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DETERMINATION OF SOME ENGINEERING PROPERTIES OF CASSAVA TUBERS GROWN IN NORTHERN NIGERIA

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ABSTRACT

Several cassava processing operations have been mechanized successfully, but cassava peeling is still largely carried out manually; however, in this work some selected engineering properties of 5 cassava varieties mostly grown in northern part of Nigeria were determined to provide basic data for the design of cassava peeling machine. These properties include thickness of the peel, the length, and axial dimensions - major, intermediate and minor diameter and the Strength of peel (peeling force), and Bioyield(breaking force). The average length of the tubers measured are in the range of 15.4 – 68.51 cm while the maximum and minimum thickness of the peel are 6.01 and 0.54 mm respectively. The peel reduces in thickness from the radicle towards the apex and the larger the diameter of the tuber, the thicker the peel. The highest and lowest values of the peeling force are 2248 kN/m² and 401 kN/m²respectively. It was observed that the peeling force value increases and reduces along the length of the tuber. Also the peeling force reduces with time after harvest and has the highest value at 24 hours after harvest. This could be due to the deterioration of the tuber with time. The major, minor and intermediate diameters of the tubers determined are in the range of 3.00 –10.35 cm, 2.15 – 10.05 cm and 0.87 – 6.04 cm respectively. The maximum bioyield force was 3880 kN/m² and minimum was 769.3 kN/m². All these are important in the design of a cassava peeling machine.

Keywords: Cassava peeling, Engineering properties, Strength and bioyield force

INTRODUCTION

Cassava (*Mahihotesculenta*)is a woody shrub of the *Euphorbiaceae*with numerous uses and by-products. It is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root(Aregheoreand Agunbiade, 1991; Rehm and Espig, 1991; Kawano, 2000). Cassava is the third largest source of carbohydrates for human food in the world. Cassava is classified as "sweet" or "bitter" depending on the level of toxic cynogenicglucosides (CBN Newsletter, 1996; Wheatley, Chuzel and Zakhia,2003).

Cassava roots are very rich in starch, and contain significant amounts of calcium (50mg/100g), phosphorus (40mg/100g) and vitamin C (25mg/100g). However, they are poor in protein and other nutrients. In contrast, cassava leaves are a good source of protein if supplemented with the amino acid methionine despite its cyanide content (IITA, 1990; RMRDC, 2004; Williams and Chew, 1980). It is an important food in many South and Central American countries, parts of West Africa, where it is processed into a product known as '*garri*'. The tubers are used as animal feed, for making glucose and sodium glutamate and in preparation of high grade starch (Williams and Chew, 1980; Jeon and Halos, 1992). Some varieties have high concentrations of toxic substances (hydrocyanic glucosides) which form cyanide when the tubers are harvested or the tissue is damaged. The yield varies from as low as 5 tonnes to more than 60 tonnes per hectare (CBN Newsletter, 1995; Mohsenin, 1970). World production of cassava root was estimated to be 184 million tonnes (FAO, 1991). The majority of production is in Africa where 99.1 million tons are grown. Fifty-one and a half (51.5) million tons were grown in Asia and 33.2 million tons in Latin America and the Caribbean. Nigeria is the world's largest producer of cassava. However, based on the statistics from the Food and Agricultural Organization (FAO) of the United Nations, Thailand is the largest exporting country of dried cassava with a total of 77% of world export in 2005. The second largest exporting country is Vietnam, with 13.6% followed by Indonesia (5.8%) and Costa Rica (2.1%).

Worldwide cassava production increased by 12.5% between 1988 and 1990 (RMRDC, 2004).
Before cassava tuber is processed into any of its food and non-food products, it must be peeled (Odigboh, 1976; Polson and Spencer, 1991; Felix, 2004). Several cassava processing operations have been mechanized successfully, but cassava peeling had been a serious global challenge to design engineers involved in cassava processing (Olukunle, 2005, RMRDC, 2004;Olukunle*et al.,* 2006, Olawale, 2007).

