FRICTIONAL PROPERTIES OF THE ROOTS OF THREE CASSAVA CULTIVARS

ORIOLA,[1] Kazeem. Olaniyi and RAJI,[2] Abdulganiy Olayinka

[1]Department of Agricultural Engineering,
Ladoke Akintola University of Technology,
Ogbomoso, Nigeria.
E-mail: kooriola@lautech.edu.ng

[2]Department of Agricultural and Environmental Engineering,
University of Ibadan, Ibadan, Nigeria

[1]Corresponding Author: kooriola@lautech.edu.ng; kazzyoris@yahoo.com

ABSTRACT

Frictional properties of cassava are needed in the design and development of machines for postharvest operations of cassava roots. Most postharvest processing operations of cassava tubers are still being done manually. Efforts at mechanizing these operations have recorded modest success due largely to scarce publications on the engineering properties of cassava, frictional properties of cassava inclusive. This study was conducted to determine the coefficients of friction, internal friction and rolling resistance of two improved cassava cultivars; TMS 30572, and TME 419 and TME 7 (locally called Oko iyawo) at five moisture levels of 40 - 60% (wet basis) at 5% interval. The coefficients of friction and rolling resistance were determined on stainless steel, galvanized sheet and wood surfaces. The data were analyzed using ANOVA on SPSS 15. Mean coefficient of friction ranged from 0.20 - 0.28, 0.43 - 0.55 and 0.61 - 0.78 respectively on stainless steel, galvanized sheet and wood surfaces with positive linear relationship with moisture increase. A reverse trend was observed for coefficient of internal friction which ranged from 0.40 – 0.69 while the coefficient rolling resistance of the periderm, cortex and flesh of the tubers ranged from 0.14 - 0.15, 0.20 - 0.26 and 0.25 - 0.30; 0.10 - 0.13, 0.16 - 0.19 and 0.20 - 0.26, and 0.08 - 0.09; 0.12 - 0.1 and 0.15 - 0.19 on stainless, galvanized and wood respectively. Moisture content significantly influenced the coefficients of friction and internal friction while skin coverings of the roots significantly influenced the coefficient of rolling resistance of the roots. The study provided useful data essential for the design and development of effective cassava processing and handling machines.

Keywords: *Coefficient of friction; coefficient of internal friction; coefficient rolling resistance; cortex; periderm.*

1. INTRODUCTION

Cassava is a tuberous root crop grown majorly in the tropical regions of the world such as Southern America, Sub-Sahara Africa, and Asia. Its drought tolerance and ability to thrive in marginal soils has been widely acknowledged (El-Sharkawy, 2006; Kolawole and Agbetoye, 2007; Uthman, 2011; Julianti *et al.*, 2011), and this endears it to most farmers. It is known globally as a cheap source of calorie in human diet and animal feeds especially in Africa where it accounts for 60% of root crops consumption. Currently, it is fast becoming a foreign exchange earner due to its new status as a major industrial raw material for the production of wide varieties of flour-based and starch-based products such as *Lafun* (fermented flour), *gari* (flakes), High Quality Cassava Flour (HQCF), alcohol for fuel, glue, starch etc. (Agbetoye, 2003; Kolawole *et al.*, 2010). Today, about 60% of cassava is used for industrial purposes while 40% is consumed by the households (Olusegun and Ajiboye, 2010). In Nigeria, a Federal Government directive on 10% cassava flour utilization in wheat-based baking flour has triggered a serious hike in demand for cassava.

