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Determination of selected engineering properties of cashew nut (*Anacardium Occidentale*) related to the design of cashew nut processing equipments

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Abstract

Cashew plant is a tree in the family Anacardiaceous. Cashew with botanical name *Anacardium occidentale* is extensively cultivated in the tropics mainly for its apples and nuts. This study aims at investigating the interactions of physical properties of the cashew nuts and its moisture content. The size and shape were described in relation to its surface area and sphericity, geometric mean diameter and arithmetic mean diameter. They were characterized using established procedure. Density was described on the basis of its true and bulk density which resulted to the porosity of the nuts. They were determined with reference using water displacement method. The frictional characteristics which are angle of repose and coefficient of friction were determined on three different structural surfaces plastic, metal and plywood on an inclined plane. Result obtained revealed that the mean value for the nuts major diameter, intermediate diameter, minor diameter, arithmetic mean diameter, geometric mean diameter, sphericity, surface area, mass, volume, true density, bulk density and porosity were 31.58±0.75 mm, 24.25±0.40 mm, 17.23±0.55 mm, 24.35±0.51 mm, 23.63±0.51 mm, 0.75±0.01 mm, 1754.20±75.14 mm^2, 7.75±0.72 g, 7.65±0.52 cm^3, 1.01±0.03 g/cm^3, 0.58±0.03 g/cm^3 and 42.53±0.04 % respectively at a moisture content ranging between 5 % to 8 % wet basis. The mean value for coefficient of friction for wood, plastic and metal structural surface was 0.068±0.01, 0.102±0.033 and 0.100±0.037 respectively at a moisture content ranging between 5 % to 8 % wet basis. The mean value for angle of repose for metal, plastic and plywood structural surface were 31.5±1.73°, 25.5±1.29° and 26.25±4.35° respectively. The effect of moisture content on the physical properties considered was significant, the results were expressed graphically.

Keywords: Cashew Nut; Engineering Properties; Processing; Determination; Physical Properties

1. Introduction

The world production of cashew in the year 2000 exceeded 1.2 million tonnes with Asian and African continents producing 0.6 million and 0.4 million tonnes respectively (FAO, 2004).

The most important product of the cashew tree is the cashew nut. This is so because all other products of cashew are almost non-utilized, so therefore it could be said that it is mainly cultivated for its seed. The report of the United Nations Conference on Trade and Development revealed that the cashew nut sub-sector has not suffered from unfavourable government policies, but even enjoyed tax free export and additional incentives for the exporters (Emeka, 2011).

Engineering properties of cashew nut just like any biological materials are essential criterion for the utilization and the formulation of processing method and also in the design of equipment. The engineering properties include; rheological,

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thermal, optical, electrical, physical, and mechanical properties. These engineering properties forms an integral part during the design of machines, structures, processes and controls.

In determining the method of cleaning and separation, the size and shape comes to play most significantly in the pneumatic method of cleaning or separating biological materials whereas during calculations relating to the thermal diffusivity, the density and specific gravity are utilized (Mijinyawa and Omoikhoje, 2005). Engineering properties of biological materials are also significant to the food scientists and processors, plant and animal breeders and other scientists who also use them in their respective fields.

This study is therefore set out to determine the relationship between the moisture content and the physical properties of Cashew nut (*Anacardium occidentale*).

2. Material and methods

2.1. Source of Material

Cashew nuts used for this study were collected from a small-scale farm at Budo-Loke village in Imosokan community, Ifelodun L.G.A, Kwara State, Nigeria. They were sorted and cleaned of unwanted materials and defected nuts and kept in a container in preparation for the experiment.

2.2. Determination of Physical Properties

2.2.1. Size Determination

The three linear dimensions (major diameter, intermediate diameter and minor diameter) of the nuts were measured using a digital Vernier caliper with the resolution (0.1 mm/0.01´´), accuracy (±0.1 mm/0.01´´) and battery (SR44/LR44 1.5V) for all the prepared samples as given by Seyed *et al;*(2011) and also by Bart-Plange *et al;* (2012).

