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Investigation of The Effects of Yield On Selected Physical Properties of Cassava Tubers

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Engineering properties, cassava tubers, cassava biomass, industrial process

A B S T R A C T

This research investigated the effect of some engineering properties (length, width, thickness, size, aspect ratio, surface area, sphericity, roundness, mass, volume, true density, bulk mass, bulk volume, bulk density, porosity, angle of repose and coefficient of static friction) on cassava biomass in relation to industrial processes. The results revealed that as the biomass increases the size, sphericity, bulk mass, length, width, thickness, aspect ratio, surface area, mass, volume, true density, bulk density, bulk volume and porosity increases whereas roundness, angle of repose and coefficient of static friction decreases as the biomass increases. There is significant difference between the biomass and the size, bulk mass, width, surface area, mass, volume and bulk volume whereas there is no significant difference between the biomass and the roundness, sphericity, length, thickness, aspect ratio, true density, bulk density, aspect ratio, coefficient of static friction and porosity. Correlation is significant at the 0.05 and 0.01 levels (2-tailed). Effects of yield on selected physical properties of cassava tubers had been investigated. The information provided in this research will be useful for farmers, engineers and energy providers who may wish to increase their biomass production capacity. Also, in the design of cassava implements and machinery for automation and mechanization of cassava tubers into useful products through the knowledge of the physical properties.

1. Introduction

Cassava is a root crop, a single specie dicotyledonous plant belonging to the family of Euphorbiacease and is the most important root crop grown in the tropics (Anikwe and Onyia, 2005). Nigeria is by far the highest producer of the crop in the world with production level estimated at 49 million tons per year. This is a third more than the production in Brazil (The world's second largest cassava producer). And almost double the production of Indonesia and Thailand (Uthman, 2011). Africa currently accounts for more than 50% of the world's annual output of 184 million tonnes of cassava (Afuwape et al., 2010). Cassava (Marihot esculenta) represents the main source of energy for 200 to 300 million people all over the world (Abowei et al., 2006). The root is drought resistant and capable of growing in different types of soil and seasons (Taiwo, 2006). It is known for drought tolerance and for thriving well on marginal soils, a cheap source of calories intake in human diet and a source of carbohydrate in animal feed (Kordylas, 2002). It grows well in areas with annual rainfall of 500-5000mm and full sun, but it is susceptible to cold weather and frost (Agodzo and Owusu, 2002).

Root and tuber crops respond differently to zero or minimum tillage. Jongruaysup et al (2007) reported that the fresh root yield of cassava (Manihot esculenta Crantz.) grown under zero tillage system was significantly higher than that of cassava grown using conventional tillage on fine loamy soil (Oxic Paleustults) in Thailand. But in Khaw Hin Sorn and TTDI sites in Thailand, the cassava tuber yield was comparable whereas in Huay Pong and Rayong sites of the same country lowest yield was obtained.

The physical properties play an important role in detecting quality differences during harvesting, handling and storage. Various types of cleaning, grading and separating equipment are designed based on their physical properties (Teye and Abano, 2012). According to Esref and Halil (2007), the knowledge of physical properties constitutes an important and essential engineering data in the design of machines, storage structures, and processing.

Physical properties affect the converting characteristics of solid materials either by air or water, cooling and heating of food products (Sahay and Singh, 1994; Teye and Abano, 2012). This research will provide both adequate information on physical properties and the biomass of the cassava variety TMS 0581 thereby enhancing full mechanization of the crop from the field to processing and storage.

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2.   Materials and Methods

2.1   Collection and Preparation of samples

The cassava tubers samples were obtained from the Research and Training Farm of Federal University Technology Akure, Ondo state, Nigeria. The study work was conducted in the department of Agricultural and Environmental Engineering of the same University. Cassava variety TMS 0581 was used.

2.2   Determination of Physical Properties and Biomass Yield of the Cassava Plants

2.2.1   Determination of length

The length of each of the cassava tuber was determined using a measuring tape.

