Effects of Tuber Age and Variety on Physical Properties of Cassava [*Manihot Esculenta* (Crantz)] Roots

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This research was financed by the Competitive Agricultural Research Grant Scheme (CARGS) of the Agricultural Research Council of Nigeria (ARCN).

Abstract
Poor postharvest storability of cassava roots has led farmers into leaving the tuber in-ground for a long time even after maturity thereby leading to lignifications. Besides, this practice has been reported to result in changes in the physiological structure of the roots, hence the need to investigate the influence of this on the engineering properties of the root. Two improved cassava varieties, TME 419 and TMS 30572 and a local variety, *Oko-iyawo* were investigated in this study. Selected physical properties which include diameter and peel thickness at the head, middle and tail (D_H, D_M, D_T, P_H, P_M and P_T), mass, length, Peel Proportion by Weight (PPW) and density for tubers aged 12, 15 and 18 Months After Planting (MAP) were measured using standard methods. The data were analyzed using the two way ANOVA in SPSS 15. The mean D_H, D_M, D_T, P_H, P_M, P_T, mass and length ranged respectively from 36.67 (8.76) – 43.32 (11.53) mm, 35.26 (15.77) – 45.58 (7.68) mm, 26.06 (12.94) – 33.87 (10.30) mm, and 1.30 (0.25) – 4.60 (1.13) mm, 1.23 (0.23) – 4.52 (1.08) mm, 1.19 (0.16) – 4.06 (1.05) mm, 229.78 (146.98) – 489.11 (274.28) g, and 232.98 (85.43) – 344.18 (90.37) mm. They were significantly influenced by age except D_M and D_T while oval shape was established from the dimensions indicating suitability for mechanical peeling. Mean PPW ranged from 17.36 (2.73) – 24.09 (7.32) % which showed that younger tubers have more flesh for human consumption and older tubers thick peels more useful in animal feed. Analysis of variance showed that the tuber age had a very strong influence on all the physical properties except D_M and density. Varietal influence on tuber mass, D_H, D_M and density was not statistically significant. The study established the importance of tuber age and variety as factors to be considered in the design and development of cassava processing and handling equipment for effective and efficient performance of the machines.
Keywords: Cassava, postharvest, tuber age, cassava variety, physical properties

1. Introduction

Cassava roots are considered ripe as from the age of twelve months after planting, but are often left in the ground until sixteen months in Thailand (Sriroth *et al*., 1999), up to 24 months in Nigeria (Ngendahayo & Dixon, 1998) and occasionally up to 48 months in the past before the development of improved varieties (Odigboh 1976). Although, economic reasons are cited at times, but the main reason for this practice, often time, is the problem of poor storability of cassava roots after harvesting (Ngeve 1995) whereas, its quality is sustained when left in-ground up to 24 months and beyond. Even though this common practice among cassava farmers has some advantages such as easy and flexible harvesting time, year round availability of the crop etc., one of its greatest shortcomings is that the roots become more fibrous and woody with time. Besides, previous studies have revealed the influence of age on tuber yield, dry matter and starch accumulation, culinary quality of cooked roots, as well as the quality and physico-chemical properties of the starch and flour produced from them (Moorthy & Ramanujam 1986; Ntawuruhunga *et al.* 1995; Ngeve 1995; Deflour 1995; Ngendahayo & Dixon 1998; Defloor *et al.* 1998; Sriroth *et al.* 1999; Chatakanonda *et al.* 2003; Chotineeranat *et al.* 2006; Apea-Bah *et al.* 2011;). Presumably, this factor can also be responsible for the different values of physical properties of the roots as revealed by literature search. However information on these physical and other engineering properties are scarce in literatures. Only a few publications were found on the influence of tuber age on the engineering properties of cassava roots.