In the food industry, the peel must be completely removed without removing the useful tuber flesh (Odigboh, 1976, Asogwa, Umeh and Ater, 2006). It is worthy to note that the peel represent about 15 percent of the weight of the root and its cyanogens content is usually 5 to 10 times greater than the root parenchyma.

In Nigeria, peeling is usually done by using a knife. On the average one woman can peel about 20 to 25kg of roots in an hour. It is reported that 30kg of fresh weight is lost during the manual peeling because woody tips are removed. The process is slow and labour-intensive, averaging 25kg per man-hour, but it gives the best result. Various peeling machines have been developed but they are not effective,resulting in high wastage. The available locally developed mechanical peelers are generally wasteful in the peeling process with low peeling efficiency (Bokanga, 2010, Adetan, Adekoya and Aluko, 2002; Ezekwe, 1979) while the imported ones are very expensive costing up to $7,500.00equivalent to 1 million Nigerian Naira and inadaptable to our local conditions.
It is worthy to note that the major problem in cassava peeling arises from the fact that cassava roots exhibit appreciable differences in weight, size and shape (Alade, 2005). There are also differences in the properties of the cassava peel, which varies in thickness, texture and strength of adhesion to the flesh (Agbetoye, 2003). Another major constraint of cassava is that the roots deteriorate rapidly (IITA, 1990). Cassava tubers have a shelf life of 24-48 hours after harvest (Akintunde, Oyawale and Tunde, 2010). Fresh roots must be processed within 2 to 3 days from harvest.
Thus for the aforementioned reasons there is therefore the need to determine some engineering properties of Cassava tubers to aid in the design of more effective cassava tuber peeling machine.

MATERIALS AND METHODS

Some engineering properties of 5varieties of cassava tubers (TSM 82/00661, TMS 81/00110,TMS30001, TSM 4(2)30572 and TSM 82/0249) were determined. These physical properties include length, axial dimensions (major, minor and intermediate diameters) and thickness of peel while the mechanical properties are the force required to peel cassava tubers and the bioyield (breaking) force.

The materials used in executing this research work include five(5) varieties of cassava tubers obtained from Kure – Ultra modern market, Minna, Niger State. A variety of tools and instruments were used to carry out different measurements on the root tubers. A tap measure was used to measure the lengths of roots while the diameters of the roots were measured using a pair of Vernier caliper. The weights of roots before and after peeling and that of the peels were measured with an electronic weighing balance while the thickness of the root peel was measured by micrometer screw gauge.

a – Peeling knife with hand b – Penetrometer c – Assembled Peeling Tool

Figure 1: The developed Peeling tools

A penetrometer (dynamometer - 4682.6332kN/m^2) was used to measure the peeling force while developed peeling knives (with peeling section width of 26 mm) (Figures 1abc) were used in peeling the peel. Developed plastic supportswere used to determine the bioyield(breaking force). In the course of the experiment, the tubers were categorized into three different classes namely; small, medium and large sizes.

Determination of Physical properties of cassava tuber

A cross section of a typical cassava tuber (Figure 2) is labeled to show its component parts such as the periderm, sclerenchyma, cortical parenchyma and phloem. The peel (1 – 4) is the most important during peeling because it has to be removed from the food storage section of the cassava tuber.

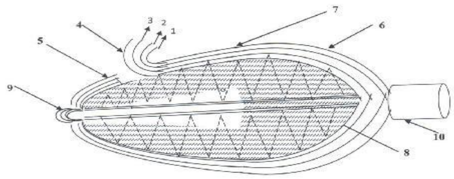

Figure 2: Cross section of cassava tuber

Legend:1. Periderm, 2. Sclerenchyma, 3. Cortical parenchyma, 4. Phloem, 5. Cambium, 6. Storage parenchyma, 7. Xylem, 8. Xylem vessels and fiber, 9**.** Apex, 10. Radicle