2.2.2   Determination of intermediate diameter (width)

The intermediate diameter was determined using the analog vernier caliper to measure perpendicularly to the major axis of the cassava tuber.

2.2.3   Determination of thickness

The thickness was determined by measuring three different segment of the cassava tubers and finding the average; gives the true thickness of the cassava tuber.

2.2.4   Determination of geometric mean diameter

The geometric mean diameter (Dg) was calculated using equation recommended by Mohsenin (1986)

Equivalent diameter, $Dg = (abc)^{1/3}$……………1

Where Dg is the equivalent diameter;a is the length; b is the width and c is the thickness.

2.2.5   Determination of aspect ratio

Aspect ratio was calculated using the equation recommended by Burum (2004).

Aspect ratio, $Ra = b/a * 100\%$...2

Where Ra is the aspect ratio; b is the width and a is the length.

2.2.6   Determination of surface area

Surface area was calculated using the equation recommended by Mohsenin (1986).

$$S_a = \pi Dg^2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots3$$

Where Sa is the surface area and Dg is the geometric mean diameter.

2.2.7   Determination of Sphericity

According to Dharamajah and Cleasby (1986) with these dimensions being known, the sphericity may be calculated from the following equation.

$$\text{Sphericity index, } S_p = \frac{(abc)^{1/3}}{a} 100\% \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots4$$

Where Sp is the sphericity; a is the length; b is the width and c is the thickness.

2.2.8   Determination of Roundness

Roundness was determined by using the following equation as recommended by Mohsenin (1986).

$$\text{Roundness, } R_o = \frac{A_P}{A_C} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots5$$

Where, Ro is the roundness;Ap is the largest projected area of object in natural resting position and Ac is the area of the smallest circumscribing circle.

2.2.9   Angle of Repose "a"

Angle of repose was determined using the apparatus consisting of plywood box with a fixed stand attached with a protractor and an adjustable plate at the surface. The sample was placed on the adjustable surface and allowed to incline gradually in order for the tuber to follow and assume a natural slope (Tabatabaeefar, 2003; Mohsenin, 1986). This was done on just the galvanized sheet surface alone.

2.2.10   Coefficient of Static friction

Coefficient of static friction is the tangent of the angle of inclination at which a material begins to slide on a surface. The coefficient of friction was calculated from the relationship given by Mohsenin (1986).

$$\mu = \tan\alpha \dots\dots\dots\dots\dots\dots\dots.................................6$$

Where μ, is the coefficient of static friction and α is the angle of repose.

2.2.11   Determination of mass

A weighing balance of 10,000g (10kg) was used in weighing of the cassava tuber. Each cassava tuber in each of the stand was measured on the weighing balance.

2.2.12   Determination of Volume

The volume was determined in litres and then converted to m3 by dividing the litres by 1000. This was done by putting a known mass of a (unit) sample into a cylindrical container of water, change in level of the liquid in the cylinder gives the unit volume of the material according to (Mohsenin, 1980).

2.2.13   Determination of True density

A tuber of known mass was immersed into a known volume of water inside a measuring cylinder. The volume of water displaced was found to be the volume of cassava tuber (Mohsenin, 1986).

The ratio of the mass of the tuber to the volume of water displaced due to the immersed tuber gave the true density of the tuber.

$$\rho_t = \frac{W_t}{V_t} \quad \text{------------------------------------} 7$$

Where ρt is the true density; Wt is the true weight and Vt is the true volume.

2.2.14   Determination of Bulk density

In determining the bulk density, a cylindrical container of known weight and volume was filled with cassava tubers striking excess samples off the brim without compacting the tubers (Zwedu and Solomon, 2007) and weighed. The weight of the tubers was calculated by the difference between the weight of the empty cylinder and the weight after it was filled with tubers. The ratio of the weight of the tubers to the volume of the cylindrical container gives the bulk density (ρ_b)

$$\rho_b = \frac{W_s}{V_s} \quad \text{--------------------------------} 8$$

Where ρ_b is the bulk density in Kgm^{-3}; Ws is the weight of the sample in kg; and V_s is the volume occupied by the sample in m^3

2.2.15   Determination of Bulk mass

All cassava in a stand was weighed together by placing all the cassava in a bucket and then weighed on the weighing balance, the bucket was weighed first before placing all cassava inside for bulk mass determination.

