frequency	%
Wood	27	54
Cement masonry	16	32
Corrugated roofing sheet	7	14
Age of Structure (years)	Frequency	%

<2	9	18
2-5	26	52
6-10	12	24
>10	2	4

3.4 Design Considerations

The amount of necessary building maintenance could be reduced by improved method of design, specification and construction. Farmers in the study area were interviewed to determine if they considered design requirements when constructing their poultry houses. Table 3 shows respondents adherence to design considerations.

Table 3. Addherence to Design Considerations (N=50)

Space requirements	Frequency	%
Yes	33	66
No	17	34
Minimum ventilation requirment	**Frequency**	**%**
Yes	12	24
No	38	76
Protection from predators	**Frequency**	**%**
Yes	31	62
No	19	38
Source of Light	**Frequency**	**%**
Yes	11	22
No	39	78
Ridge cap	**Frequency**	**%**
Yes	3	6
No	47	94

3.5 Types, Causes and Location of Defects

The physical defects observed in poultry structures are usually on the roof and wall of the structure. The major physical defect includes insect infestation and rot for the wooden structures and rust for the poultry house constructed with corrugated roofing sheet. Others include leakages of roof and cracks on the wall.

Plate 4: Termite Infested Wooden Structures

These defects are usually as a result of poor strength of materials, change in climate condition and structural failure.

3.5 Maintenance Practices

The maintenance methods include the repair and replacement of structural parts. Insect infested wooden parts are either replaced completely or a new wood is placed on top of the affected area. Rusted corrugated roofing materials are replaced. Annual maintenance cost for all types of building materials depends on the extent of defects, locality, age and regularity of maintenance. The average annual maintenance cost ranges between N2,000 – N10,000.

4. CONCLUSIONS AND RECOMMENDATIONS

The common structures used to house poultry in the study area were made of wood, mould bricks, corrugated roofing sheet and block masonry. Major defects include insect infestation, rot for the wooden structures, rust for corrugated roofing sheet, leakages of roof and cracks on the wall. It was evident from the result of the study that these structures do not provide comfortable housing environment for birds. Improvement on the design consideration such as adoption of prefab foundation could reduce the defects from insect infestation as shown in plate 4 above Illiteracy, poor maintenance culture and lack of adequate capital were the major limitations to technology adoption in livestock production in the study area.

There is need for more research efforts on low-cost livestock housing, as one of the major limitations to adequate housing is the high cost of building materials. There is also the need for an improvement in the extension services provided to poultry farmers so as to keep them abreast with improved housing systems developed in various research institutes. Poultry farmers would do better if they could have access to loan to pump into their business. There is need to organize soft loan facilities for farmers either by the government or corporate bodies. They could also organize themselves into cooperative associations in order to have access to loan for poultry business. A higher level of education will enable Poultry farmers to access relevant information that will stimulate their production and also there is need for governments at all levels to address the issue of loan acquisition, so as to enable farmers, both large and small scale to provide the needed facilities for a better production output.

REFERENCES

Alabi, R. A. and Aruna, M. B. 2005. Technical efficiency of family poultry production in Niger-Delta, Nigeria. Central European Journal of Agriculture. Volume 6 No. 4 (531-538)

Clauer, P. J. 2009. Small Scale Poultry Housing. Virginia Tech Cooperative Extension. www.ext.vt.edu/pubs/poultry/factsheets

Federal Republic of Nigeria Official Gazette 2007. Legal Notice on Publication of the Details of the Breakdown of the National and State Provisional Totals 2006

Census (PDF). http://www.Nigerianstat .gov.ng /nbsapps/Connections/Pop2006 .pdf. Retrieved 2010-07-01

Okonkwo, W. I. and C. O. Akubuo, 2001. Thermal analysis and evaluation of heat requirement of a passive solar energy poultry chick brooder in Nigeria J of Renewable Energy, 9: 1

Okumadewa, F. O. 1999. Livestock Industry as a tool for poverty alleviation. Tropical Journal of Animal Science. 2: 21-30.

Okunlola, J. O. and Olofinsawe, A. 2007. Effects of extension activities on Poultry Production in Ondo State, South Western Nigeria. Agricultural Journal, 2: 559-563.

Plamondon, Robert. 2009. Range Poultry Housing. Appropriate Technology Transfer for Rural Areas. http://www.attra. org/attra-pub /PDF/ poulthous.pdf

Sonaiya, E.B 1995. Feed resources for smallholder poultry production in Nigeria. World Animal Review 82(1): 25-33.