Processing tubers into stable forms such as chips offer an alternative to storage (Raji, and Igbeka, 1994), from which other products can be produced. Also, the chips as an intermediate product can be used in the production of animal feeds, cassava flour and starch and starch-based products. Presently, large quantities of cassava chips are being ordered from Nigeria to Asian countries for industrial uses (Agbetoye, 2005). This increase in demand for cassava tubers and its products implies increased cassava production, processing and handling operations which consequently makes the mechanization of these processes imperative in order to remove the negative attributes of the traditional processing methods currently in use. Thus, cassava processing is very essential in order to reduce its perishability since it deteriorates within few days after harvest (Ngeve, 1995; Akintunde *et al.,* 2005). Mechanization of cassava processing operations will no doubt play a pivotal role in removing the drudgery associated with the traditional processing techniques and promote large scale production. Mechanization implies the design and development of efficient and cost effective machines and equipment for cassava postharvest processing and handling operations, the success of which solely depends on thorough understanding of the engineering properties of the roots such as the frictional properties among others. The importance of the frictional properties of fruits and vegetables against machine parts has been underscored as one of the main causes of mechanical injuries during handling (Singh *et al.,* 2004). Irtwange and Igbeka (2002) also emphasized the importance of the knowledge of the frictional properties of materials in the adequate design of theoretical performance of machines and mechanisms. Review of literature showed that sufficient data have been published on frictional properties of grains, fruits and seeds as a function of moisture content (Visvanathan *et al*., 1996; Suthar and Das, 1998; Simonyan *et al.,* 2008). However, this was found to be scanty for cassava roots. For instance, the published study on the frictional properties of cassava by Ejovo *et al.* (1988) was conducted with scanty number of samples (3 samples), one cassava variety of unspecified genotype and without considerations for the effects of moisture contents of the roots on the frictional properties being studied. Therefore, it is essential to study the frictional properties as a function of different factors such as moisture content and variety since cassava features are dependent on genotype (variety) and environmental conditions (Alves, 2002), hence, the aim of this study was to determine the coefficients of friction, internal friction and rolling resistance of three cassava varieties at five different moisture contents.

2. MATERIALS AND METHODS

The cassava cultivars used for the study were TMS 30572, TME 419 and TME 7 (*Oko iyawo*). *Oko iyawo* is a local cultivar popular among cassava farmers in the south western part of Nigeria while the first two were improved varieties, the stems of which were obtained from the International Institute for Tropical Agriculture (I.I.T.A), Ibadan, Nigeria.

2.1 Preparation of Samples

The samples used for the experiments were prepared from freshly harvested 12 months old roots obtained from Ladoke Akintola University of Technology, Ogbomoso Teaching and Research farm which was established purposely for this study. The tubers used for the determination of the coefficients of friction and internal friction were cleaned and carefully peeled and cut manually, into sizes of (30 x 20 x 10) mm using very sharp stainless steel knives (Chijindu *et al.*, 2008; Palaniswami *et al.,* 2008; Tunde-Akintunde and Afon, 2009). The initial moisture content of the samples was first determined with the use of an OHAUS MB 35 Halogen moisture analyzer. Thereafter, the samples were placed in a DHG 9101.1SA (UK) oven which had already attained a temperature of 50^oC for conditioning to the desired moisture content. They were brought out in batches after attaining the desired moisture contents of 40, 45, 50, 55, and 60% (wb) and placed in a dessicator for about an hour for moisture equilibration before being used for experimentation. The coefficient of rolling resistance was determined using 60 mm long roots cut out from the straight portions of the roots with the periderm, cortex and flesh of the tubers against stainless steel, galvanized sheet and wood surfaces.

2.2 Determination of Coefficient of Friction

The coefficient of friction of the chips was determined using the inclined plane with adjustable top. Cassava chips of size 30 x 20 x 10 mm (Chijindu *et al.*, 2008; Palaniswami *et al.,* 2008; Tunde-Akintunde and Afon, 2009) was placed on the table and tilted until sliding occurred. The angle at which this occurs was noted and recorded. The tangent of this angle gave the coefficient of friction of the chip. This experiment was replicated five times each on stainless steel, galvanized sheet and wood surfaces (in turns) and the values averaged.

2.3 Determination of Coefficient of Internal Friction of Cassava

The coefficient of internal friction of roots was determined using chip samples of size (30 x 20 x 10) mm. A big wooden frame of size (120 x 80 x 10) mm and a smaller guide block of size (90 x 60 x 10) mm were used in addition to a frictionless pulley, a chord and a scale pan. The big wooden frame and the guide block were filled with chip samples. The guide block was placed atop the bigger frame. A light chord attached to the smaller frame was passed over the frictionless pulley. The other end of the chord bored the scale pan. Weights were then added to the scale pan until sliding of the guide block (filled with cassava chips) occurred over the big frame (also filled with cassava chips). The weight (M_1) causing the sliding was noted and recorded. The guide block was then emptied and placed back on the bigger frame and the scale pan loaded until the empty guide block just started to move over the contents of the big frame. The weight (M_2) causing sliding of the empty frame was also noted. The coefficient of internal friction was then calculated at the above mention moisture contents using equation 1.

$$\mu = \frac{M_1 - M_2}{W} \qquad (1)$$

Where,
$M_1 - M_2$ = Weight required to slide the sample material (g)
W = Weight due to the sample material in the cell = vol. of cell (cm^3) x bulk density of the samples (g/cm^3).
μ = Coefficient of internal friction
Five replicates of each experiment were produced at each moisture level.