2.2.16   Determination of Bulk volume

For bulk volume, 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 gives the bulk volume (Mohsenin, 1986).

2.2.17   Determination of Porosity

The porosity of bulk samples was computed from the values obtained for true and bulk density (Mohsenin, 1986). Where □ is the porosity; is the true density and ρ is the bulk density.

$$\square = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad \text{----------------------------} 9$$

2.2.18   Biomass determination

The residues used for the biomass are gotten after the harvesting of a particular cassava stand. The residue of the cassava were detached and sorted into their components, which is the stalk, the stem and the leave.

2.2.19   Weighing of wet samples

The residues were weighed in batches; the first is weighing of the stalk on the weighing balance, after weighing of the stem was the leave.

2.2.20   Drying and weighing of samples

The drying was done by spreading the stem, stalk and the leave to dry naturally under natural conditions which is the sun. The dried samples were reweighed on the weighing balance.

2.3   Statistical Analysis

Excel and Statistical Package for Social Science (SPSS) window 21 versions were used to analyze the data generated from this study using Correlate Bivariate to compare the relationship between the biomass and physical properties of cassava tubers.

4.   Results and Discussion

4.1   Effect of Biomass on Physical Properties of Cassava Tubers

According to Table 1 the results revealed that as the biomass increases the size, sphericity, bulk mass, length, width, thickness, aspect ratio, surface area, mass, volume, true density, bulk density, bulk volume and porosity increase whereas roundness, angle of repose and coefficient of static friction decreases as the biomass yield increases. There is significant difference between the biomass and the size, bulk mass, width, surface area, mass, volume and bulk volume whereas there is no significant difference between the biomass and the roundness, sphericity, length, thickness, aspect ratio, true density, bulk density, aspect ratio, coefficient of static friction and porosity. This may be due to soil factor as reported by other researchers that soil factor would influence size and shape of cassava tubers which constitutes major bottleneck in cassava peeling (Olukunle and Oguntude 2007). Correlation is significant at the 0.05 and 0.01 levels (2-tailed) for all the results presented in this research.

4.2   Effect of Size on Biomass and other Physical Properties of Cassava Tubers

Table 1 revealed that as the size increases the sphericity, bulk mass, length, width, thickness, aspect ratio, surface area, mass, volume, true density, bulk density, bulk volume, roundness, angle of repose, coefficient of static friction and porosity increases. There is significant difference between the size and the biomass, bulk mass, length, width, thickness, surface area, mass, volume, true density and bulk density whereas there is no significant difference between the size and the roundness, sphericity, aspect ratio, bulk volume, angle of repose, coefficient of static friction and porosity.

4.3 Effect of Roundness on Biomass and other Physical Properties of Cassava Tubers

Table 1 revealed that as the roundness increases the size, bulk mass, length, surface area, mass, volume, true density, bulk volume, angle of repose, coefficient of static friction and porosity increase whereas biomass, sphericity, width, thickness, aspect ratio and bulk density decrease. There is significant difference between the roundness and sphericity, length, width and aspect ratio whereas there is no significant difference between the roundness and the biomass, size, bulk mass, thickness, surface area, mass, volume, true density, bulk density, bulk volume, angle of repose, coefficient of static friction and porosity.

4.4 Effect of Mass on Biomass and other Physical Properties of Cassava Tubers

Table 2 revealed that as the mass increases the roundness, length, width, biomass, size, bulk mass, thickness, surface area, volume, true density, bulk density, bulk volume, angle of repose, coefficient of static friction and porosity whereas sphericity and aspect ratio decrease. There is significant difference between the mass and roundness, length, width, biomass, size, bulk mass, thickness, surface area, volume, true density, bulk density,

bulk volume, angle of repose, coefficient of static friction and porosity and whereas there is no significant difference between the mass and sphericity and aspect ratio.