In a study conducted by Obigbesan & Agboola (1973) it was reported that root size continued to increase with age even when left in the soil beyond 24 months. Ngendahayo & Dixon (1998) however concluded in their study that the increase in tuber yield when left in the ground beyond 15months was only due to production of more fibre and accumulation of water in the tubers. Only Kolawole *et al.* (2007) actually studied the influence of tuber age on the engineering properties of cassava by determining the dewatering parameters of grated cassava mash and concluded that the 15 months old samples compressed more than the 12 and 9 months old samples. However, other researchers (Odigboh 1976; Ejovo *et al.* 1988; Adetan *et al*. 2005) only observed that the tuber age might have influenced their results but they never made conscious efforts at studying the effects that age could actually

have on the engineering properties of the tubers.
Sriroth *et al.* (1999) reported that the age of root considerably influenced the starch granule size, granule structure, granule size distribution and hydration properties. The granule size distribution changed from normal to bimodal distribution with increase in tuber age, implying that the structural and functional properties of cassava tubers could be influenced by the age of the root. Apea-Bar *et al.* (2011) also reported a significant influence of tuber age on cassava flour yield, crude protein and ash content of the resulting flour reducing with time while Chotineeranat *et al.* (2006) reported that roots with different ages exhibited different levels of chemical compositions and cyanide content and thus resulted in the production of flour exhibiting different levels of cyanide contents depending on the age of the tuber used.
Ngeve (1995) investigated the cooking properties/quality of some cassava clones in Cameroon and reported that all the clones investigated would cook when harvested at the age of 8 months after planting beyond which some of them, classified as 'non-cookable', would not cook while the cooking time of the 'cookable' clones increased with increase in age of the roots. This corroborated the findings of Moorthy & Ramanujam (1986) who had earlier reported a similar observation.
Adejumo *et al.* (2011) in a review underscored the importance of detailed information such as root age and varieties, among other things, in the study of cassava starch quality as these are some of the major factors that greatly affect the quality of starch products. Also, Alagbe (2012) acknowledged the influence of tuber age on gari quality and yield, as well as the ease of peeling of the tubers,but pointed out that this is not common to all the cassava varieties.
From the foregoing, a serious death of research publications on the studies of the influence of age on the engineering properties of cassava tuber is apparent even though a lot has been reported on the effects of age on many of the properties of the starch and other by-products produced from its roots and in spite of the acknowledgement of some of the earlier researchers of a possible influence of tuber age on the engineering properties of the root. This implies that little is presently known about cassava in relation to the influence of tuber age on its engineering properties. Most of the earlier works on the engineering properties of cassava were either conducted using one cassava variety most of which were not of the same clone, or they were determined using crude methods or insufficient number of samples that cannot be said to be representative of the characteristics of the crop, hence the need for an in-depth study of the influence of age and variety on the engineering properties of the root which this paper intended to address.

2. Materials and Methods

Two improved cassava cultivars and one local cultivar namely; TMS 30572, TME 419 and *Oko iyawo* (TMS 30001) respectively were used in this study. Cuttings of the two improved cassava varieties were obtained from the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria. The cuttings of the local variety (*Oko-iyawo*) were sourced from local farmers. The three cassava varieties were selected for their popularity among cassava farmers in Nigeria especially in the south-western part of the country where IITA is located. These cuttings were used to establish an experimental farm in Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria. The farmland was divided into three portions (1 acre each) for each of the three cassava cultivars studied. A plant spacing of 1m x 1m was used. The planting was deliberately done in April so that the period of the experiment fell within the raining season.

2.1 Experimental Procedures

Determination of the engineering properties of each of the cassava varieties was done at 12, 15 and 18 Months After Planting (MAP) using fifty root samples selected randomly from the harvested lots. Whole length of one hundred and fifty (150) pieces of cleaned unpeeled tubers, fifty (50) pieces from each of the three cassava varieties were measured with the use of a (0.01mm precision) vernier caliper and tape rule and subsequently recorded. The masses of each of the above mentioned unpeeled tubers were using with an electronic weighing balance (Mettle Instrumente PJ6 (Switzerland) and subsequently recorded.
The same specimens whose lengths and weights were earlier measured (as above) were marked into three portions (head, middle and tail) and their diameters (i.e. D_H, D_M, and D_T) measured along these marked portions from the head to the tail along two perpendicular lines with a vernier caliper and the average values for the readings at each portion of the tuber were calculated. Thus, three tuber diameters were obtained for each tuber. The tubers were then cut into three slices along the marked lines. Subsequently the peels (periderm + cortex) were carefully and neatly unrolled from the flesh (without any flesh loss to the peel). The thickness of the peels unrolled from each of the slices was then measured with the caliper to obtained three values of peel thickness from each tuber [i.e. Peel thickness at the head (P_H), middle (P_M) and tail (P_T)].