2.4 Determination of Coefficient of Rolling Resistance

Root samples of length 60mm were carefully cut off from whole cassava roots and placed on an inclined plane with adjustable angle of inclination (tilting top). Care was taken to ensure that the samples were cut from the straight portions of the roots. The top of the table was then tilted with the specimen until the tuber just started rolling down the inclined plane. The angle at which this occurs was measured and recorded. This was done using the periderm, the cortex, and the tuber flesh in turns against stainless steel, galvanized sheet and wood surfaces. The coefficient of rolling resistance was then calculated using equation (2).

$$\mu = R \tan \theta \qquad (2)$$

Where,

R = Average radius of the tuber

θ = Angle of inclination at which tuber just started rolling down the plane

Each experiment was replicated five times for each variety of cassava.

Statistical analysis was carried out to study the effects of moisture content on the engineering properties of the cassava cultivars studied using SPSS 15 software. Analyses of Variance of the mean values of the engineering properties studied were carried out to determine the level of significance of the differences in the measured parameters

3. RESULTS AND DISCUSSION

3.1 Coefficient of Friction

The mean coefficient of friction (COF) of TMS 30572, TME 419 and *Oko-iyawo* cultivars used in this study are presented in Table 1. The coefficient of friction of the samples ranged from 0.20 to 0.28; 0.42 to 0.55 and 0.61 to 0.78 on stainless steel, galvanized sheet and surfaces respectively for the three cassava cultivars at different moisture content levels (MC)

Table 1: Mean Coefficient of Friction of different Cassava Cultivars

SURFACE	MC	TMS 30572	TME 419	*OKO IYAWO*
	40	0.20	0.21	0.21
Stainless	**45**	0.21	0.22	0.22
Steel	**50**	0.23	0.24	0.23
	55	0.26	0.26	0.24
	60	0.27	0.28	0.28
	40	0.44	0.43	0.43
Galvanized	**45**	0.45	0.45	0.47
Sheet	**50**	0.46	0.49	0.49
	55	0.52	0.52	0.53
	60	0.53	0.53	0.55
	40	0.61	0.61	0.61
Wood	**45**	0.67	0.63	0.62
	50	0.69	0.69	0.67
	55	0.74	0.73	0.75
	60	0.76	0.75	0.78

Generally, the coefficient of friction of the roots increased with increase in MC moisture content on all the three surfaces (Figures 1- 3). This may be due to the fact that the moisture made the starchy surface of the samples to become stickier thereby increasing the force of adhesion between the surface of the samples and that of the stainless steel as the moisture content of the samples was increased. Expectedly, the coefficient of friction of the samples was lowest, within the moisture content studied, on the stainless steel surface and highest on wood due to the difference in the degree of roughness of the three surfaces used in the study, stainless steel surface being smoother than the other two surfaces. Table 1 also shows that the TME 419 cassava variety shares the same coefficient of friction with TME 7 (*Oko iyawo*) at low moisture contents (40 – 45%) while it exhibited the same trend with TMS 30572 at high moisture content (55 – 60%) on stainless steel. A closer look at the values of the coefficient of friction of the three cassava varieties shows that they are very close, which suggest that the value of COF for one of them can be used for the other.

However, the values of COF obtained for the root flesh in this study are slightly higher especially on galvanized sheet and wood when compared with the results (0.364 and 0.404) reported by Ejovo *et al.* (1988) for mild steel and wood. This may be due to the difference in the ages of the cassava roots used in the two studies. The result obtained in this study for the coefficient of friction of cassava on stainless steel surface were, however, slightly within the range of value (0.213) reported by Ejovo *et al.*1988 for coefficient of friction of cassava flesh on aluminum.