ECONOMIC FEASIBILITY STUDY OF COMPOSITE PHASE CHANGE TROMBE WALL SOLAR POULTRY BROODER

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ABSTRACT

This work showcases the enormous potentials in poultry production especially with regards to design, development of cost implication of its construction, the cost of performance evaluation as well as cost benefit effect of investing in such projects. The system design was articulated in a systematic approach taken into account the design consideration for a deep litter system of poultry production. The design incorporates the solar (thermal) storage medium and collector as integral part of the building with the orientation southward. Therefore, the brooding system developed is an independent, renewable, environmentally and user friendly. It has the capacity of brooding 200 birds in a batch and can brood for 11 (eleven) months in a year for optimum performance. It takes about ₦862,990 to construct the brooding house and about ₦254,582.05 to offset the bill accruing from interest on capital, interest on investment, insurance, repair cost, depreciation, and tax. Also about ₦434,170 annually is spent in carrying out the brooding operation. Therefore, total cost is ₦1,551,742.05. The return on investment is at the ratio 1:5 that is at 22.5%. This implies that it takes 4 years and 2 months for the business to break even and about 14 years and 8 months to make profit. Therefore, it is lucrative to invest in this project provided, the aim is to brood and sale the birds.

KEYWORD: Brooding, construction, solar, cost, benefit, poultry, trombe wall.

1. INTRODUCTION

Agriculture employs about two-third of Nigeria's total labour force, contributed 42.2% of gross domestic product (GDP) in 2007 and provides 88% of non-oil earnings. The agricultural GDP is contributed by crops (85%), livestock (19%), fisheries (4%) and forestry (1%). The poultry sub-sector is the most commercialized (capitalized) of all the sub-sectors of the Nigerian Agriculture. The types of poultry that are commonly reared in Nigeria are chicken, ducks, guinea fowls, turkey, pigeons and more recently ostriches. Those that are of commercial or economic importance given the trade in poultry, however, are chicken, guinea fowl and turkeys, amongst which the chickens predominate (Manyong et.al., 2005). For sustainability in agricultural production to continue, there is need for systemic synergy geared towards agricultural production ranging from crop production, animal production, processing of produce and storage, and economic viability of agricultural production. The poultry business at commercial level is lucrative if there is thorough and articulated feasibility study in terms of economic investment especially on poultry building design and construction which amount to the large fixed capital allotted to poultry production. In order to provide solutions to these problems, the economic feasibility study of a trombe wall solar brooder was carried out to unveil the opportunities therein in poultry production.

Brooding is the care of newly hatched chicks from day old to a period of 4-6 weeks of age. It is an activity that requires energy supply. Provision of heat to young chicks is a basic necessity for the survival of the chicks within the period of brooding. Supplemental heating enables the day old chicks to maintain or attain the adult body temperature without much stress or mortality (Oluyemi and Reborts, 1979). In addition to supplemental heat, chick brooding entails the provision of adequate water, feed and ventilation. The efficient combination of these factors determines the level of physical and physiological development and mortality of the chicks (Oluyemi and Roberts, 1979). Oluyemi and Roberts (1979) recommended optimum brooding temperatures of 32.2-35^{0}C, 29.7-32.2^{0}C and 26-27^{0}C for the first, second and third weeks of brooding. The temperature ranges have to be reduced by about 1.6^{0}C daily until ambient environmental is attained. Freeman (1966) gave 35^0C for the first week and 31^0C for the second week while French et al. (1981) recommended 35^0C for the first week but to be reduced by 2.8^0C each successive week. According to Deaton et.al (1974) broilers can be brooded at as much as 5.5^0C lower than the normal recommended temperature of 35^0C for the first week, 32.2^0C for the second and 29.4^0C during the third week.

Chicks as metabolic animals are known to produce certain amount of heat proportional to the body weight as they grow. The decreasing brooding temperature coincides with the increasing heat output of the chicks (Echiegu, 1986, Okonkwo, 1993). Young chicks are known not to withstand low temperature because they have not developed the thermo-regulatory mechanisms needed to adjust to change in temperature. Low temperature results in high mortality rate due to salmonella infection (Thaxton et al., 1971) and aspergillosis flavin (Carr et al., 1976). Too low temperature leads to huddling (Kleiber and Winchester, 1933), hunching and crowding with the accompanying evil of smothered chicks, paralysis of respiratory system and dimension in thrift on the part of the entire flock (Carr and Neisheim, 1975), prolonged period of severe chilling may be detrimental to growth but birds perform better when they are subjected to short period of chilling treatment during early stages of life. Higher temperature above maximum recommendation results to chicks' heat stress. Chicks are under heat stress when the comfort zone is exceeded. Birds do not have sweat glands and therefore cannot loose body heat by sweating. The response of birds to excessive heat is by panting, reduction in feed intake and increase of water intake (Obioha, 1992). French et al, (1981) reported that when temperature in the chicks' house exceeds 32.2^0C. It causes some stress and above 37.8^0C .Some chicks may die from heat stroke. Relative humidity is considered to be of no importance in poultry houses, but it has effect on the young chicks. Oluyemi and Roberts, (1979) and French et al, (1981) recommended optimum relative humidity between the range 50-80% in poultry brooding environment, while Obioha, (1992) recommended 75%. Too low humidity causes dehydration of chicks and too high humidity stimulates the growth of mould (fungi) and proliferation of pathogens such as coccidiosis in the litter. Relative humidity has a direct relationship with temperature. Skin and feather temperature increases with increase in relative humidity. Relative humidity above 80% and temperature greater than 26^0C has an adverse effect on chick performance. High humidity in chicken house is an important cause of deaths of young poultry during the rainy season.