2.1.1 Peel Proportion by Weight (PPW)

Freshly harvested tubers were weighed and the mass was recorded (M_1). The peels were then carefully removed as explained above. The peels from each of the tubers were then weighed (M_2) and recorded. Then the peel proportion by weight (W_β) was determined using Equation 1;

$$W_\beta = \frac{M_2}{M_1} \qquad (1)$$

2.1.2 Solid Density

Unpeeled whole tuber of cassava was weighed and recorded (M, g). It was dropped into a big cylinder of known volume which was filled to the brim with water. The displaced volume (V, cm^3) was recorded. The density was subsequently calculated using Equation 2;

$$D = \frac{M}{V} \qquad (2)$$

Fifty replications were done for each cassava variety and the data were analyzed using the two way ANOVA in SPSS 15.

3. Results and Discussion

The results of the selected physical properties determined for the tubers for the three cassava varieties at the ages of 12, 15 and 18 MAP are as presented in Tables 1, 3 and 5

3.1 Physical Properties of TMS 30572 Cultivar

The mean tuber length, diameter at the head (D_H), middle (D_M) and tail (D_T) portions of the tubers and other physical properties determined for the TMS 30572 cultivar at the ages of 12, 15 and 18 MAP are as presented in Table 1.

The length and diameter were highest at the age of 15 months. The lowest mean length of 288.02mm was, however, obtained at 18 months while the lowest values for diameter were obtained at the age of 12 months after planting. This tends to suggest that the tubers were still growing up to 15 months while shrinkage occurred towards 18 months. This may be due to the on-set of dry season (October) which resulted into loss of moisture from the tubers at the time the crop was 18 months old as pointed out by Prapapan *et al.* (2008) that molecular processes underlying root and starch physiology may be affected by prevailing environmental conditions at the time of harvest. The lengths were however, in good agreement with the mean value (316.6mm) reported by (Ejovo *et al*. 1988), especially at the age of 15 months old, but higher than the mean length (228mm) reported by Adetan *et al.* (2003). The mean diameter reported by Adetan *et al*. (2003) was, slightly higher (46.2mm) even though the TMS 30572 cassava variety (18 months old) was one of the two varieties used in their experiments. The variations may be due to the fact that growth and development of the root are a function of climatic conditions and soil type (Odigboh 1976; Santisopasri *et al.* 2001) and that their tubers were probably harvested in the raining season. The D_M values were the highest (except at 12MAP) while the D_T values were the least implying that the roots of the TMS 30572 cultivar were not conical as those of Ejovo *et al.* (1988) but elongated ovoid in shape as described by Odigboh (1976).

The average peel thicknesses were 1.36, 1.33, and 1.22 mm at the head (P_H), middle (P_M) and tail (P_T) respectively for 12 MAP, 3.13, 2.87, and 2.03 mm for 15 MAP and 3.69, 3.27 and 2.58 mm respectively for 18 MAP. This implies that the peel thickness increased with the age of the tubers just like the diameter and length. On the other hand the density decreased with age from 1.07 g/cm^3 at 12MAP down to 0.81 g/cm^3 at 18 MAP (Table 1). The peel proportion by weight (PPW) reduced from 17.89% at 12months old to 17.74% at the age of 15 months and increased slightly to 18.54% as it approached the age of 18 months. This is an indication that the optimum age at which more flesh but less peel can be obtained from the root is 15 MAP, while more peel percentage could be obtained at 12 MAP, depending on the proposed end use (either for human consumption or animal feeds). The range of PPW is in reasonable agreement with the range (20-35%) reported by Ekundayo (1980) and the mean values were also in good agreement with the_values of peel proportion by weight (10.6-21.5%) reported by Adetan *et al.* (2003).

The results of the analysis of variance of the physical properties of this cassava cultivar are as presented in Table 2. The influence of age on the tuber length, the D_H, D_T and PPW was not statistically significant ($p>0.05$). It was, however significant on D_M, P_H, P_M, and P_T with the mean of the D_M of the 15 and 18 months old tubers being homogenous.