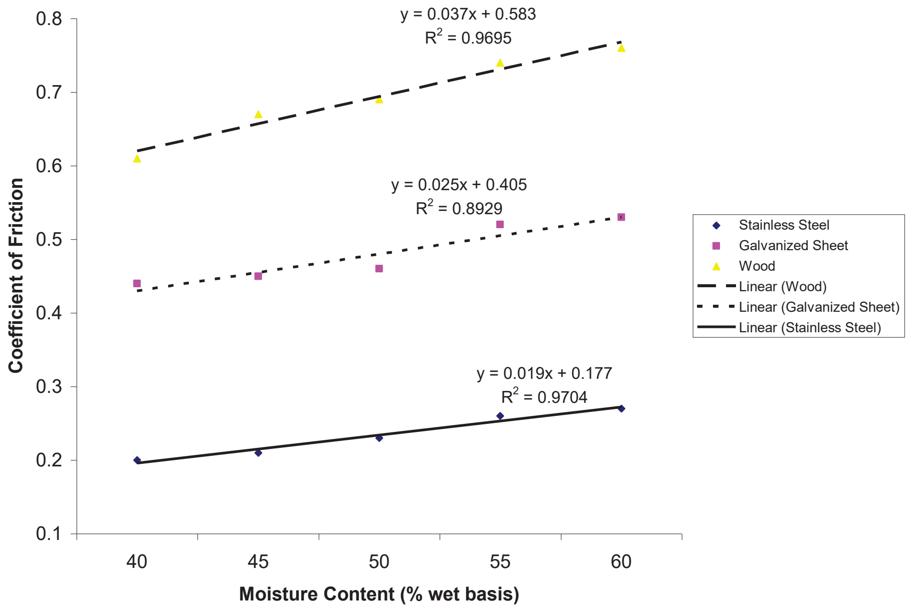

Figure 1: Coefficient of Friction of TMS 30572 Cassava Cultivar

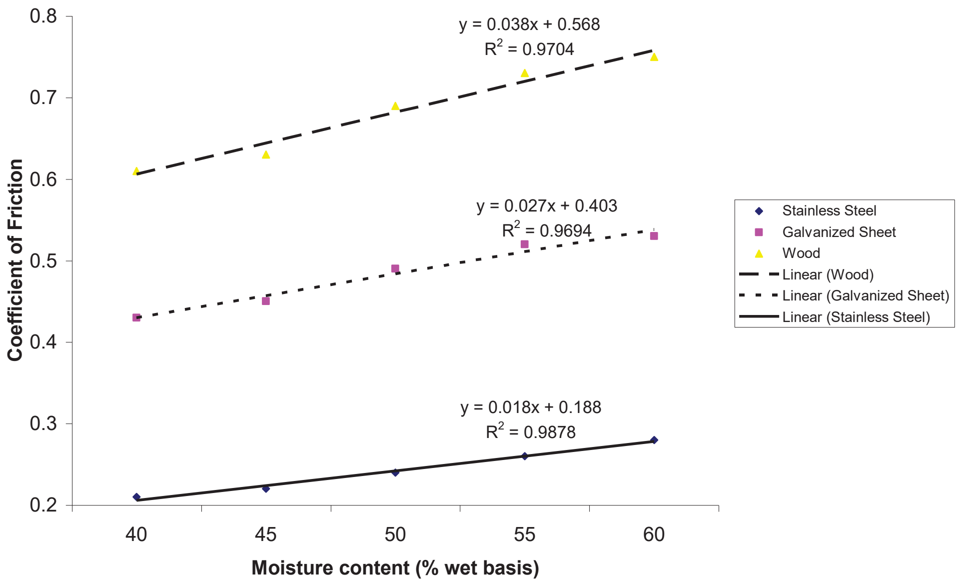

Figure 2 : Coefficient of Friction of TME 419 Cassava Cultivar

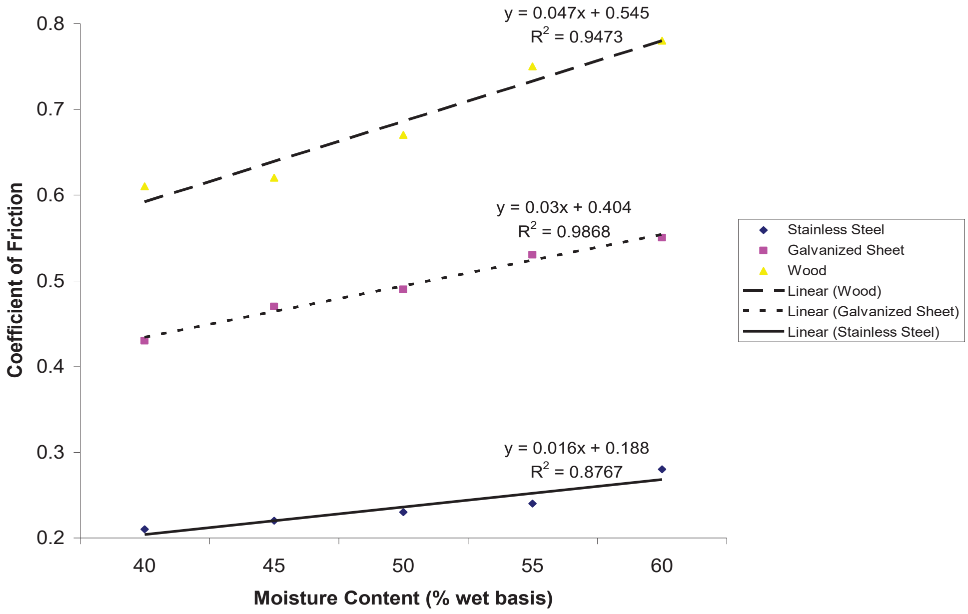

Figure 3: Coefficient of Friction of TME 7 Cassava Cultivar

The coefficient of friction of the cassava samples on galvanized sheet were also very close, with that of TME 7 being the highest within the moisture content studied and those of the improved cassava varieties being almost the same. Also, at moisture contents between 40 and 50% (wet basis) samples of the local cassava variety generally had the least COF while the two improved varieties had the highest (Table 1). A reverse trend was however observed when the moisture content was raised beyond 50% with samples of TME 419 exhibiting the least COF on wood. Results of the ANOVA showed that the influence of moisture content of the samples on their coefficients of friction on the three structural surfaces was very significant ($P < 0.05$) except that of TME 419 on wood.

3.2 Coefficient of Internal Friction

Results of the coefficient of internal friction (CIF) of the cassava samples are presented in Table 2. It ranged from 0.44 to 0.57; 0.58 to 0.69 and 0.40 to 0.58 for samples of TMS 30572, TME 419 and *Oko iyawo* varieties respectively at different Moisture content levels (MC).

Table 2: Mean Coefficient of Internal Friction of different Cassava cultivars

MC	TMS 30572	TME 419	*Oko Iyawo*
40	0.57	0.69	0.58
45	0.56	0.68	0.57
50	0.56	0.63	0.54
55	0.46	0.60	0.41
60	0.44	0.58	0.40

It was observed that the CIF reduced with increase in moisture content of the samples (Figure 4) with TME 419 exhibiting the highest CIF within the moisture content studied while

TMS 30572 and TME 7 had the least at moisture contents below and above 50% respectively. A linear negative relationship exists between the CIF and moisture content as shown in Figure 4, with the R^2 values of the CIF graphs ranging between 0.9657 and 0.8266. The negative linear relationship may be due to strong influence of the ability of moisture to reduce the friction between two surfaces over and above the influence of the cohesive force between the surfaces of the cassava samples, hence, as the moisture content increased the friction between the surfaces of the cassava samples decreased. Result of analysis of variance showed that the influence of moisture content was significant on the coefficient of internal friction of samples of all the three cassava varieties studied.