Ventilation is concerned with almost the individual items of the micro-climate of the poultry environment. Too much ventilation has been discovered to have adverse effect on birds. It increases the body surface conductance and heat loss by convention (Barre and Sammet, 1984). Ventilation is very important to temperature and relative humidity control in the poultry houses. Insufficient ventilation may exert its effect not only through rising temperature and humidity but also by gaseous contamination. Ventilation control in poultry houses could be through the introduction of vents, window and doors. At hatching, day old chicks have not become homoeothermic because the chicks lack the effective feather covering which acts as insulator. The chicks' blood vessels are covered with thin layer of skin tissues and down feathers which permit quick loss of heat from the body to the environment when the surrounding is not heated up sufficiently. Therefore for the newly hatched chicks to survive, they need a warm environment to heat them up in order to attain adult temperature (40^0C) from 38.9^0C body temperature when they were hatched. This is usually carried out under a brooding system. Systemic classification of poultry brooding systems is shown in Figure 1.

Under natural brooding system, the services of a brooding mother hen is employed. The brooding hen takes care of the young chicks from the moment they are hatched to the end of brooding period. All the heat and nutritional requirements for the chicks to survive are provided by the mother hen. Natural method of brooding chicks is not however suitable for brooding a good number of chicks in large scale poultry production. The young chicks are exposed to parasitic infections since they are free to feed on anything including soil. The young chicks are object of attack by predators such as hawks, hence chicks mortality is very high, at times about 70-80% (Okonkwo, 1993).

