EVALUATION OF THE ENGINEERING PROPERTIES OF CASHEW KERNEL OBTAINED FROM DIFFERENT PLANTATIONS IN NSUKKA

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ABSTRACT

In this study, the engineering properties of cashew kernels grown in Nsukka were evaluated. The experiments were carried out in replicates from different plantations in order to achieve near accurate average values. The results showed no significant difference in the physical and thermal properties while terminal velocity, coefficient of friction, compressive force and stress were significantly different. Thus, since the physical properties were significantly the same then a processing system developed using the property values of a particular batch of kernel can be conveniently used with any other batch of the kernel. However varying force applications are to be used depending on the batch due to significant differences in the values of the mechanical properties and end-product of operation the same due to the fact that deformation was significantly the same. The thermal response of any batch will be the same since the thermal properties were significantly the same.

Keywords: thermal, mechanical, physical, cashew, kernel, processing.

1. INTRODUCTION

Cashew kernel is part of the nut of the fruit of the tree (*AnarcardiumOccidentale L.*) (Figure 1). Cashew tree, a long-lived perennial plant is native to northeast region of Brazil but has expanded to become global tropical evergreen tree [1]. Some varieties of cashew tree can reach up to 14 m in height [2].The cashew nuts are thermally processed to get kernels. The kernels may be further processed into value-added products such as fried, roasted, or chocolate-coated and flour kernels, and various confectioneries [3, 4].

In 2015, global production of cashew kernel was 738,861 tonnes, led by India and Côte d'Ivoire each with 23% of the world total [5]. The health benefits associated with the kernels are: reduction in mortality rate and cardiovascular disease, especially in case of stroke, a decreased risk of metabolic syndrome and diabetes, Prevents cancers, good for bone health, skin health, healthy brain function and nerve health, help weight loss [6-11]. The overall composition of the kernel is protein 21%, fat 46% and carbohydrates 25% [12].
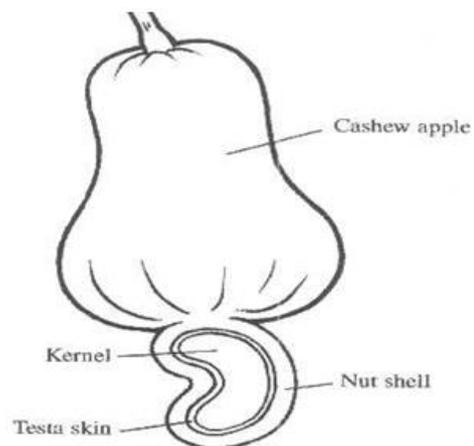

Figure 1: A cashew fruit

In processing and handling of food and agricultural materials, their' properties need to be determined in order to maintain or increase its quality. These properties which include physical and thermal properties among others are not constant but fluctuate depending on the variety of the product (see for example Figure 2).
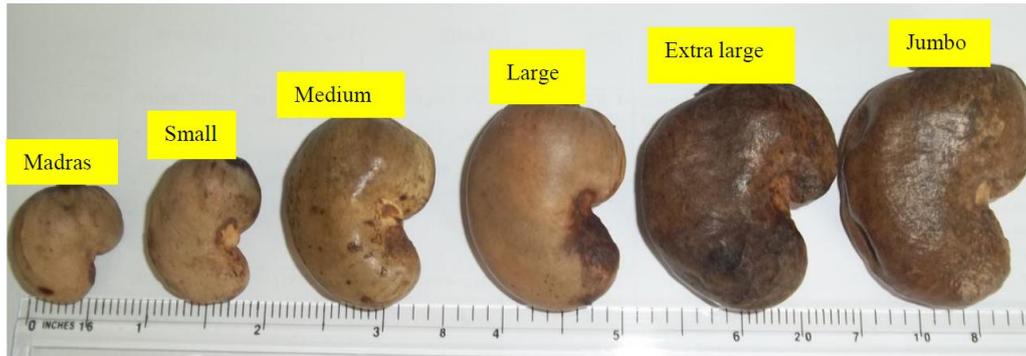
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Figure 2: Different sizes of Cashew nuts [15].

Knowing and understanding the physical properties of a food product is very important in designing of systems/machines, general processing and developing structures for storage [13]. How food materials and products react under heat applications is influenced by the thermal properties of the material, while mechanical properties determine how the materials react to the application of force to them [14].

In other to develop machines and equipment for processing and handling of the kernels, there is then the need to study the properties of cashew kernels especially the physical, mechanical and thermal properties. Several studies have been done on the evaluation of properties of cashew kernel [14, 16]. However, the values of these properties differ from study to study due to location and variety. Hence, there is the need to study the properties of cashew kernels grown in Nsukka in order to generate data that could be used for machine/system designs for Nsukka cashew kernel processing.

The engineering properties considered were limited to only the physical, mechanical and thermal properties. Data on engineering properties of a biomaterial are dependent on a number of factors such as variety and the climatic environment where it is cultivated [17]. Thus, making it desirable that the engineering properties of cashew kernels grown in Nsukka cashew plantations be determined.

2. MATERIALS AND METHODS
2.1 Sample Preparation
Five kilograms of cashew nuts were collected from Nsukka cashew plantations in Enugu State, Nigeria. The plantations were Obimo, Ogbede and Orba cashew plantations identified as samples *A, B* and *C* respectively. The nuts were sorted according to their plantation locations. The sample nuts were cleaned thereafter soaked in water which reduced scorching

when roasted in a drum. Then the sample was roasted and cracked manually to get the kernels [18]. The kernels were conditioned to 5% (wb) moisture content using a standard oven method at 103±2ºC [19]. To this, the kernels were sprayed with water, then put inside a polythene bag and tied. This was then kept for five days in a refrigerator set at five degree Celsius to allow the moisture content to be uniform. Then it was brought out and dried in oven until the moisture content dropped to 5%. For proper storage of cashew kernel, the recommended moisture content is 5% (wet basis) [20].All tests were in triplicates.