Table 1: MEANS OF PHYSICAL PROPERTIES OF TMS 30572 CASSAVA VARIETY

	12 months				15 months				18 months			
PARAMETERS	**Min**	**Max**	**Mean**	**S.D**	**Min**	**Max**	**Mean**	**S.D**	**Min**	**Max**	**Mean**	**S.D**
Length (mm)	90	500	295.64	94.31	140	520	324.36	85.12	120	644	288.02	91.18
Diameter												
Head (mm)	20.80	60.80	38.33	7.44	24.5	58.5	42.00	9.19	17.90	69.50	41.87	11.94
Middle (mm)	16.10	57.00	38.06	8.10	28.40	59.50	45.58	7.68	21.00	70.00	43.80	13.10
Tail (mm)	15.00	46.80	30.28	6.57	18.30	45.50	33.87	7.93	13.30	55.50	33.87	10.30
Peel Thickness												
Head (mm)	1.02	2.73	1.36	0.36	1.50	4.50	3.13	0.66	1.50	5.40	3.69	0.86
Middle (mm)	0.90	3.30	1.33	0.42	1.50	4.20	2.87	0.64	2.10	5.00	3.27	0.85
Tail (mm)	0.60	2.24	1.22	0.23	1.10	3.40	2.03	0.52	1.30	3.50	2.58	0.56
Mass (g)	59	722	298.12	148.34	128.8	979.3	486.99	204.00	131.9	920.5	478.11	239.41
Volume (cm^3)	92	546	290.64	155.59	180	910	483.50	200.98	210	1020	572.40	227.75
Density (g/cm^3)	0.12	1.67	1.07	0.27	0.44	1.89	1.04	0.26	0.52	1.34	0.81	0.15
PPW (%)	5.07.	32.91	17.89	3.65	7.56	33.99	17.74	5.29	8.07	27.11	18.54	4.37

Table 2: Analysis of Variance of Influence of Age on TMS 30572 Cassava Cultivar

		Sum of Squares	df	Mean Square	F	Sig.
Length (mm)	Between Groups	36724.973	2	18362.487	2.253	.109
	Within Groups	1198172.020	147	8150.830		
Mass (g)	Between Groups	1135762.709	2	567881.355	14.087	.000
	Within Groups	5925862.213	147	40311.988		
PPW (%)	Between Groups	18.064	2	9.032	.449	.639
	Within Groups	2956.416	147	20.112		
Volume (cm^3)	Between Groups	2056785.453	2	1028392.727	25.721	.000
	Within Groups	5877330.340	147	39981.839		
D_H (mm)	Between Groups	434.332	2	217.166	2.308	.103
	Within Groups	13830.442	147	94.085		
D_M (mm)	Between Groups	1546.301	2	773.151	7.835	.001
	Within Groups	14505.296	147	98.675		
D_T (mm)	Between Groups	430.322	2	215.161	3.042	.051
	Within Groups	10398.857	147	70.741		
P_H (mm)	Between Groups	148.968	2	74.484	171.318	.000
	Within Groups	63.911	147	.435		
P_M (mm)	Between Groups	104.927	2	52.463	120.075	.000
	Within Groups	64.227	147	.437		
P_T (mm)	Between Groups	46.198	2	23.099	108.156	.000
	Within Groups	31.395	147	.214		
Density (g/cm^3)	Between Groups	1.923	2	.961	17.343	.000
	Within Groups	8.148	147	.055		

3.2 Physical Properties of TME 419 Cassava Cultivar

Results of the engineering properties studied for the tubers of the TME 419 cultivars are presented in Table 3. It was observed that the two improved cassava varieties (TMS 30572 and TME 419) exhibited almost the same physical properties within the study period. For instance, the length and diameter were very close except that TME 419 variety were generally slightly longer while the TMS 30572 tubers were just slightly bigger (in diameter) and heavier. This may be due to the fact that they were cloned from the same institute and probably from similar cassava parent varieties (Alves 2002). The percentage of peel by weight of the TME 419 cultivar was generally higher than those of the TMS 30572 (Tables 1 and 3), indicating that the TME 419 cassava varieties may be more suited for livestock feed production while TMS 30572 is more suited for human consumption since less peel and more flesh could be obtained from its tubers. Statistical analysis for the TME 419 cultivar presented in Table 4 showed that the influence of age on P_H, P_M and the P_T was highly significant ($p<0.05$) even though the peel thicknesses of the 15 and 18 months old tubers were homogenous. However, the influence of age on the tuber length, D_H, D_M, D_T and the density of tubers was not statistically significant.

