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Research Article

Investigation of Some Physical Properties of Two Varieties of Sweet Potato (*Ipomoea batatas* (L.) Lam)

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ABSTRACT

Physical properties of agricultural materials are essential in the development of machineries, equipment and devices. In this research, forty sample each of two unique varieties namely Jewel-orange flesh sweet potatoes (JOFSP) and Oriental-purple flesh sweet potatoes (OPFSP) physical properties were determined using standard methods and equations. The results show that JOFSP gave the mean length (110.68±24.59 mm), width(61.40±8.09 mm), geometric mean (39.72±8.19 mm), volume (187.78±73.85 ml), surface area (4950.00±203.32 mm^2) and roundness (1.81±0.50) which were of higher values compared to that of OPFSP which gave the length (68.46±10.16 mm), width (59.32±5.82 mm), geometric mean (36.32±3.90 mm), volume (137.83±10.97 ml), surface area (4320.20±98.00 mm^2) and roundness (1.41±0.30) respectively. JOFSP gave moisture content, thickness, mass, sphericity and true density of 58.00±10.17 %, 37.60±7.17 mm, 202.87±65.12 g, 0.35±0.08, and 1.17±0.27 g cm^{-3} which were of lower values compared to that of OPFSP which gave 79.32±3.84 %, 45.94±9.04 mm, 271.87±15.72 g, 0.53±0.08, and 1.89±0.14 g cm^{-3} for OPFSP respectively. The mean of the angle of repose and the static coefficient of friction considered for the three-separate surfaces namely plywood (9.35±2.87°, 0.17±0.05), stainless steel (8.50±3.50°,0.15±0.05) and galvanized steel (8.30±3.20°) of lower values for JOFSP compared to that of plywood which gave (11.80±2.25°, 0.21±0.04), stainless steel (9.90±2.02°, 0.19±0.05), galvanized steel (10.90±2.28°) for OPFSP while the coefficient static of friction of stainless steel for JOFSP gave a higher value of 0.20±0.13 compared to that of 0.17±0.04 for OPFSP respectively. These findings provide engineers with valuable information for designing different handling, grading, and drying systems for industrial processing.

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INTRODUCTION

Ipomoea batatas (sweet potato) is ranked amongst the root and underground stem crops of the flora and fauna, the seventh utmost precious sustenance produces, and following to cassava (Ray and Ravi, 2005). Bulkiness, storage problems, transportation, and fairly low-slung money worth for every piece of weight have led to an actual little level of significance in foreign jobs. According to Naskar *et al.* (2008), sweet potato is expected to lead in the fight against food shortages and the resultant malnutrition that may likely occur due to population explosion and the attendant over usage of land. In a unit area and in a unit duration, it can generate a high number of calories. Sweet potato efficiency of production of consumable energy is outstanding in the developing countries (Ramesh and Tomlins, 2010).

Fresh roots and tubers must be converted to non-perishable commodities through processing operations to reduce post-harvest losses (Oluwamukomi and Akinsola, 2015). According to Balami *et al.* (2012), the ever-growing significance of farming crops, along with the intricacy of recent expertise used intended for their making, handing out and storing, demands a clear understanding of their engineering possessions.

It is important to comprehend the physical regulations governing the reaction of farming crops consequently that equipment, methods and supervision processes can be strategic meant for optimum productivity in addition to the best standards of last harvests (Mohsenin, 2010). Over the years most agricultural produce has been underexploited in their region of production especially in unindustrialized nations. The various current sweet potato uses to make it important to evaluate the engineering properties of this highly valued agricultural commodity in order to carry out a more elaborate study to recognize and locate more areas of sweet potato value. The most important criteria for deciding the appropriate type of development of sorting, conveying, processing and packaging systems are the physical features of farming products, according to Tabatabaeefar and Rajabipour (2005).

Knowledge of engineering properties of food materials such as specific heat energy, density, thermal diffusivity, and thermal conductivity are relevant not only since they are significant, but because other properties and characteristics are the most common indicators (Oke *et al.*, 2007). Density, size, and drag coefficients all have a role in determining an object's terminal velocity in a fluid (Isik and Unal, 2007). According to Kachru et al. (1994), determining the physical properties of biomaterials (such as sweet potato) is critical for the right design of equipment for sweet potato handling, transporting, separation, drying, aeration, and mechanical expression. Textural measurement of unprocessed and processed food materials; reduction of mechanical damage to agricultural produce during postharvest handling, processing, and storage; and determination of design parameters for harvesting and postharvest systems are all goals of determining engineering properties of biomaterials under static or dynamic loading (Anazodo, 1983).