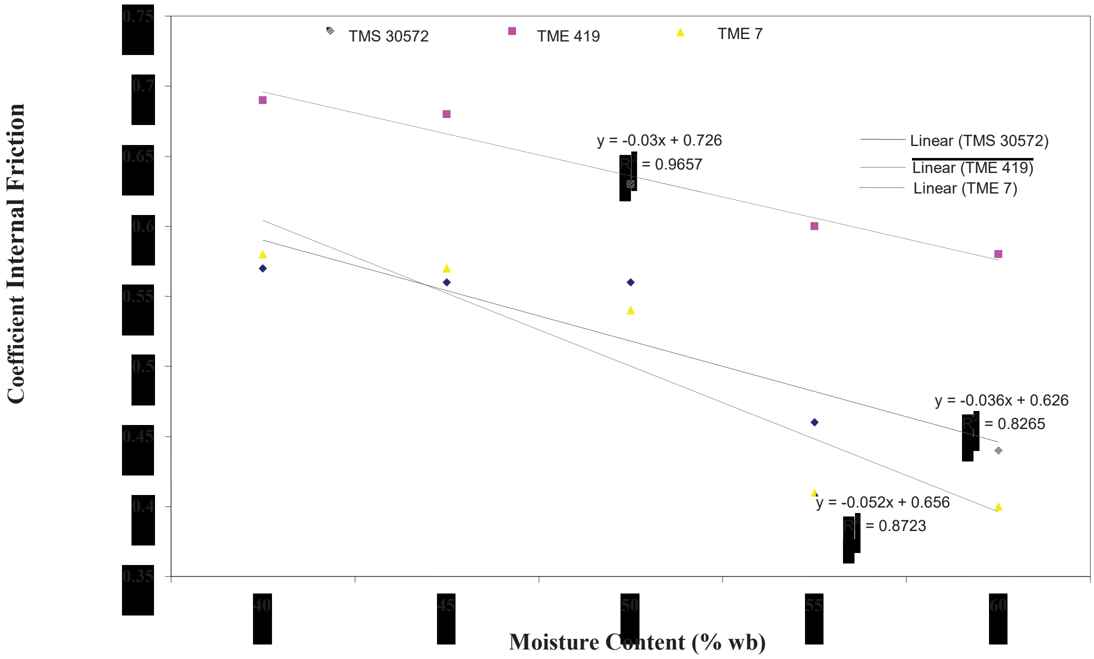

Fig 4: Coefficient of Internal Friction of Cassava

3.3 Coefficient of Rolling Resistance

Mean coefficient of rolling resistance (CRR) of the three cassava cultivars using the periderm, cortex, and flesh of the tuber against stainless steel, galvanized sheet and wood surfaces are presented in Table 3. As expected, the coefficient of rolling resistance of the cassava roots was generally lower on stainless steel and highest on wood. Also, the periderm gave the highest coefficient of rolling resistance on all the surfaces while the tuber flesh gave the least.

Table 3: Average Coefficient of Rolling Resistance of different Cassava Cultivars on Different Surfaces

	TMS 30572			TME 419			*OKO IYAWO*		
Covering	Stainless	Galvanized	Wood	Stainless	Galvanized	Wood	Stainless	Galvanized	Wood
Periderm	0.14	0.22	0.25	0.14	0.20	0.25	0.15	0.26	0.30
Cortex	0.10	0.16	0.20	0.12	0.18	0.20	0.13	0.19	0.26
Flesh	0.08	0.12	0.15	0.09	0.13	0.17	0.08	0.14	0.19

This is due to the fact that the periderm of the roots was the least smooth compared to the cortex and flesh. The roots of TME 7 cultivar exhibited the highest coefficient of rolling resistance on all the surfaces irrespective of the root covering (periderm, cortex or wood) used. The influence of tuber skin coverings was significant on the coefficient of rolling resistance of the roots irrespective of the surface used.

4. CONCLUSIONS

The values of coefficient of friction of cassava were generally higher than those of the coefficient of rolling resistance on the three surfaces used for the study. Coefficient of friction of the three cassava cultivars on stainless steel surface were very close within the moisture content and age studied thereby suggesting that the values of one variety may be used for the other but it increased with increase in moisture content. TME 419 had the highest Coefficient of internal friction and exhibited negative relationship with moisture content like the two other cultivars. The coefficient of rolling resistance of the roots of TME 7 was generally higher than those of the roots of the improved varieties. Moisture content significantly influenced the coefficients of friction and internal friction of all the cassava cultivar while root coverings influenced the coefficient of rolling resistance. The study provided useful data essential for the design and development of effective cassava processing and handling machines.

REFERENCES

Agbetoye, L. A. S. 2003. Engineering Challenges in Developing Indigenous Machinery for Cassava Production and Processing. Proceedings of Nigeria Society of Engineers Conference and Annual General Meeting. pp 80-86.

Agbetoye, L. A. S. 2005. Improving the Technology of Cassava Harvesting and Processing Mechanisation for Food Security in Nigeria. Proceedings of the International Conference on Science and Technology. Federal University of Technology, Akure, Nigeria, 196 – 205.