3.3 Physical Properties of *Oko iyawo* (TMS 30001) Cassava Cultivar

Results of the physical properties determined for the local cassava cultivar (*Oko iyawo*) are presented in Table 5 where the length and diameter of the tubers were found to be highest at the age of 18 months and lowest at 12 months. This is an indication that the tubers continued to grow and develop throughout the study period unlike the improved varieties whose sizes have started depreciating at 18 months. This fact was corroborated by the good physical appearance and healthy state of the slices cut out of the 18 months old tubers of the *oko iyawo* cultivar during experimentation while the other two (improved) varieties have started showing signs of spoilage. The values were however, in good agreement with the root length of 316 mm reported by Ejovo *et al*. (1988) (Table 7), especially at 18 MAP. This is probably due to the fact that a local cassava cultivar harvested at about the same age (18-20 months) was also used for the study.

Table 3: MEANS OF PHYSICAL PROPERTIES OF TME 419 CASSAVA VARIETY

	12months				15 months				18 months			
PARAMETERS	**Min**	**Max**	**Mean**	**S.D**	**Min**	**Max**	**Mean**	**S.D**	**Min**	**Max**	**Mean**	**S.D**
Length (mm)	147	520	300.08	93.07	190	640	344.18	90.37	120	520	320.90	106.24
Diameter												
Head (mm)	16.80	55.30	36.67	8.76	23.20	66.80	41.07	10.26	17.00	65.00	39.05	10.81
Middle (mm)	14.4o	59.20	38.32	9.67	23.90	66.00	39.00	10.29	19.40	65.50	40.10	11.14
Tail (mm)	11.00	48.80	29.27	8.59	14.40	46.70	28.66	8.97	12.00	52.00	27.29	9.66
Peel Thickness												
Head (mm)	1.06	2.26	1.37	0.32	1.60	4.00	2.74	0.51	1.50	4.50	2.78	0.65
Middle (mm)	1.02	2.18	1.38	0.29	1.50	3.70	2.56	0.47	1.50	4.20	2.70	0.66
Tail (mm)	1.00	2.08	1.19	0.16	1.30	3.50	2.22	0.46	1.20	3.40	2.18	0.58
Mass (g)	20.18	670.09	262.65	143.44	65.8	1500	459.25	268.15	84.10	982.90	483.48	245.22
Volume (cm^3)	25	604	286.24	141.56	125	1200	473.32	221.85	158	990	480.17	206.60
Density (g/cm^3)	0.44	1.67	0.90	0.18	0.54	1.65	0.97	0.26	0.36	1.96	1.01	0.33
PPW (%)	3.36	42.28	18.81	6.92	4.02	58.34	24.09	7.32	13.99	30.99	21.05	3.67

Table 4: Analysis of Variance of Influence of Age on TME 419 Cassava Cultivar

		Sum of Squares	df	Mean Square	F	Sig.
Length (mm)	Between Groups	48670.680	2	24335.340	2.597	.078
	Within Groups	1377661.560	147	9371.847		
Mass (g)	Between Groups	1466784.107	2	733392.053	14.417	.000
	Within Groups	7478086.925	147	50871.340		
PPW (%)	Between Groups	701.252	2	350.626	9.157	.000
	Within Groups	5628.580	147	38.290		
Volume (cm^3)	Between Groups	1253758.493	2	626879.247	16.365	.000
	Within Groups	5631055.780	147	38306.502		
D_H (mm)	Between Groups	485.129	2	242.564	2.436	.091
	Within Groups	14638.314	147	99.580		
D_M (mm)	Between Groups	80.460	2	40.230	.373	.689
	Within Groups	15855.273	147	107.859		
D_T (mm)	Between Groups	103.200	2	51.600	.625	.537
	Within Groups	12135.544	147	82.555		
P_H (mm)	Between Groups	64.177	2	32.088	121.521	.000
	Within Groups	38.816	147	.264		
P_M (mm)	Between Groups	52.452	2	26.226	106.531	.000
	Within Groups	36.189	147	.246		
P_T (mm)	Between Groups	33.886	2	16.943	88.553	.000
	Within Groups	28.126	147	.191		
Density (g/cm^3)	Between Groups	.303	2	.152	2.147	.120
	Within Groups	10.381	147	.071		