The scarcity or inaccessibility of sweet potato processing and preservation machinery and equipment may be attributable to the lack or inaccessibility of data on the engineering properties of sweet potatoes essential for machine development. The objective of the study was to determine the selected physical properties of two varieties of sweet potato that are considered to be critical in the development of devices, equipment and agricultural machinery for harvesting, handling, conveying, separation, processing, dehydration, size reduction and packaging.

MATERIALS AND METHODS

Two types of sweet potato (*Ipomoea batatas*) are the agricultural crops used to determine these physical properties: jewel-orange flesh and oriental-purple flesh. The specimens were obtained from Oja Oba market Akure, Ondo State. Forty (40) pieces from each of the two varieties were used for the experiment.

Determination of cassava tubers' physical properties

Sweet potato physical properties with Jewel's average moisture content of 58.00% (orange flesh) and 79.32% for Oriental (purple flesh) were determined as shown in Table 1.

Statistical analysis

Excel was used to compute the raw data and analyzed. Models were developed using Linear Regression. IBM SPSS (Statistical Package for Social Science) Windows Statistics, Version 21.0 was utilized to analyze the data produced from the analysis for specific physical properties (IBM SPSS, 2012).

Table 1. Determination of sweet potato physical properties.

Property	Method or equation for determining physical properties	Reference
MC	The moisture content of sample was determined by oven drying (100±2° C) method until constant weight was reached. MC (% wb) $= \frac{Wi-Wf}{Wi} \times 100$	Kashaninejad *et al.* (2003)
L (mm)	Measuring tape	Olukunle and Akinnuli (2012)
W (mm)	Digital vernier caliper	Olukunle and Akinnuli (2012)
T (mm)	Measuring three different segments of the sweet potatoes using digital vernier caliper.	Olukunle and Akinnuli (2012)
D_g (mm)	$D_g = (LWT)^{1/3}$	Ozguven and Vursavus (2005) Akaaimo and Raji (2006)
S_a (mm^2)	$S_a = \pi D_g^{\ 2}$	Yalcin *et al.* (2007); Olukunle and Akinnuli (2012)
S_p (mm)	$S_p = \frac{(LWT)^{1/3}}{L}$ 100%	Yalcin *et al.* (2007); Olukunle and Akinnuli (2012)
R_o	$R_o = \frac{A_P}{A_C}$	Yalcin *et al.* (2007); Olukunle and Akinnuli (2012)
α (^{0})	The apparatus consisting of a plywood box with a fixed stand attached with a protractor and an adjustable plate at the surface. The sweet potatoes were placed on the adjustable surface and allowed to incline gradually in order for the tuber to follow and assume a natural slope.	Tabatabaeefar (2003)
μ (^{0})	$\mu = \tan \alpha$	Yalcin *et al.* (2007); Olukunle and Akinnuli (2012)
M (g)	A digital weighing balance of 10 kg was used in weighing each of the sweet potatoes.	Yalcin et al. (2007); Olukunle and Akinnuli (2012)
V_t (cm^3)	By putting a known mass of a (unit) sample into a cylindrical container of water, a change in level of the liquid in the cylinder gives the unit volume.	Ozguven and Vursavus (2005)
ρ_t (g cm^{-3})	$\rho_t = \frac{W_t}{V_t}$	Akaaimo and Raji (2006); Yalcin *et al.* (2007)
ρ_b (g cm^{-3})	$\rho_b = \frac{W_s}{V_s}$	Akaaimo and Raji (2006), Yalcin *et al.* (2007), Zwedu and Solomon, (2007)
Ws (g)	By weighing together all the sweet potatoes in a bucket.	Olukunle and Akinnuli (2012)
vs (cm^3)	The whole sample in a stand was put into the cylindrical container of water, and the change in level of the liquid in the cylinder	Ozguven and Vursavus (2005)
ε	$\varepsilon = (1 - \frac{\rho_b}{\rho_t}) \times 100$	Akaaimo and Raji (2006)