2.2.2. Determination of Geometric Mean Diameter

The geometric mean diameter of the cashew nuts was computed following the equation given by Baryeh**,** 2002

$$Gm = (l \times w \times t)^{\frac{1}{3}} \quad \text{.....(1)}$$

Where;

Gm: geometric mean diameter
l: $major\ diameter\ of\ nut$
w: $intermediate\ diameter\ of\ nut$
t: $minor\ diameter\ of\ nut$

2.2.3. Determination of Arithmetic Mean Diameter

The arithmetic mean diameter of the cashew nuts was computed by using the equation given by Tarighi *et al*; 2011

$$D_a = \frac{l+w+t}{3} \text{.....(2)}$$

2.2.4. Determination of Surface Area

The surface area of the cashew nuts was determined using the equation given by Mahbobeh *et al*; (2011) as

$$S = \pi Gm^2 \quad \text{.....(3)}$$

2.2.5. Mass Determination

100 unit of cashew nut mass was determined by using an electronic digital weighing scale with model number EK5350, resolution, and accuracy of 0.1 g and ±0.1 g respectively.

2.2.6. Volume Determination

The volume of the cashew nut was determined using water displacement method. A measuring cylinder was filled half way with distilled water the readings was taken, the nuts were poured in the measuring cylinder and the level of the displaced water was recorded. The volume of the seed equals the difference between the change in the level and the initial level of water in the cylinder. The procedure was repeated 10 times as described by Soyoye *et al*., (2018)

2.2.7. Bulk Density

The bulk density of cashew nuts was determined by dividing the bulk mass by bulk volume

2.2.8. True Density

It was determined by dividing mass of the kernel by its volume using the equation given by Parksoy *et al*; 2004

$$\rho = m/v \qquad \text{.....(4)}$$

Where;

ρ: $density$ in gcm-3

m: $mass\ of\ nut$ in g

v: $volume\ of\ nut$ in cm^3

2.2.9. Porosity

Porosity of the cashew nuts was calculated from the bulk density and true density using the relationship given by Mohammed (2010) as follows:

$$\epsilon = \frac{(\rho_t - \rho_b)}{\rho_t} \times 100 \text{.....(5)}$$

Where;

ϵ: $porosity$ in %

ρ_t: $true\ density$ in gcm-3

ρ_b: $bulk\ density$ in gcm-3

2.2.10. Coefficient of Friction

The coefficient of friction (μ) was determined on three different structural surfaces such as plywood, mild steel sheet, and plastic using an inclined plane. The inclined plane consists of two horizontal flat members hinged at one tilted end; one of the members is the base while the other can be tilted at any angle of inclination. It has a protractor which gives the angle of inclination. The inclined plane also has a pulley fixed to it at the other end. The inclined plane was set at a convenient angle of inclination, the structural surface to be tested was placed on it then a box opened at both ends was placed on the surface. A thread attached to the box was allowed to run through the pulley at the end of the plane then set of known weights were loaded onto the thread until the box slides. The procedure was then repeated by filling the box with known mass of seed. The coefficient of static friction was then computed using the equation give thus:

$$\mu = \frac{(F_T - F_E)\sin\alpha}{W\cos\alpha} \qquad \text{.....(6)}$$

Where:

F_T is the force pulling the box filled with seed
F_E is the force pulling the empty box
α is the angle at which the plane is inclined
W is the mass of seed in the box

2.3. Angle of Repose

The angle of repose of cashew nuts was measured by the inclined plane method. For the inclined plane method, an apparatus consisting of two horizontal flat members hinged at one end was used. The bottom member serves as the base which is fixed while the top member can be tilted to any angle ranging from 0^0 to 90^0 and it also consists of a graduated protractor from which the angle of inclination can be read. The seeds were placed on the top member after which it is been tilted gradually until the seeds begin to fall freely. The point at which the seeds begin to fall freely is recorded as the angle of repose and the value is taken from the protractor.

2.4. Statistical Analysis

A statistical tool (Microsoft Office Excel) was used to obtain results of the mean, minimum, maximum and standard deviation of all the obtained values. Graphical representation of results was also made to see the effect of moisture content on the various physical properties.