5.0 Conclusion

The findings showed that the biomass wet basis increased in the same magnitude with the following parameters: biomass dry basis by 0.93 kg, the size by 0.45 cm, the sphericity by 0.20 cm, the bulk mass by 0.55 kg, the length by 0.09 cm, width by 0.49 cm, thickness by 0.44 cm, aspect ratio by 0.23%, surface area by 0.49 cm2, mass by 0.48 kg, volume by 0.52 m3, true density by 0.15 kg/m3, bulk density by 0.07 kg/m3, bulk volume by 0.59 m3 and porosity by 0.09% whereas the biomass wet basis decreased in the opposite magnitude with the following parameters: roundness by 0.120, angle of repose by 0.01 and coefficient of static friction by 0.04%. The research provides information on some physical properties and biomass which could use in determining the yield of cassava tubers and mechanization of cassava tubers from the field to finished product as physical properties constitutes an important and essential engineering data in the design of machines, processing and storage structure.

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Table 1: Effect of Biomass Yield Wet and Dry Basis on Phys ical Properties of Cassava Tubers

	B-m.w (kg)	B-m.d (kg)	S (cm)	R	Sph (cm)	B-m (kg)	L (cm)	W (cm)	Th (cm)	Aspr (%)	S.A (cm^2)
B.m.w	1.00	0.93**	0.45*	-0.12	0.20	0.55*	0.09	0.49*	0.44	0.23	0.49*
Sig.		0.00	0.05	0.61	0.41	0.01	0.71	0.03	0.06	0.33	0.03
B.m.d	0.93**	1.00	0.46*	-0.02	0.16	0.62**	0.18	0.39	0.46*	0.16	0.51*
Sig.	0.00		0.04	0.95	0.50	0.04	0.45	0.09	0.04	0.51	0.02
S	0.45*	0.46*	1.00	0.08	0.05	0.52*	0.58**	0.80**	0.78**	0.03	0.99**
Sig.	0.05	0.04		0.74	0.83	0.02	0.01	0.00	0.00	.090	0.00
R	-0.12	-0.02	0.08	1.00	-0.80**	0.18	0.81**	-0.45*	-0.29	-0.83**	0.09
Sig.	0.61	0.95	.074		0.00	0.44	0.00	0.05	0.22	0.00	0.69
Sph	0.20	0.16	0.05	-0.80**	1.00	-0.08	-0.72**	0.44	0.57**	0.96**	0.06
Sig.	0.41	0.50	0.83	0.00		0.73	0.00	0.06	0.01	0.00	0.79
B.m	0.55*	0.62**	0.53*	0.18	-0.08	1.00	0.39	0.29	0.40	-0.19	0.57**
Sig.	0.01	0.04	0.02	0.44	0.74		0.09	0.21	0.08	0.62	0.09
L	0.09	0.18	0.58**	0.81**	-0.72**	0.39	1,00	0.08	0.06	-0.71**	0.58**
Sig.	0.71	0.45	0.07	0.00	0.00	0.09		0.74	0.80	0.00	0.01
W	0.49*	0.39	0.79**	-0.48*	0.44	0.29	0.08	1.00	0.72**	0.52*	0.78**
Sig.	0.03	0.09	0.00	0.08	0.06	0.21	0.74		0.00	0.02	0.00
Th	0.44	0.46*	0.79**	-0.29	0.57**	0.40	0.06	0.72**	1.00	0.45*	0.78**
Sig.	0.06	0.04	0.00	0.22	0.01	0.08	0.80	0.00		0.05	0.00
Aspr	0.23	0.16	0.03	-.083**	0.96**	-0.12	-0.71**	0.53*	0.45*	1.00	0.04
Sig.	0.33	0.51	0.90	0.00	0.00	0.62	0.00	0.02	0.05		0.86

*.Correlation is Significant at the 0.05 level (2 - tailed)

**.Correlation is Significant at the 0.01 level (2 - tailed)

N. B. B.m.w is the biomass wet; B.m.d is the biomass dry; S is the size; R is the roundness; Sph is the sphericity; B.m is the bulk mass; L is the length; W is the width; Th is the thickness, Aspr is the aspect ratio and SA is the surface area.