RESULTS AND DISCUSSION

The length, width, thickness and geometric mean diameter

The physical property outcomes are presented in Tables 2 and 3. The mean and standard deviation of the length (L), width (W), thickness (T) and geometric mean diameter (D_g) of Jewel and Oriental were found as 110.68±24.59 mm, 61.40±8.09 mm, 37.6±7.17 mm, 39.72±8.19 mm and 68.46±10.16 mm, 59.32±5.82 mm, 45.94±9.04 mm, 36.32±3.90 mm at the 58.00 % and 79.32 % moisture contents correspondingly. The mean length and width of the Jewel and Oriental varieties were marginally higher, while the small diameters were lower in the Norchip potato variety than what was observed by McClure and Morrow (1987). The width, thickness, and geometric mean diameter (size) were greater in Jewel than Oriental for these moisture contents. The main diameter (length) was, however, higher in Oriental than in Jewel. The maximum ratio is shown by L/T in Jewel, followed by L/W and L/D_g. The size values (D_g) are usually the lowest, followed by W and T in Jewel. A comparable pattern in groundnut Bambara was recorded by Baryeh (2001). L/W, however, indicates the highest ratio in Oriental, followed by L/T, and L/D_g suggests that D_g is usually the highest, followed by T and W in Oriental. Baryeh (2001) reported the ratio for Bambara groundnut which was lower than the ratios obtained from this study.

Mass of root

The average and standard deviations were 202.87±65.13 g and 272.91±14.51 g respectively for the unit root mass of Jewel and Oriental ipomoea batatas varieties respectively. The individual root masses are normally higher than the Jewel in the Oriental (Tables 2 and 3). Since the Oriental had a higher moisture content than Jewel's, this was not surprising. These variations may be due to the different configurations of cells and the fact that weight is influenced by moisture. It has been reported that the mass of cocoa bean increases as the moisture content increases (Bart-Plange and Baryeh, 2003).

Surface Area

Surface area of the Jewel ipomoea batatas variety was greater than that of the Oriental, showing a mean value of 4950.00±203.32 mm² to 4320.20±98.00 mm², respectively, as shown in Tables 2 and 3.

The bulk volume

The experimental bulk volume was found to be 7511 ml for Jewel and 5513 ml for the Oriental variety of sweet potato the standard volume of the roots. The Jewel and Oriental average volumes, which could be utilized in designing storage and packaging structures, are 187.78±73.85 ml and 137.83±39.32 ml, respectively (Tables 2 and 3). With a rise in moisture, the volume increased linearly. In equation 1, the relationship between the volumes and the content of moisture is presented. Obviously, the increase in volume is due to the rise in the moisture content.

$$V = 0.175MC + 3.905 \ (R^2 = 0.866) \quad (1)$$

The sphericity

Tables 2 and 3 revealed that the sphericity for jewel was 0.35±0.08 at an average moisture content of 58.00±10.17% moisture content while that of Oriental was 0.53±0.08 at 79.32±3.84% moisture content. The sphericity decreased as the moisture content decrease and increased as the moisture increases as shown in JOFSP with lower moisture content of content of 58.00±10.17 % and of OPFSP with higher moisture content of 79.32±3.84%. Deshpande et al. (1993) reported that as the moisture content increases the soybean sphericity also increases.

Table 2. Selected physical properties of Jewel-orange flesh sweet potato (JOFSP) samples.

S/N	Measured parameters	Unit	Maximum value	Minimum value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Moisture content	%	87.00	41.18	58.00	10.17	18
2	Length	mm	170.08	60.89	110.68	24.59	22.21
3	Width	mm	89.08	30.20	61.40	8.09	11.52
4	Thickness	mm	55.75	24.06	37.60	7.17	19.06
5	Geometric mean diameter	mm	52.75	25.59	39.72	8.19	20.61
6	Mass	g	371.00	80.00	202.87	65.13	32.10
7	Volume	ml	500.00	75.00	187.78	73.85	39.32
8	Spericity		0.57	0.24	0.35	0.08	196.00
9	True density	g cm^{-3}	1.89	0.74	1.17	0.27	23.07
10	Surface area	mm^2	8709.69	2215.36	4950.00	203.32	4.10
11	Roundness		2.90	1.07	1.81	0.50	27.62
12	Bulk volume	ml			7511.00		
13	Bulk mass	g			7333.74		
14	Bulk density	kgm^{-3}			114.90		
15	Porosity	%			0.9764		
16	500-Root weight	kg			202.80		

Table 3. Selected physical properties of oriental-purple flesh sweet potato (OPFSP) samples.