3. Results

The summary of the average result of the engineering properties of Cashew Nut (*anacardium occidentale*) with varying moisture content wet basis were shown in Tables 1 – 3 below while the graphical representation of the relationship between the moisture content and the engineering properties were shown in figures 1- 5 below:

Table 1 Summary of the Physical Properties of Cashew Nut (*anacardium occidentale*)

Property	M_0 (5%wb)	M_1 (6%wb)	M_2 (7%wb)	M_3 (8%wb)	Mean	Maximum	Minimum	Standard Deviation
Major diameter (mm)	30.68	31.42	31.71	32.50	31.58	32.50	30.68	0.75
Intermediate diameter (mm)	23.74	24.12	24.54	24.61	24.25	24.61	23.74	0.40
Minor diameter (mm)	16.50	17.10	17.60	17.70	17.23	17.70	16.50	0.55
Arithmetic mean diameter (mm)	23.64	24.21	24.62	24.94	24.35	24.94	23.64	0.51
Geometric mean diameter (mm)	22.91	23.49	23.94	24.18	23.63	24.18	22.91	0.51
Sphericity	0.746	0.748	0.754	0.76	0.75	0.76	0.74	0.01
Surface area (mm^2)	1648.23	1733.28	1798.15	1838.29	1754.49	1838.29	1684.23	75.14
Mass (g)	6.90	7.50	8.00	8.60	7.75	8.60	6.90	0.72
Volume (cm^3)	7.00	7.50	7.90	8.20	7.65	8.20	7.00	0.52
True density (g/cm^3)	0.99	1.00	1.01	1.05	1.01	1.05	0.99	0.03
Bulk density (g/cm^3)	0.61	0.60	0.56	0.56	0.58	0.60	0.56	0.03
Porosity (%)	38.62	39.80	44.80	46.89	42.53	46.89	38.62	0.04

Table 2 Summary of the Average Coefficient of Friction of Cashew Nut (*anacardium occidentale*)

Surface	Number of Samples	M_0 (5%wb)	M_1 (6%wb)	M_2 (7%wb)	M_3 (8%wb)	Mean	Maximum	Minimum	Standard Deviation
Wood	100	0.053	0.073	0.073	0.073	0.068	0.073	0.053	0.01
Plastic	100	0.053	0.118	0.118	0.118	0.102	0.118	0.053	0.033
Metal	100	0.054	0.118	0.118	0.118	0.099	0.118	0.054	0.037

Table 3 Summary of the Average Angle of Repose of Cashew Nut (*anacardium occidentale*)

Surface	Number of Samples	M0 (5%wb)	M1 (6%wb)	M2 (7%wb)	M3 (8%wb)	Mean	Maximum	Minimum	Standard Deviation
Wood	100	29	32	32	33	31.5	33	29	1.73
Plastic	100	20	25	26	27	24.5	27	20	1.29
Metal	100	24	27	28	30	27.25	30	24	4.35

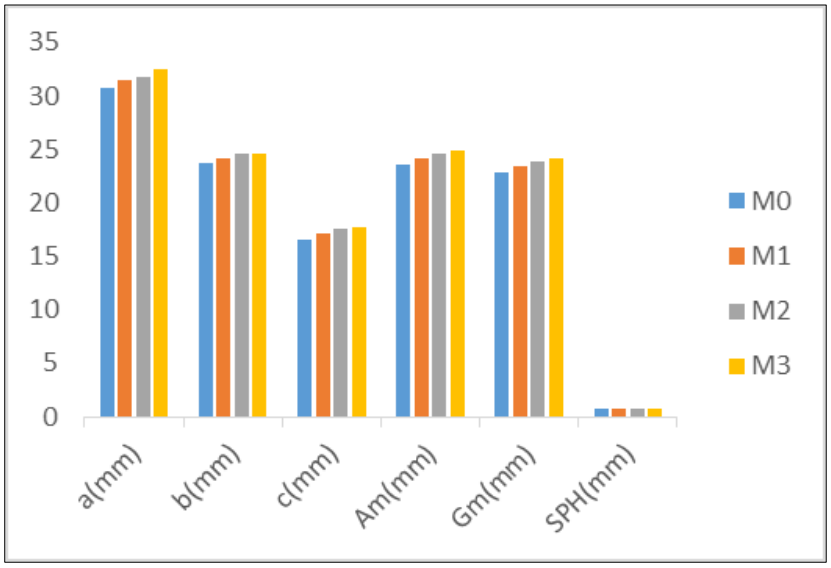

Figure 1 Relationship Between Moisture Content and the Size and Shape of Cashew Nuts (*anacardium occidentale*)