However, the mean length values were higher than the 228 mm reported by Adetan *et al.* (2003), but the mean diameter at the middle were very close (45.20 mm) especially for the 18 MAP old root samples although the mean diameter at the head in the two studies were considerably different probably due to varietal differences. Also, D_H was generally highest while D_T values were the least except at 18 MAP when the D_M was greater than the D_H implying that the roots of the local cassava variety were conical in shape (Odigboh 1976), especially when they are less than 18months old. The peel thicknesses were found to increase with the age, as well as diameter of the tubers just like those of the improved varieties, while the density decreased up to 15MAP and later increased towards the age of 18 MAP where the highest value was obtained (Table 5). The average peel thickness which ranged from 4.06 – 4.60 mm for 18 MAP roots were observed to be higher than the range of average values of 1.9-2.8 mm reported by Ejovo *et al.* (1988) (Table 8) and the 2.21 mm reported by Adetan *et al*. (2003) for roots of the same age bracket (Table 9). The values of the peel proportion by weight were within the range of 10-21.5% reported by Adetan *et al.* (2003). The peel proportion by weight increased from 12 to 15 months and decreased slightly as it approached the age of 18 months but were generally lower than those of TME 419, hence, less suitable for feed production than TME 419. Statistical analysis showed that the length, D_T, and D_M of the 12 and 15 months old tubers was homogeneous whereas those of the 18 months old were distinctively different from the younger ones and the influence of age on all the parameters studied was significant ($p<0.05$) (Table 6). The results of the Analysis of Variance (ANOVA) conducted for this cultivar showed that the influence of age on all the studied parameters were statistically significant ($P< 0.05$), except D_H (Table 4.).

In the overall, when the randomized two way ANOVA was conducted across the varietal divides, all the parameters studied were found to be significantly influenced by age except D_M and D_T whereas only D_H, P_M, and mass were not significantly influenced by varietal differences.

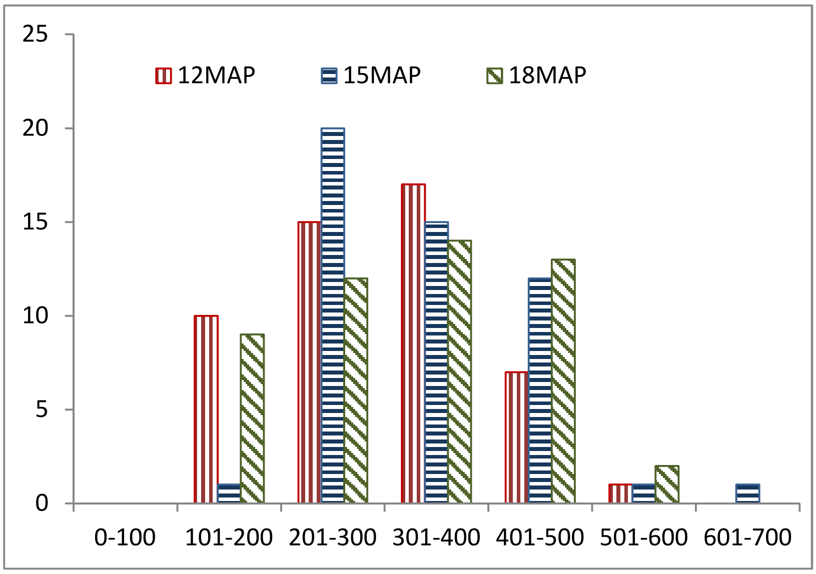
Table 5: MEANS OF PHYSICAL PROPERTIES OF *OKO IYAWO* CASSAVA VARIETY