Table 2: Effect of Biomass Yield Wet and Dry Basis on Physical Properties of Cassava Tubers

	M (kg)	Vol (m³)	T.D (kg/m³)	B.D (kg/m³)	B.V (m³)	ARP (⁰)	C.S.F	Por (%)
B.m.w	0.48*	0.52*	0.15	0.07	0.59**	-0.01	-0.04	0.09
Sig.	0.03	0.02	0.52	0.78	0.01	0.98	0.99	0.69
B.m.d	0.56*	0.58**	0.25	0.06	0.66**	0.21	0.22	0.19
Sig.	0.01	0.01	0.28	0.78	0.01	0.38	0.36	0.42
S	0.88**	0.64**	0.66**	.58**	0.33	0.41	0.39	0.44
Sig.	0.00	0.02	0.01	0.01	0.15	0.07	0.09	0.05
R	0.38	0.41	0.27	-0.14	0.25	0.26	0.26	0.25
Sig.	0.10	0.07	0.25	0.56	0.30	0.27	0.26	0.29
Sph	-0.19	-0.18	-0.11	0.02	-0.09	-0.07	-0.07	-0.01
Sig.	0.42	0.44	0.63	0.94	0.71	0.78	0.79	0.97
B.m	0.68**	0.57**	0.42	0.39	0.92**	0.37	0.33	0.16
Sig.	0.01	0.08	0.07	0.09	0.00	0.16	0.16	0.51
L	0.76**	0.64**	0.56*	0.21	0.33	0.36	0.35	0.40
Sig.	0.00	0.02	0.01	0.38	0.15	0.12	0.13	0.08
W	0.54*	0.35	0.35	0.49*	0.12	0.09	0.07	0.17
Sig.	0.02	0.13	0.13	0.03	0.62	0.69	0.78	0.47
Th	0.59**	0.37	0.50*	0.53*	0.25	0.41	0.39	0.39
Sig.	0.07	0.11	0.02	0.02	0.28	0.07	0.09	0.09
Aspr	-0.21	-.016	-0.19	-0.05	-.011	-0.20	-0.19	-0.09
Sig.	0.36	0.50	0.43	0.83	0.63	0.40	0.40	0.69

N. B. B.m.w is the biomass wet; B.m.d is the biomass dry; S is the size; R is the roundness; Sph is the sphericity; B.m is th e bulk mass; L is the length; W is the width; Th is the th ickness, M is the mass, Vol is the volume, TD is the true density, BD is the bulk density, BV is the bulk volume, ARP is the angle of repose, CSF is the coefficient of static friction and Por is the porosity .

Table 3: Effect of Biomass Yield Wet and Dry Ba sis on Physical Properties of Cassava Tubers