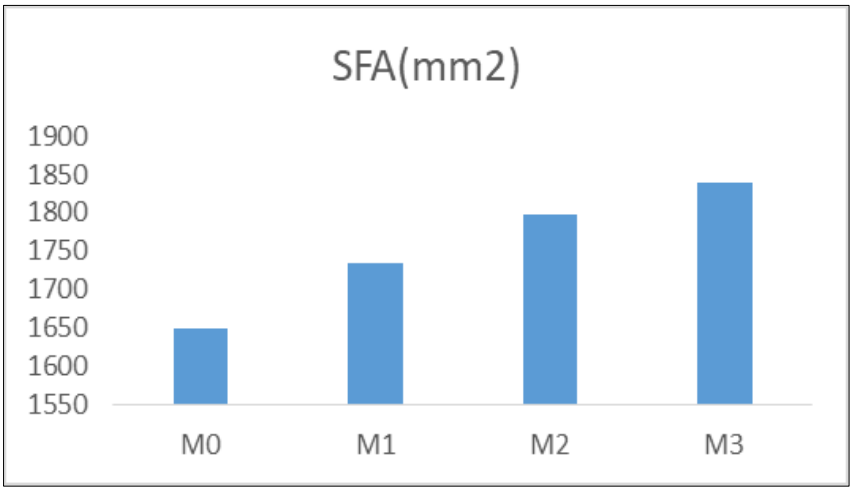

Figure 2 Relationship Between Moisture Content and the Sphericity of Cashew Nuts (*anacardium occidentale*)

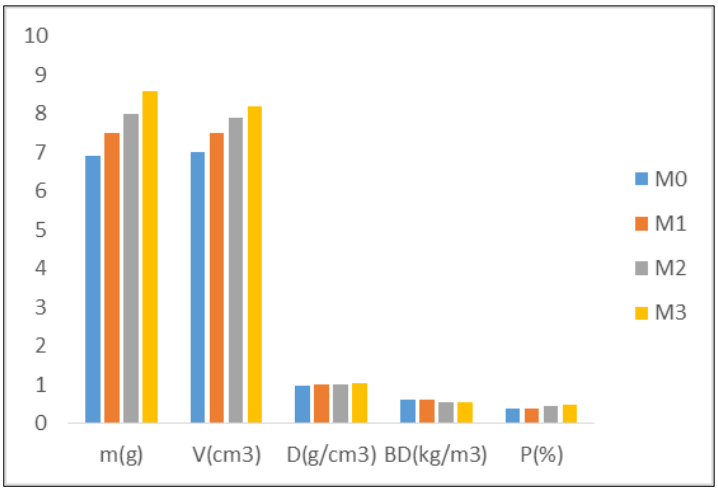

Figure 3 Relationship Between Moisture Content and the Gravimetric and Volumetric properties of Cashew Nuts (*anacardium occidentale*)

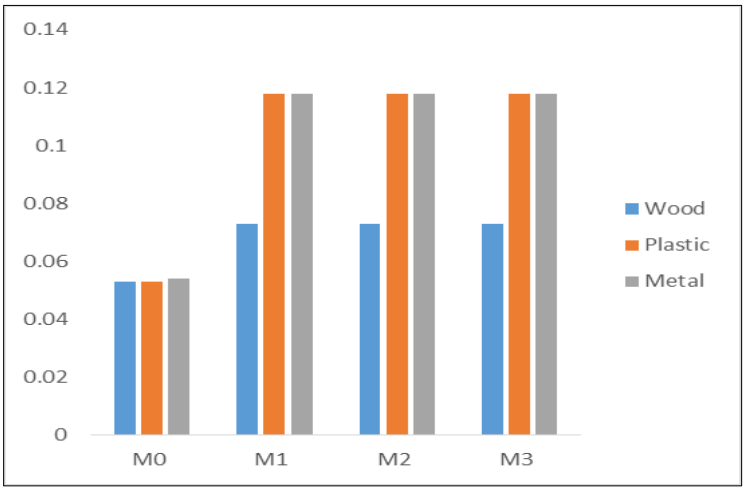

Figure 4 Relationship Between Moisture Content and the Coefficient of Friction of Cashew Nuts (*anacardium occidentale*)