In Figure 3, a cassava tuber is marked according to the diameters to be measured in the study as follows:

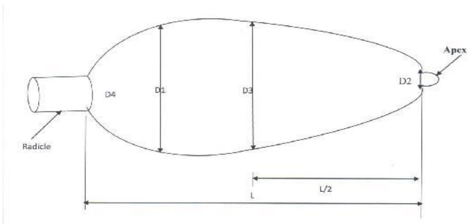

Fig. 3: Dimensions of interest of cassava tuber

Legend: L= Length of cassava tuber, D_1 = Major diameter, D_2 = Minor diameter, D_3 = Intermediate diameter, D_4 = Diameter at the radicle.

Determination of Length and Axial dimensions

The tap measure was used to measure the length of the roots while the diameters of the roots were measured using a pair of vernier calipers.

Determination of thickness of peel

The peel is the skin covering the storage parenchyma of the tuber. It consists of four layers, the periderm, sclerenchyma, cortical parenchyma and phloem. Two methods of peeling were used in removing the peel using the developed peeling tools namely;

- by forcing the sharp edge of the knife at an angle 5 to 15 degreesalong the length of the tuber (Adetan*etal*., 2003) as shown in Figure 4 and,
- by forcing the sharp edge of the knife or peeling tool vertically downwards on the tuber and levering the peel while rotating the tuber so that the peel is completely removed from the storage parenchyma (Figure 5).

After removing the peel, the thickness is then measured by using a micrometer screw gauge.

Figure 4: Hand peeling at 5 – 15 degrees vertically downward placed on tuber

Figure 5: Hand peeling with knife along the length of tuber

Determination of Mechanical properties of cassava tuber

Determination of peeling force

This is the force generated by the peeling knife to remove the peel. As the peel is being removed using the assembled tool (penetrometer attached to the peeling knife) for the two methods, the peeling force was taken/read from the scale of the penetrometer which served as the handle. This was replicated thrice.

Bioyield force

This is the force required to break the cassava under pressured. This force was determined by horizontally placing the tuber on two plastic supports and by pressing the penetrometer vertically thereby reading off the force from the scale of the penetrometer (Figure6).

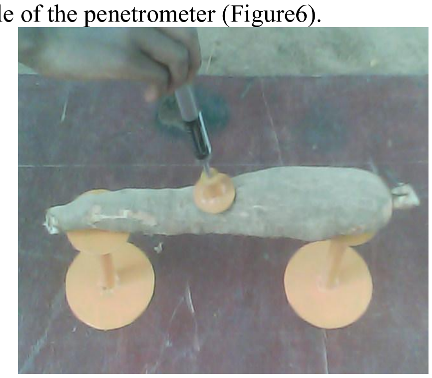

Figure 6: Determination of bioyield force

The peeled cassavas with the developed tools are shown in Figure 7.

Figure 7: Peeled cassava tubers using the developed peeling tools

RESULTS

The results on physical properties of the five (5) selected varieties of cassava are shown in Table 1 while the results on the mechanical properties are shown in Table 2.

Discussion of results on Physical Properties

Table 1 presents the physical properties of the five (5) selected varieties of cassava mostly grown in northern part of Nigeria. The average length of the 5 varieties TMS 82/00661, TMS 81/00110, TMS 30001, TMS 4(2)30572 and TMS 82/0249 were 45.91 cm, 27.45 cm, 35.15 cm, 33.96 cm and 27.70 cm respectively.