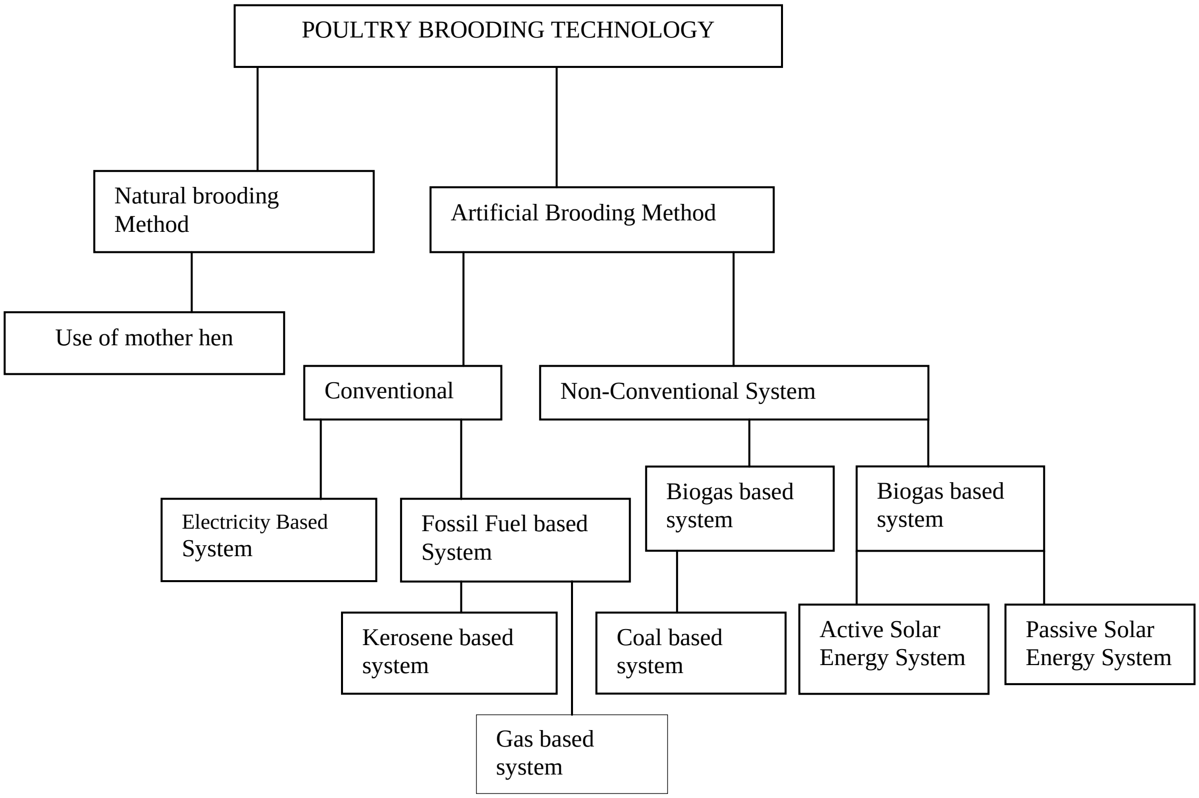

Fig. 1: Systematic classification of poultry brooding systems source: (Okonkwo and Akubuo, 1993)

A wide range of artificial brooding systems have been developed in order to optimize poultry production performance. These include cage rearing of broiler chicks , heated floor brooding (Portmouth, 1978), low temperature brooding (Deaton et .al., 1974) cage brooding followed by floor grow out (Thaxton, et al., 1980, microwave brooding , Rockby et al., 1992, 1993, Echiegu, 1986, and Okonkwo et al., 1992, 1993 and 1997). Floor, canopy or hover and deep litter brooding is the most commonly practiced. The popularity of these is derived partly from the ease of operation and relative cheapness of the system. Battery cage brooding of chicks involves the rearing of one or more chicks in a cage. Heated floor brooding system is characterized by heated pipes or wire positioned under the floor. Slatted floor brooding involve raising day old chicks on raised wire floor (false floor). Low temperature brooding system makes use of chicks own heat production from metabolic activities. In active solar heating systems fans or pumps are used to transfer heat through the solar collector loop or the load loop to the point of application such as into a chamber.

The availability of solar radiation in a given location on the earth surface is intermittent and seasonal in nature. For a given place the average amount of solar radiation on a flat surface depends on weather, latitude of the place, surface orientation and tilt angle to horizontal. Utilization of solar energy involves its collection with solar energy collector, usually, the collector surface facing the sun is painted black to act as solar energy absorber, which subsequently converts the energy into heat. The concentrating collectors focus the direct rays of the sun, which are incident on a reflector onto a smaller absorbing area (Tuner et al., 1977). Because of the focusing effect, a concentrating collector can absorb heat to a much higher temperature than flat plate collectors. However, the use of only direct rays, tracking (follow) the sun across the sky makes concentrating collectors more expensive. Flat plate collectors have the advantages of using both the direct and diffuse solar radiation. They are mechanically very simple in construction and operations than the concentrating types. For these reasons, flat pate collectors are the logical choice for space heating needs (Turner et al., 1977).

Trombe wall is the massive wall of a building which collects solar energy. The energy collected is stored in the wall for heating purposes. Trombe wall system is a modified direct gain solar radiation of a living space through the introduction of a thermal storage wall between the solar aperture and the living space. Composite Phase Change Trombe wall is the massive wall of a building made of blocks (paraffin wax + sand + cement as binding material) which collects solar energy. The energy collected is stored in the wall for heating purposes. Composite Phase Change Trombe wall is characterized by one or more layers of glass or transparent plastic located a few centimeters from the wall. The wall is usually painted black to absorb solar energy. The dark wall is heated by solar radiation transmitted through the glazing. The heat energy absorbed by the wall is stored in the massive wall and transmitted into the living space through conduction, convection and radiation heat transfer. Vents are usually provided at the bottom and top of the wall to allow air from the conditioned space to rise in the gap between the wall and the glazing and returned to the heated space through the vents Trombe wall system is normally oriented due south to make maximum use of solar radiation throughout the year.

The objectives of the work were to develop design and cost estimates for constructing a composite phase change trombe wall solar brooder that is adaptable in Nigeria for poultry production; to carry out cost-benefit analysis for constructing such designs to ascertain if such design can be viable for poultry production and to analyse the time value of such project. It is expected to consider the design factors, development of the structural design, cost estimates of the building materials and stages of the construction work as well as cost-benefit analysis of the project bearing in mind the time value of the project.