S/N	Measured parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Moisture content	%	82.29	66.70	79.32	3.84	5
2	Length	mm	88.60	54.26	68.46	10.16	14.84
3	Width	mm	82.28	29.00	59.32	5.82	12.91
4	Thickness	mm	60.00	25.10	45.94	9.04	19.67
5	Geometric mean diameter	mm	44.48	30.15	36.32	3.90	10.73
6	Mass	g	281.63	225.00	272.91	14.51	5.31
7	weight	g	281.90	225.00	271.87	15.72	6
8	Volume	ml	156.00	120.00	137.83	10.97	16.72
9	Sphericity		0.68	0.36	0.53	0.08	15.09
10	True density	g cm^{-3}	2.17	1.60	1.89	0.14	7.40
11	Surface area	mm^2	6663.5	2905.62	4320.20	98.00	22.68
12	Roundness		2.00	1.00	1.41	0.30	21.27
13	Bulk volume	ml			5513		
14	Bulk mass	g			5368.61		
15	Bulk density	kgm^{-3}			171.00		
16	Porosity	%			0.97381		
17	500-Root weight	kg			272.91		

The densities of the root and bulk

For Jewel and Oriental, the mean root densities were 1.17±0.27 g cm^{-3} and 1.89±0.14 g cm^{-3} at 58 and 80 percent moisture content, respectively. 114.9 kg m^{-3} and 171 kg m^{-3} were the corresponding bulk densities. The recorded densities of particles and bulk suggested that the Oriental sweet potatoes were higher than that of Jewel. The values of bulk densities obtained conform with that of apple with a bulk density of 577 kg m^{-3} (Tables 2 and 3). An increase in moisture content from 58 percent in Jewel to 80 percent in Oriental led to increase in the densities. The true density increases as the moisture content increase but the moisture content had a little impact on the true density as indicated in Equation 2.

$$\rho_t = -0.004\,MC^2 + 0.051MC + 1.073 \qquad (2)$$

Equation 3 showed that as the bulk density increases the moisture content increase but the moisture content had a little impact on the bulk density.

$$\rho_b = -0.005MC^2 + 0.069MC + 0.937, \qquad R^2 = 0.872 \qquad (3)$$

Researchers had reported that the bulk densities of seeds such as Bambara groundnut, pumpkin and karinga increases as the moisture content increases. On the other hand, seeds like sunflower, cumin and soybeans densities decreases as the moisture content increase (Deshpande *et al.*, 1993; Joshi *et al.*, 1993; Singh and Goswami, 1996; Suthar and Das, 1996; Baryeh, 2001). The variations recorded as the moisture increases may be due to the composition of the cells and the features of different grains, roots, and seeds increasing in volume and mass.

Porosity

The porosity of Jewel sweet potato was 0.9764 while that of Oriental sweet potato was 0.97381 (Tables 2 and 3 respectively). Jewel porosity is significantly higher than Oriental porosity. This shows that from a moisture content of 58 percent in Oriental to 80 percent in Jewel, the porosity increased. The porosity values mean that the air spaces between the Oriental are greater than the Jewel variety when the roots of the two varieties are put in a jar. The documented values are consistent with the porosity of grains and seeds (wheat, sorghum, soybeans, and shelled maize) which had porosity ranging from 39-48% (Thompson and Isaac, 1967). The variation is not significant, as found in these grains and seeds.

The weight of the 500-root

Tables 2 and 3 showed that, for the Jewel and Oriental, the 500-Root weight was 202.80 kg and 272.91 kg respectively. On average, the Oriental variety's 500-tuber weight was heavier at 80% and 58% moisture content, respectively, than the Jewel variety. The Oriental had a larger amount of moisture than the Jewel. These variations may be due to the different configurations of cells and the fact that weight is influenced by moisture. Bart-Plange and Baryeh (2003) reported that the mass of cocoa bean increases as the moisture content increases.