Table 1: Physical properties of some selected varieties of cassava mostly grown in northern Nigeria

S/No.	Cassava Variety	Length, cm			Diameter, cm								
					Major			Intermediate			Minor		
		Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.
1	TMS 82/000661	23.30	68.51	45.91	3.00	4.49	3.75	2.15	3.92	3.04	0.92	4.87	2.90
2	TMS 81/00110	15.40	39.50	27.45	3.26	4.68	3.97	3.25	4.99	4.12	0.87	1.95	1.41
3	TMS 30001	27.10	43.20	35.15	3.36	4.20	3.78	3.10	3.89	3.44	1.45	1.99	1.72
4	TMS 4(2)30572	23.61	44.30	33.96	4.05	5.75	4.90	3.28	5.39	4.34	1.38	5.56	3.47
5	TMS 82/0249	23.95	31.45	27.7	5.89	10.35	8.12	5.35	10.05	7.70	3.17	6.04	4.61

Table 2: Mechanical properties of some selected varieties of cassava mostly grown in northern Nigeria

S/No.	Cassava Variety	Peeling Force, kN			Bioyield Force, kN/m^2			Thickness of peel, mm		
		Min.	Max.	Aver,	Min.	Max.	Aver.	Min.	Max.	Aver.
1	TMS 82/000661	602	1940	1271	1940	3211	2575.5	0.86	1.99	1.43
2	TMS 81/00110	468	1405	936.5	1771	3880	2825.5	1.00	2.58	1.79
3	TMS 30001	401	1472	936.5	1739	2408	2073.5	0.54	3.36	1.95
4	TMS 4(2)30572	535	2074	1304.5	3345	4181	3763	0.68	2.98	1.83
5	TMS 82/0249	1241	2248	1744.5	769.3	9237	5003.2	2.00	6.01	4.01

TMS 81/00110 variety has the shortest length of 27.45 cm while TMS 82/000661 has the longest length of 40.75 cm. The TMS 82/0249 cassava variety has the maximum average values of major, intermediate and minor diameters of 81.2 cm, 7.70 cm and 4.61 cm respectively while TMS 82/000661 has major and intermediate diameters as 3.75 cm and 3.04 cm respectively. The TMS 81/001100 has the least average value for minor diameteras 1.41 cm. The results on the tuber diameters fall within the range reported by Adetan*et al.* (2003) and Ezekwe (1979).

Discussion of results on Mechanical Properties

The mechanical properties of the five (5) varieties of cassava mostly grown in the northern part of Nigeria are presented in Table 2. The TMS 82/00661, TMS 81/00110, TMS 30001, TMS 4(2)30572 and TMS 82/0249 varieties have average peeling force of 1271 kN, 936.5 kN, 936.5 kN, 1304.5 kN and 1744.5 kN respectively. Also the peeling force reduces with time after harvest and has the highest value at 24 hours after harvest. This could be due to the deterioration of the tuber with time.TMS 4(2)30572 has the highest average bioyield force of 3773 kN/m^2 while TMS 81/001100 and TMS 30001 have the least average value of bioyield force of 936.5 kN/m^2. The average thickness of the peel for TMS 82/00661 – 1.43 mm, TMS 81/00110 – 1.79 mm, TMS 30001 – 1.95 mm, TMS 4(2)30572 –1.83 mm and TMS 82/0249 – 4.01 mm. TMS 82/0249 has the maximum thickness of peel as 4.01 mm while TMS 82/000661 has the least value of thickness of peel of1.43 mm. The results on the peeling and bioyield forces are closely in agreement with the report of the work (Adetan*et al.,* 2003; Ezekwe, 1979). The peel reduces in thickness from the radicle towards the apex and the larger the diameter of the tuber, the thicker the peel. All these are important in the design of a cassava peeling machine.

CONCLUSION

Some engineering properties of Cassava Tubers grown in northern Nigeria were determined. These properties include thickness of the peel, the length, and axial dimensions - major, intermediate and minor diameter and the Peeling force, and breaking force (bioyield force). The highest and lowest values of the peeling force are 2248 kN/m^2 and 401 kN/m^2 respectively. The maximum bioyield force is 3880 kN/m^2 and minimum is 769.3 kN/m^2. It could be concluded that the larger the diameter of the tuber, the thicker the peel. The peeling force also reduces with time after harvest and has the highest value at 24 hours after harvest. All these are important in the design of a cassava peeling machine.

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