2. MATERIALS AND METHODS

2.1 Design Consideration

The composite phase change trombe wall passive solar brooder is designed based on the components that make up the brooding system, they includes three major components of the solar brooding house, namely:

1. Composite Phase change Trombe wall system.
2. Poultry brooding room.
3. Air chimney.

The Composite phase change Trombe wall formed an integrated part of the house duly orientated southward for maximum solar energy collection all the year round. This is made of 0.22 m thick solid block (composite phase change masonry wall - made of paraffin wax and sand + cement as binding material) to form the thermal storage and solar collector. The external surface of the wall, which is exposed to the environment is treated with black paint for the absorption of radiant energy from the sun. Eight vents measuring 0.05m in diameter were made, four each at the upper and lower part of the wall respectively. The wall is covered with a single glass distanced at an air space of 0.25 m. the glazing reduces excess heat losses by long wave radiation and convention to the ambient environment. During the day, the composite phase change trombe wall painted black (solar collector and storage) receive energy transmitted across the glass cover. The radiant rays striking the composite phase change trombe wall are absorbed thereby and converted into heat energy. The absorbed heat is transmitted and stored in the composite phase change wall for dissemination into the house (room). The vents provide good facilities for air circulation between the wall and the glass into the brooding room/house. Air sweeping across the wall surface carries hot air during the day from the wall into the brooding room while the absorbed radiant energy is conducted across the wall into the poultry brooding room. To supplement and augment heat storage capacity of the wall a thermal pebble storage bin measuring 2m x 1.5m, filled with black pebbles is strategically located outside the wall but connected with pipes through the floor into the brooding room. This contributed to the thermal increment of the room. At night, due to inherent properties of the composite phase change material, it has the capability of storing more thermal energy that will be released to keep the brooding chamber at its optimum temperature thereby improve the thermal efficiency of the system especially at night when there are usual drop in temperature. The choice of composite phase change trombe wall and pebble for study was due to high performance and improvement from already existing trombe wall solar brooder, and availability of locally and less expensive material used to develop this system. The brooding house has an internal dimension of 3m x 3m x3m giving a floor area of 9m^2 for 180 to 200-day –old chicks for four weeks brooding period at a recommended brooding space for drinkers and feed troughs (Oluyemi and Roberts,1979). The other walls of the brooding house were constructed with hollow blocks and rendered. The roof is made of conventional roofing sheets (zinc) and sealed with asbestos ceiling board to the chimney. To enhance even temperature distribution within the brooder, an air chimney is centrally located and positioned within the brooder to allow exhaust air from the brooding chamber to escape to the ambient environment as well as the respired carbon dioxide from the chicks. The chimney measures 1.5m x 1m x 1.3m and extends well above the roof of the brooder. This create drought for natural air convention/ circulation. The structural design drawing showing the details of different views as well as the sectional drawing is shown below in figure 2-7.

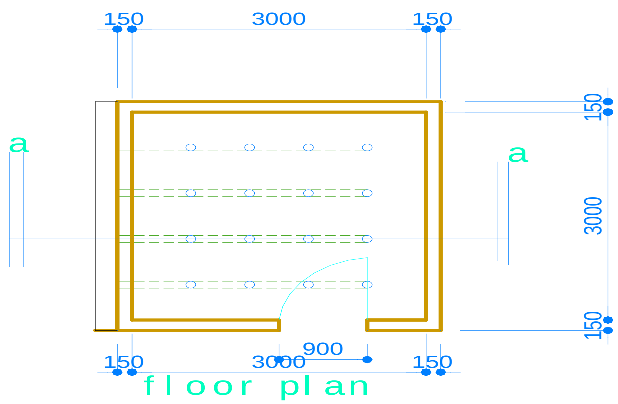

Fig.2: shows the floor plan of the structure

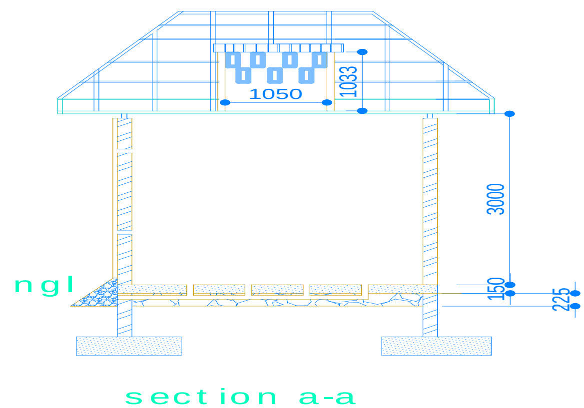

Fig.3: shows the section A-A

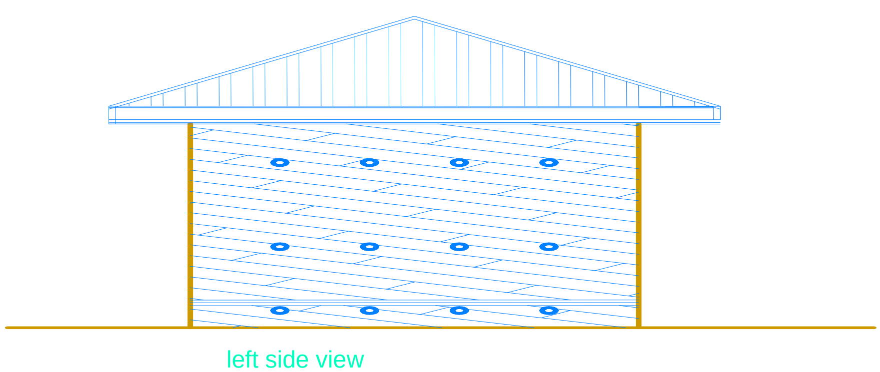

Fig.4: shows the left side (composite phase change trombe wall)