	12 months				15 months				18 MONTHS			
PARAMETERS	**Min**	**Max**	**Mean**	**S.D**	**Min**	**Max**	**Mean**	**S.D**	**Min**	**Max**	**Mean**	**S.D**
Length (mm)	40	435	232.98	85.43	110	500	263.90	84.35.	100	620	320.14	95.42
Diameter												
Head (mm)	14.90	63.50	38.98	10.48	15.00	70.00	37.30	15.51	23.50	67.50	43.32	11.53
Middle (mm)	22.00	61.90	38.66	9.21	17.50	76.00	35.26	15.77	21.50	71.50	45.20	11.24
Tail (mm)	10.90	42.95	27.77	7.02	12.10	66.80	26.06	12.94	12.50	65.50	33.80	11.55
Peel Thickness												
Head (mm)	1.02	2.24	1.30	0.25	1.50	8.80	3.91	2.33	1.50	5.90	4.60	1.13
Middle (mm)	1.01	2.33	1.23	0.23	1.30	5.90	3.22	1.43	1.60	5.90	4.52	1.08
Tail (mm)	1.00	2.61	1.26	0.31	0.41	5.90	2.91	1.34	1.30	5.30	4.06	1.05
Mass (g)	41	671	229.78	146.98	64	1480	441.10	302.82	68.40	1560.80	489.11	274.28
Volume (cm^3)	50	615	226.02	131.00	70	930	464.90	217.37	72	1250	439.50	219.52
Density (g/cm^3)	0.69	2.61	1.02	0.31	0.58	1.80	0.91	0.29	0.15	2.16	1.14	0.35
PPW (%)	12.07	24.39	17.36	2.73	12.80	38.13	21.30	5.50	12.86	36.74	20.67	5.00

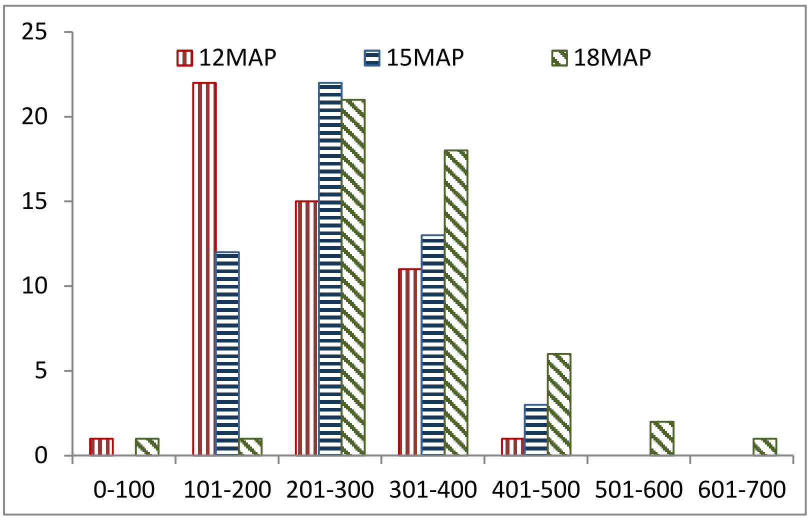
Table 6: Analysis of Variance of Influence of Age on *Oko Iyawo* Cassava Cultivar

		Sum of Squares	df	Mean Square	F	Sig.
Length (mm)	Between Groups	195264.160	2	97632.080	12.455	.000
	Within Groups	1152333.500	147	7839.003		
Mass (g)	Between Groups	1903593.503	2	951796.751	15.146	.000
	Within Groups	9237967.440	147	62843.316		
PPW (%)	Between Groups	448.780	2	224.390	10.731	.000
	Within Groups	3073.890	147	20.911		
Volume (cm^3)	Between Groups	1721375.413	2	860687.707	22.472	.000
	Within Groups	5630077.980	147	38299.850		
D_H (mm)	Between Groups	963.770	2	481.885	2.990	.053
	Within Groups	23688.253	147	161.145		
	Total	24652.023	149			
D_M (mm)	Between Groups	2554.661	2	1277.330	8.331	.000
	Within Groups	22538.061	147	153.320		
D_T (mm)	Between Groups	1652.807	2	826.404	7.078	.001
	Within Groups	17162.529	147	116.752		
P_H (mm)	Between Groups	303.305	2	151.653	67.412	.000
	Within Groups	330.696	147	2.250		
P_M (mm)	Between Groups	275.299	2	137.649	126.642	.000
	Within Groups	159.777	147	1.087		
P_T (mm)	Between Groups	198.298	2	99.149	98.699	.000
	Within Groups	147.670	147	1.005		
Density (g/cm^3)	Between Groups	1.307	2	.653	6.380	.002
	Within Groups	15.055	147	.102		