The repose angle

In Jewel, the angle of repose was reported to be 9.35±2.87° (plywood), 8.50±3.50° (stainless steel), 8.30±3.20° (galvanized steel), and in Oriental 11.80±2.25° (plywood), 9.90±2.02° (stainless steel), 10.90±2.28° (galvanized steel) as reported in Tables 4 and 5 respectively. A low angle of repose allows the roots to spread broader on a flat surface related to a high angle of rest. A low angle of repose is usually chosen during belt conveying, whereas a high angle of repose is often chosen when unloading to a horizontal surface. This means that the Jewel sweet potato spreads wider than the

Oriental as it forms a natural heap. The resting angle of several grains rises from 19.80 at 5 percent moisture content to 23.50 at 20 percent grain moisture content and then decreases gently to 210 at 35 percent moisture content (Baryeh, 2001). The small change in the root angle of repose may be due to the variations in the surface roughness of the two sweet potato types.

Table 4. Angle of repose of Jewel-orange flesh sweet potato (JOFSP) samples

S/N	Measured parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Plywood	$(^0)$	16	6	9.35	2.87	31
2	Stainless Steel	$(^0)$	15	3	8.5	3.50	41
3	Galvanized Steel	$(^0)$	15	5	8.3	3.20	39

Table 5. Angle of repose of oriental-purple flesh sweet potato (OPFSP) samples

S/N	Measured parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Plywood	$(^0)$	15	9	11.80	2.25	19
2	Stainless Steel	$(^0)$	13	7	9.90	2.02	20
3	Galvanized Steel	$(^0)$	15	8	10.9	2.28	21

The friction coefficient

The static coefficient of friction of the moisture content considered for the three separate structural surfaces of plywood, stainless steel, and galvanized steel gave 0.21±0.04, 0.17±0.04, 0.19±0.05 for Oriental and 0.17±0.05, 0.20±0.04, 0.15±0.04 for Jewel as reported in Tables 6 and 7 respectively. For plywood and galvanized steel, the coefficient of friction values was more in Oriental but less for stainless steel in Jewel. The highest was recorded by plywood. This pattern could be ascribed to the purity of the materials and the better polished surface. As they slip on them, the roots may also stick to certain surfaces. Various researchers had reported that the coefficient of friction on plywood was greater than of galvanized iron for millet and guna seeds (Aviara *et al.*, 1999; Baryeh, 2000). To improve the discharging process, however, discharging requires less friction. This is helpful in determining the sieve hole's diameter.

Table 6. The coefficient of friction of Jewel-orange flesh sweet potato (JOFSP) samples

S/N	Measured parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Plywood		0.29	0.11	0.17	0.05	32
2	Stainless Steel		0.52	0.08	0.20	0.13	64
3	Galvanized Steel		0.27	0.09	0.15	0.06	40

Table 7. The coefficient of friction of oriental-purple flesh sweet potato (OPFSP) samples

S/N	Measured parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation	Coefficient of Variation (%)
1	Plywood		0.27	0.16	0.21	0.04	20
2	Stainless Steel		0.23	0.12	0.17	0.04	21
3	Galvanized Steel		0.27	0.11	0.19	0.05	26

CONCLUSION

At 79.32 percent and 58 percent moisture content, the physical properties of Jewel-orange fleshed sweet potato and Oriental-purple fleshed sweet potato were determined.

The selected engineering properties are critical factors that will determine the efficiency of any device, equipment and machinery used for harvesting, sorting, handling, processing and packaging sweet potatoes. The data collected is needed for the design and manufacture of sweet potato harvesting, handling, processing equipment, storage devices and machineries.

DECLARATION OF COMPETING INTEREST

The author(s) must declare that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.

Olufemi Adeyemi Adetola: Planning, perform the statistical analysis, manage the analyses of the study, manage the literature searches, draft of the manuscript, and approve the final manuscript.

Oluwatusin Seun Adeniyi: Planning, perform the statistical analysis, manage the analyses of the study, manage the literature searches, and approve the final manuscript.

Deji Lawrence Akindahunsi: Planning, perform statistical analysis, manage the analyses of the study, manage the literature searches, and approve the final manuscript.

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