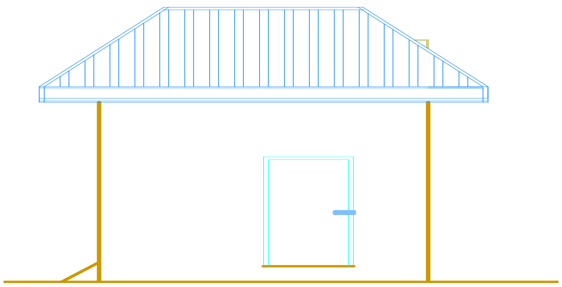

Fig.5: shows the front view

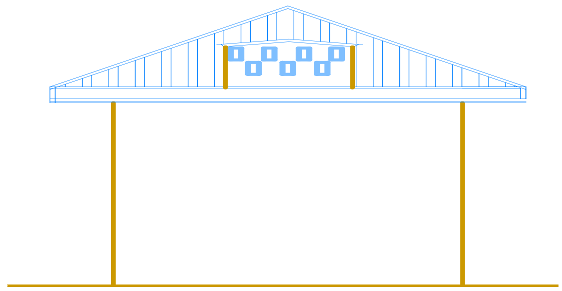

Fig.6: shows the right view

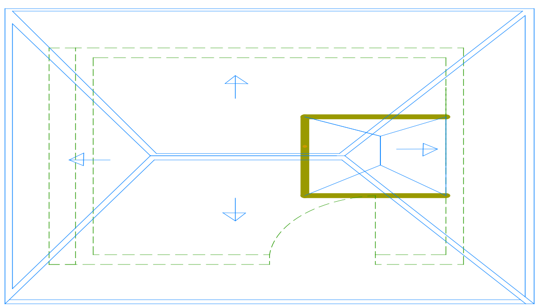

Fig.7: shows the top/roof view

3. RESULT AND DISCUSSION

3.1 Cost Estimate for the Construction of Composite Phase Change Trombe Wall Solar Brooder

The cost estimate for the construction of the composite phase change trombe wall solar brooder is tabulated to capture the step by step procedure for the execution this work/project. Table 1-2 show costs involved to carry out the project as well as performance evaluation using day-old chicks (a batch)

Table 1: Shows the Cost Implication for Constructing Composite Phase Change Trombe Wall Solar Brooder

S/N	Component	Material	Specification	Quantity	Unit price	Amount
C1	Land/site clearing	Hand tools:				
		digs	3 digs	3 digs	N5,000.00	N15,000
		Cutlass	2 cutlass	2 cutlasses	N2,000.00	N4,000
		Hoe	2 hoes	2 hoes	N1,200.00	N24,000
		Peg	16 pegs	16 pegs	N100.00	N1600.00
		Robe	20 metres	20 metres	N120.00	N8,000.00
		Labour	4- persons	N2000/day	N2000.00	N24,000.00
					Subtotal	N76600.00
C2	Foundation/ Basement Formation	Cement	Portland -50kg	30bags	N1700.00	N51000.00
		Sand	White sand	2 trips	N12000.00	N24000.00
		Water	Table water	200 gallons	N1,00.00	N200.00
		Gravel/stone	0.5-1.0 diameter	1 trip	N15000.00	N15000.00
		Block	6 inches for	200 blocks	N200.00	N40,000.00
		Labour	4 person for 3days	12persons/day	N2000.00	N2400.00
					Subtotal	N154200.00
C3	Solar Collector	Perplex Glass	(12x12x2) inches	1	N50,000.00	N50,000.00
		Paint (black)	8 gallons (gloss)	1	N16,000.00	N16,000.00