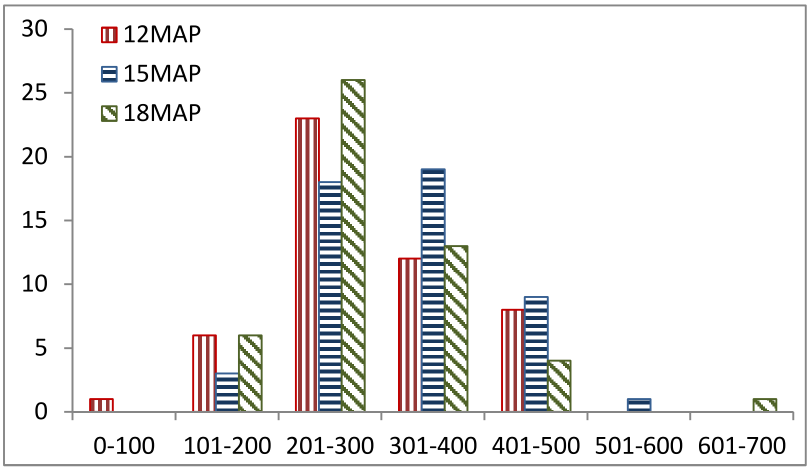
The skewness and kurtosis analysis for the frequency distribution curve for the 50 readings taken for each dimension are shown in Fig. 4 (a – c). The curves show near to normal distribution for the length with the peaks being around the means which agrees with earlier results by Ige (1977) for five varieties of cowpea, Irtwange and Igbeka (2002) for two African yam bean accessions and Taser *et al.* (2005) for vetch seed and Akaaimo & Raji (2006) for *Prosopis Africana* seeds. This is an indication that the axial dimensions are relatively uniform and these are useful information in the design of separation and size reduction systems. Skewness characterises the degree of symmetry of a distribution around its mean. Positive skewness indicates a distribution with an asymmetric tail extending towards more positive values (skewed to the right) and vice versa for negative. Kurtosis characterises the relative peakedness or flatness of a distribution compared to normal distribution (Table 7).



a



b



c

Figure 1: Distribution of length (mm) for (a) TME 419 (b) TME 3001 (*Oko iyawo*) and (c) TMS 30572

Table 7: Level of Statistical Distribution of Length and D_H

LENGTH	419-12MAP	419-15MAP	419-18MAP	3001-12MAP	3001-15MAP	3001-18MAP	30572-12MAP	30572-15MAP	30572-18MAP
Kurtosis	-0.892	0.813	-0.872	-0.445	0.400	1.395	-0.422	-0.049	4.185
Skewness	0.145	0.845	-0.093	0.318	0.473	0.712	0.232	0.187	1.556
D_H									
Kurtosis	-0.237	-0.421	-0.260	0.813	-0.422	-0.427	0.823	-1.045	-0.003
Skewness	-0.291	0.483	-0.026	-0.642	0.798	0.511	0.393	-0.229	0.510

4. Conclusions

The study has established that the age of cassava root is an important factor influencing the physical properties of cassava root and thus must be given a serious attention in the design and development of cassava processing, handling, packaging and transportation equipment. Also, the two improved cassava cultivars used in this study have displayed no significant difference in most of their physical properties, hence the data for one of them can be used for the other but there is a considerable difference in the physical properties of the roots of the improved cassava varieties and their local counterpart which suggest that some cassava processing and handling machines may need to be variety-specific in their design and development for effective and efficient performance.

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