	B-m.w (kg)	B-m.d (kg)	S (cm)	R	Sph (cm)	B-m (kg)	L (cm)	W (cm)	Th (cm)	Aspr (%)	S.A (cm²)
S.A	0.49*	0.51*	0.99**	0.09	0.06	0.57**	0.58**	0.78**	0.79**	0.04	1.00
Sig.	0.03	0.02	0.00	0.69	0.79	0.09	0.07	0.00	0.00	0.86	
M	0.48*	0.55*	0.88**	0.38	-.019	0.68**	0.76**	0.54*	0.58**	-0.21	0.91**
Sig.	0.03	0.01	0.00	0.10	0.41	0.01	0.00	0.02	0.01	0.36	0.00
Vol	0.52*	0.58**	0.64**	0.41	-0.18	0.57**	0.64**	0.35	0.37	-0.16	0.65**
Sig.	0.02	0.07	0.02	0.07	0.44	0.08	0.02	0.13	0.11	0.49	0.02
T.D	0.15	0.25	0.66**	0.27	-0.11	0.42	0.56*	0.35	0.50*	-0.19	0.69**
Sig.	0.52	0.28	0.01	0.25	0.63	0.07	0.01	0.13	0.03	0.43	0.01
B.D	0.06	0.06	0.58**	-.014	0.02	0.39	0.21	0.49*	0.52*	-.005	0.58**
Sig.	0.79	0.79	0.07	0.56	0.94	0.09	0.38	0.03	0.02	0.83	0.07
B.V	0.59**	0.66**	0.33	0.25	0-.09	0.92**	0.33	0.12	0.25	-0.11	0.39
Sig.	0.06	0.01	0.15	0.30	0.71	0.00	0.15	0.63	0.28	0.63	0.09
AR	-0.07	0.21	0.41	0.26	-0.07	0.33	0.36	0.09	0.41	-0.20	0.43
Sig.	0.98	0.38	0.07	0.27	0.78	0.16	0.12	0.69	0.07	0.39	0.06
C.S.F	-0.04	0.22	0.39	0.26	-0.07	0.33	0.35	0.07	0.39	-0.20	0.41
Sig.	0.99	0.36	0.09	0.26	0.79	0.16	0.13	0.78	0.09	0.39	0.07
Por	0.09	0.19	0.44	0.25	-0.01	0.16	0.40	0.17	0.39	-0.09	0.46*
Sig.	0.69	0.42	0.05	0.28	0.97	0.51	0.08	0.47	0.09	0.69	0.04

*.Correlation is Significant at the 0.05 level (2-tailed)

**.Correlation is Significant at the 0.01 level (2-tailed)

N. B. S.A is the surface area; M is the mass; Vol is the volume; T.D is the true density; B.D is the bulk density; B.V is the bulk volume; AR is the angle of repose; C.S.F is the coefficient of static friction, Por is the porosity, B.m.w is the biomass wet; B.m.d is the biomass dry; S is the size; R is roundness; Sph is the sphericity; B.m is the bulk mass; L is the length; W is the width; Th is the thickness and Aspr is the aspect ratio

Table 4: Effect of Biomass Yield Wet and Dry Basis on Physical Properties of Cassava Tubers

	M (kg)	Vol (m³)	T.D (kg/m³)	B.D (kg/m³)	B.V (m³)	ARP (⁰)	C.S.F	Por (%)
S.A	0.91**	0.65**	0.70**	0.58**	0.39	0.43	0.41	0.46*
Sig.	0.00	0.02	0.01	0.07	0.09	0.06	0.07	0.04
M	1	0.76**	0.77**	0.48*	0.55*	0.47*	0.45*	0.50*
Sig.		0.00	0.00	0.03	0.01	0.04	0.04	0.03
Vol	0.76**	1.00	0.24	-0.09	0.67**	0.12	0.12	0.31
Sig.	0.00		0.31	0.68	0.01	0.62	0.61	0.18
T.D	0.77**	0.24	1.00	0.64**	0.21	0.55*	0.53*	0.46*
Sig.	0.00	0.31		0.03	0.38	0.01	0.02	0.04
B.D	0.48*	-0.09	0.64**	1.00	0.03	0.54*	0.50*	0.17
Sig.	0.03	0.68	0.03		0.90	0.02	0.02	047
B.V	0.55*	0.67**	0.21	0.03	1.00	0.15	0.16	0.10
Sig.	0.01	0.01	0.38	0.92		0.54	0.50	0.67
AR	0.47*	0.12	0.55*	0.54*	0.15	1.00	0.99**	0.70
Sig.	0.08	0.62	0.01	0.02	0.54		0.00	0.06
C.S.F	0.45*	0.13	0.53*	0.50*	0.16	0.99**	1.00	0.44
Sig.	0.04	0.61	0.02	0.02	0.50	0.00		0.05
Por	0.49*	0.32	0.46*	0.17	0.10	0.43	0.44	1.00
Sig.	0.03	0.18	0.04	0.47	0.67	0.06	0.05	

N. B. S.A is the surface area; M is the mass; Vol is the volume; T.D is the true density; B.D is the bulk density; B.V is the bulk volume; AR is the angle of repose; C.S.F is the coefficient of static friction and Por is the porosity.