		Composite	140 blocks	140	N400.00	N56,000.00
		phase	¼ 0.5 diameter	¼ trip	N5,000.00	N5,000.00
		Change block	4 persons for two days	8 person	N2000.00	N16,000.00
		Limestone			Subtotal	N143,000.00
		Labour				
C4	Wall	Cement	Portland-50kg	52 bags	N1700.00	N88,400.00
		Water	Table water	500 gallon	N1,00.00	N500.00
		Sand	White sand	500kg	N6000.00	N6000.00
		Block	6 inches	460blocks	N200.00	N92,000.00
		Labour	6 person for two days	12 persons	N2000	N24,000.00
					Subtotal	N210,900.00
C5	Roofing	Roofing	2 bundles	2 bundles	N10,000.00	N20,000.00
		sheet(zinc)	(12x4x4) inch	4 pieces	N500.00	N2,000.00
		Wood	(12x3x4) inch	8 pieces	N350.00	N2800.00
			(12x2x3) inch	12 pieces	N200.00	N2400.00
			(12x2x1)inch	2 bundles	N400.00	N8000.00
		Batton	(4x4) inch	9 sheets	N600.00	N5,400.00
		Ceiling sheet	6 inches	1 kg	N120.00	N120.00
		Nails	5 inches	1 ½ kg	N180.00	N270.00
			3 inches	2 kg	N120.00	N240.00
			2 inches	2 kg	N150.00	N300.00
			1 inches	2 kg	N180.00	N360.00
			Mild steel	8 strands	N50.00	N400.00
		Labour	2 persons for two days	4 persons	N2000.00	N8,000.00
					Subtotal	N50,290.00
C6	Door					
		Metal door	Hollow 5mm thick			
		Frame	Mildsteel(12x4x5) inch	½	N8000.00	N12000.00
		Lagged metal	Mildsteel	1	N12,000.00	N12,000.00
		Door	Sheet(6x4x5) inch			
		Labour	2 persons	2 persons	N2000.00	N4,000.00
					Subtotal	N28,000.00

Table 2: Shows The Cost Estimate for Performance Evaluation Using Day-old Chicks

S/N	Component	Material	Specification	Quantity	Unit price	Amount
	Brooding	Day old Chicks				
		(improved	(improved/hybrid	200 chicks	N200.00	N40,000.00
		varieties)	birds)			
		Feeders	100g feeders	10	N150.00	N1500.00
		Drinkers	1litre drinker	10	N200.00	N2000.00
		Feeds	Superstarter			
			(18% protein)	3bags	N2500.00	N7,500.00
		water	Table water	100	N1.00	N100.00
		Drugs	Newcastle vaccine	gallons	N400.00	N800.00
			Gumboro vaccine	2 (100mg)	N400.00	N800.00
			Coccidostats	2 (100mg)	N500.00	N1000.00
		Labour	2 persons for 14	200 mg	N500.00	N14,000.00
			days	28 persons	Subtotal	N67,700.00
					Miscellaneous	
					expenses	N6770.00
					Total variable	N74,470.00
					cost	

3.2 Cost Analysis

The following factor has to be considered before arriving at articulated total cost of the project, they include:

1) land acquisition/ ownership cost = N200,000.00 for 50years lease.
2) interest of capital (money) = 14%
3) interest on investment =7%
4) insurance =1.5%
5) repair cost =2%
6) depreciation cost.
7) tax = assuming no tax rate.

The fixed cost for the structure (FC) =N662990 +N200,000=N862990.

Therefore, the interest of the capital = $14/100 \times 862990 = N120818.60.00$

For insurance, we have :

$1.5/100 \times 862990 = N12{,}944.85.00$

For repair cost, we have:

$2/100 \times 862990 = N17{,}259.80.00$

For depreciation cost, sum of the year assuming (20years service life), we have:

$\frac{N862990 - 0}{20\,years} = N43{,}149.50$.

For interest on investment, we have:

$7/100 \times 862990 = N60{,}409.30$.

The total annual fixed cost

$= N120818.60 + N12944.85 + N17259.80 + N43149.50 + N60409.30 = N254582.05$.

The total fixed cost (TFC) = N862990+N254582.05=N1,117,572.05.00

The total variable cost (TVC) =N74,470.00 +N35970 x 10month = N434,170.00

Therefore , the Total cost (TC) = (N1117572.05+N434,170.00)=N1,551,742.05

3.3 The Returns on Production

Formula for calculating return on production is given as:

(1-average mortality rate) x number of birds housed/brood x average body weight x price per kg of meat……………………………………………..(1)

Then given that the maximum mortality rate =10% per batch of 200birds, we have the average mortality rate = 5% per batch of 200 which is 10birds/0.5% per batch. The number of birds = 200. Average body weight = 500g , price of birds after brooding =N700.00. therefore, the return on production = (1-0.5) x (11monthsx 200birdsx20years) x 0.5kg x 600=N6600000.00 .

The profit = Return on production – (TFC+TVC) …………(2)

The profit = N6600000.00 -(N1,117,572.05.00+ N434170.00)

= N5,048,258.00

Therefore, the annual profit = N5,048258/20years = N252,412.90.00, at first year of production .