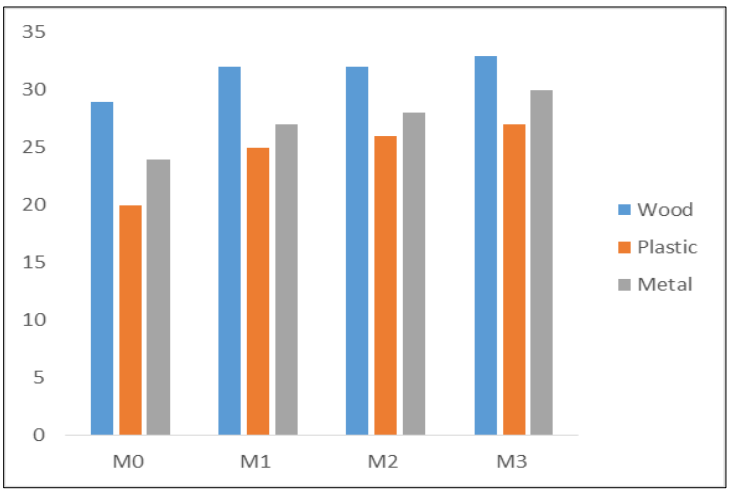

Figure 5 Relationship Between Moisture Content and the angle of repose of Cashew Nuts (*anacardium occidentale*)

4. Discussion

From Table 1, the average sizes of the Cashew Nuts (*anacardium occidentale*) were determined based on the major diameter, intermediate diameter and minor diameter at a moisture content ranging from 5 to 8 % wet basis to be 31.58, 24.25 and 17.23 mm respectively while the arithmetic mean diameter, geometric mean diameter, sphericity and surface area were 24.35 mm, 23.3 mm, 0.75 and 1754.49 mm^2 respectively. This is similar to what was reported by Bart-Plange *et al;* (2012) as the average length, thickness, width, equivalent diameter, sphericity and volume for cashew nuts at a moisture content of 5 to 9 % wet basis were 41.15 mm, 23.92 mm, 32.76 mm, 31.89 mm, 77.37 % and 312.54 mm^3 respectively.

The mass, volume, true density, bulk density and porosity were 7.75 g, 7.65 cm^3, 1.01 g/cm^3, 0.58 g/cm^3 and 42.53 % respectively at the same moisture range which is also in agreement with the findings of Bart-Plange *et al;* (2012).

From Table 2, the coefficient of friction of the Cashew Nuts (*anacardium occidentale*) on three structural surfaces were reported. The average value for the coefficient of friction at a moisture content ranging from 5 % to 8 % wet basis on wood, plastic and metal surfaces were 0.068, 0.102 and 0.099 respectively.

From Table 3, the angle of repose of the Cashew Nuts (*anacardium occidentale*) on three structural surfaces were reported. The average value for the angle of repose at a moisture content ranging from 5% to 8% wet basis on wood, plastic and metal surfaces were 31.5^0, 24.5^0 and 27.25^0 respectively.

Figure 1 to 5 depicts the interaction of the moisture content with the various engineering properties determined. It was observed that the engineering properties are dynamic as it changes with a change in the moisture content.

5. Conclusion

Some engineering properties of Cashew Nuts (*anacardium occidentale*) were determined in this study. Considering the results obtained, the under listed conclusions were drawn:

- The average geometric mean diameter and arithmetic mean diameter of cashew nuts at 5 to 8 % moisture content wet basis are 23.63±0.51 mm and 24.35±0.51 mm respectively which should be used as the minimum aperture of planter metering devices.
- The average surface area and sphericity at 5 to 8 % moisture content wet basis are 1754.49±75.14 mm^2 and 0.75±0.01 respectively, hence the seed tends to roll.
- The average true density, bulk density and porosity are 1.01±0.03 g/cm^3, 0.58±0.03 g/cm^3 and 42.53± 0.04 respectively, this should be considered when designing silo and bins at the same moisture range.
- The average angle of repose and coefficient of friction on metal, plywood and plastic surface are 27.25, 31.5, 24.5 and 0.099, 0.068 and 0.102 respectively, this should be considered when selecting materials for machine design at the same moisture range.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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