Akintunde, B. O., Oyawale, F. A. and Tunde-Akintunde, T. Y. 2005. Design and Fabrication of a Cassava Peeling Machine. Nigerian Food Journal. Vol. 23, pp 1-8

Alves, A. A. C. 2002. Cassava Botany and Physiology. In: Hillocks, R. J. Thresh, J. M & Bellotti, A. C. (Eds). Cassava: Biology, Production and Utilization. CAB International 2002.

Chijindu, E. N., Boateng, B. A., Ayertey, J. N., Cudjoe, A. R. and Okonkwo, N. J. 2008. The Effects of Processing Methods of Cassava Chips on the Development of *prostephanus truncates* (Horn). African Journal of Agricultural Research, 3(8): 537-541.

Ejovo O. N., Oboli, S. and Mgbeke, A. C. C. 1988. Studies and Preliminary Design for a Cassava Tuber Peeling Machine. Transactions of the American Society of Agric. Engineers. 31(2): 380-385.

El-Sharkawy, A. M. 2006. International Research on Cassava Photosynthesis, Productivity, Eco-physiology and Responses to Environmental Stresses in the Tropics. Photosynthetica, 44 (4): 481-512.

Irtwange S. V. and Igbeka, J. C. 2002. Some Physical properties of Two American Yam Bean (*sphenostylisstenocarpa*) Accessions and their Interrelation with Moisture Content. Applied Engineering in Agriculture. 18 (5): 567 – 576.

Julianti, E., Lubis, Z., Ridwansyah, Yusraini, E. and Suhaidi, I. 2011. Physicochemical and Functional Properties of Fermented Starch from Four Cassava Varieties. Asian Journal of Agricultural Research, 5: 292-299.

Kolawole, O. P. and Agbetoye, L. A. S. 2007. Engineering Research to Improve Cassava Processing Technology. International Journal of Food Engineering, Vol. 3 issue 6 Article 9: 1- 15.

Kolawole O. P., Agbetoye, L. A. S. and Ogunlowo, A. S. 2010. Sustaining World Food Security with Improved Cassava Processing Technologies: The Nigerian Experience. Sustainability, 2: 3681- 3694

Ngeve, J. M. 1995. Effects of Location and Age at Harvest on Yield and Culinary Qualities of Cassava (Manihot esculenta Cranz). In: Akoroda, M. O.and Ekanayake, I. J. (Eds). Root crops and poverty alleviation. Conference of the 6th Triennial Symposium of the ISTRC-AB. Lilongwe, Malawi. Pp 22-28.

Olusegun, H. D. and Ajiboye, T. K. 2010. The Design, Construction and Testing of a Vertical Squeeze Cassava Pulp Dewatering Machine. International Journal of Engineering and Applied Sciences. Vol. 2 Issue 1. Pp 27-43.

Palaniswami M. S. and Peters, K. V. 2008. Tuber and Root Crops. Horticulture Science Series. New Indian Publishing Company, Vol.9, Pp 512.

Raji, A. O. and Igbeka, J. C. 1994. A Pedal Operated Chipping and Slicing Machine for Tubers. Journal of Agricultural Engineering and Technology, 2(1): 90 - 94.

Simonyan, K. J., Yiliep, Y. D., Oyatoyan, O. B. and Bawa, G. S. 2008. Effects of Moisture Content on some Frictional Properties of *Lablab purpureus* Seeds. Journal of Agricultural Engineering and Technology, 16 (1): 37-46

Suthar, S H. and Das, S. K. 1996. Some Physical Properties of Karingda [*Citrullus lanatus* (Thumb) Mansf] Seeds. Agricultural Engineering Research, 65: 15-22.

Tunde-Akintunde T. Y and Afon, A. A. 2009. Modeling of Hot-Air Drying of Pretreated Cassava Chips. Agricultural Engineering International: CIGR E-Journal Manuscript 1493 Vol. August. Pp 1-13.

Uthman, F. 2011. Design and Fabrication of Cassava Lump Breaking and Sieving Machine. Oasis Journal of Research and Development, 1(2):42- 50.

Visvanathan, R., P. T. Palanisamy, L. Gothandapami and V. V. Sreenarayanan 1996. Physical Properties of Neem Nut. Journal of Agricultural Engineering Research, 63(1): 19 – 25.