The return on investment of the capital invested is given as profit from an investment as a percentage of the amount invested. It is also expresses as (profit from investment-cost of investment) ÷ (cost of investment).

Therefore, for the first year, the profit = N252412.90, the capital=N1,117,572.05. therefore, the return on investment =252412.90/1117572.05x100/1=22.5%.

4. CONCLUSION

This work has in no small measure tried to showcase the enormous potentials therein in poultry production especially with regards to design and development of cost implication of its construction. This system design was articulated in a systematic approach taken in consideration all the components in a view of taking care of the design considerations. Therefore, the brooding system developed is environmentally friendly, renewable, and user friendly. Farmers and researcher are highly empowered with this window of opportunity that are therein. The cost analysis of the project at different stages were captured as well as cost of performance evaluation and cost-benefit analysis of the project bearing in mind the time value of the project. Finally, the project is a lucrative one and as such farmers (both subsistence and commercial) , small and medium scale enterprises, government agencies, ministries charged with the responsibilities of propagating this innovative ideas should know that this is one of the most reliable means of poultry production that guarantees food sufficiency as well as alleviation of protein deficiency.

REFERENCES

Barre, H. J. and Sammet L. L. 1984. Farm Structures. New York:John Wiley and Sons, Incorporated

Carr, C.W., Kleiber K. and Reece, F.N., 1976. Effect of Environmental temperature on broiler performance. proc. Maryland National conf. for feed manufacturers pp28-34.

Deaton, J. W., and Reece, F. N., 1974. Effect of Environmental temperature on broiler performance. proc. Maryland National conf. for feed manufacturers pp28-34.

Echiegu, E. A. 1986. The development and testing of a passive solar energy heated poultry brooder, unpublished M. Eng., thesis, Dept of Agricultural Engineering, University of Nigeria, Nsukka..

Echiegu, E. A. 1993. Application of Solar heat to Chicken Brooding. Workshop paper, solar drying technologies for Agric. And Industries, Energy Research Centre, University of Nigeria, Nsukka.

Freeman, J., and Skapura, D. 1966. Neural Networks—Algorithms, Applications and Programming Techniques, Addison-Wesley, Boston, EUA.

French, K.M., Larry, R. and Marilyn, K. 1981. Practical poultry Raising, United States Peace Corps publication.

Monyong, V.M, Ikpi, A,Olayemi, J.K,Yusuf,S.A, Omonona,V., Okoruwa and Idachaba, F.S, 2005. Agriculture in Nigeria: Identifying Opportunities for increased Commercialization and Investments. IIta, Ibadan, Nigeria.pp:159

Kleiber, M. and Winchester 1933. Temperature regulation in baby chicks. Proc. Soc. Exp. Biol.Md.31pp156-159.

Obioha, F.C. 1992. A guide to poultry production in the tropics. Acna pub. Enugu.

Okonkwo, W.I, Anazodo, G.U.N. and Akubuo, C.O, Echiegu, E.A and Iloeje, O.C. 1992.The UNN passive solar poultry chick brooder- further improvement and preliminary test. Nig. J.solar Energy,11:32-40.

Okonkwo, W.I. 1993. Design and Construction of a medium Scale Passive Energy Chick brooder. Unpubl. M. Eng. project report, dept. of Agricultural Engineering, University of Nigeria, Nsukka..

Okonkwo, W.I., Iloeje, O.C., Echiegu, E.A. and Akubuo, C.O. 1993. Performance evaluation of a medium scale passive solar heated poultry chick brooder" nig. J Solar Energy, 12pp51-60.

Oluyemi, J.A and Roberts, F.A 1979. Poultry production in the Tropics Macmillian public. Ltd London.

Portsmouth, J. 1978. Practical poultry keeping. Saiga public. Co. Ltd. England.

Rockby, T.R.C., Redford, J.M. and Pitts, D.F. 1983. Solar heating for Commercial broiler house a further evaluation. Trans ASAE 26pp507-511

Thaxton P. ,Kleiber, M. and Winchester 1971. Temperature regulation in baby chicks. Proc. Soc. Exp. Biol.Md.31pp151-159.

Turner, M., Redford, J.M. and Pitts, D.F. 1977. Solar heating for Commercial broiler house a further evaluation. Trans ASAE 26pp507-511

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Books: Ajibola O. 1992. NSAE: Book of abstracts. NSAE: Publishers. Oba. Abakaliki, Nigeria.

Book Chapter: Mohamed S. J., Musa H. and Okonkwo, P. I., Ergonomics of referencing. In: E. I. U. Nwuba (Editor), Ergonomics of Farm Tools. Ebonyi Publishing Company, Oshogbo, Osun State, Nigeria.

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