2.2 Determination of physical properties
For the physical properties, 100 samples of kernels randomly selected were evaluated by the method of Mohsenin [21] using equations (1) – (3) to determine the size and the sphericity index of the kernels where g_{md}, a_{md}, s_i, l, b and t represent the geometric mean diameter, arithmetic mean diameter, sphericity, length, width and thickness respectively.

$$g_{md} = (lbt)^{\frac{1}{3}} \tag{1}$$

$$a_{md} = \frac{(lbt)}{3} \tag{2}$$

$$s_i = \frac{g_{md}}{l} \tag{3}$$

Equation 4 was used to determine the bulk density (b_d) using the method of Mohsenin [23] where m_k and c_v are the mass of the kernels and volume of the cylinder respectively. The Specific Gravity was determined by the method of Ogungbenle [24].

$$b_d = \frac{m_k}{c_v} \tag{4}$$

The kernels' true density (t_d) was evaluated using equation 5 as discussed in [24] where m and v are the mass and volume of each kernel.

$$t_d = \frac{m}{v} \tag{5}$$

2.3 Determination of mechanical Properties

The method of [22] was used to evaluate the coefficient of friction (μ) while the angle of repose was determined by the 'emptying method' (θ) [25]. In this method, kernels were poured in to a cylinder kept on top of a plain area surface as described by Obi and Offorha [25]. To form natural slope, the cylinder was gradually and carefully raised to allow the samples flow gradually down. Considering the height and diameter of the pile formed, the dynamic angle of repose was then given as,

$$\theta = \tan^{-1}\frac{2l}{d} \qquad (6)$$

Where, $l\ (m)$ is the pile height and $d(m)$ is the pile diameter.

The Compressive force, Stress and Deformation were analysed using a Hounsfield Monsanto Tensometer [14]. During the tests, the kernels were loaded with the position of the intermediate (width) diameter as the load bearing axis. Each kernel was compressed with a motion probe at a constant speed until the specimen fractured. The compressive force and deformation values were recorded from the data chart of the Tensometer (Figure 3).
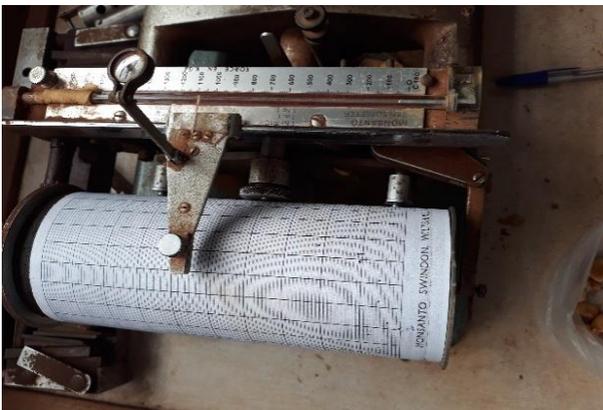

Figure 3: Tensometer chart

The terminal velocity was determined by measuring the fluid velocity required to suspend the sample in a vertical fluid stream in a calibrated cylinder. The samples were dropped into a cylinder filled with glycerine. As the sample moved down, the resistance force is said to be zero and the initial acceleration as *g.* As its speed increased, the resisting force increased until it was equal in magnitude to the sample's weight. Using Newton's second law:

$$\sum F_y = mg - kv = ma = 0 \qquad (7)$$

The acceleration became zero and there was no further increase in speed. The terminal velocity V_t, was then calculated as:

$$V_t = \frac{mg}{k} = \frac{\sqrt{2mg}}{A_p \rho C_D} \qquad (8)$$

Where, m = mass of sample, kg, g = acceleration due to gravity, m/s², k = proportionality constant, N.s/m, A_p= projected area of sample, m², C_D = drag coefficient, ρ = density of liquid, kg/m³

2.3 Determination of thermal properties

The method outlined in [26] was used to evaluate the Specific heat capacity (*Cshp*)**,** using the mixtures method where samples of given mass and temperature were en massed in water contained in a calorimeter made of copper material and stirred continuous**ly** until an equilibrium temperature was reached. The calorimeter was properly insulated to avoid heat loss. *Cshp* was then calculated as:

$$C_{shp} = \frac{(M_{oc}C_{oc} + M_{wa}C_{wa})(T_{fl} - T_{wa})}{M_{ks}(T_{ks} - T_e)} \qquad (9)$$

Where,

C_{shp} = specific heat of sample, J/kg ºC

C_{oc} = specific heat of calorimeter, J / k g ºC

C_{wa} = specific heat of water, J / k g ºC

M_{wa} = mass of water, kg

M_{oc} = mass of calorimeter, kg

M_{ks} = mass of sample, kg

T_{ks} = initial temperature of sample, K

T_{fl} = equilibrium (final) temperature, K

T_{wa} = initial temperature of water, K

T_e = equilibrium temperature, K

The principle outlined in [27] was used to evaluate the thermal conductivity (*Kco*) of the cashew kernels. A cylinder made of plastic and fixed with two thermocouples at the central point was filled with the kernel samples. The thermocouples were for temperature measurement. Other details of the set up are as discussed in [27]. Then *Kco* is given as:

$$kco = \frac{Q \ln^{t2}/_{t1}}{4\pi\ (T_{t2} - T_{t1})} \qquad (10)$$

Where, Q = heat input, W/m; t_1 = initial time, s
 t_2 = final time, s; T_{t1} = initial temperature, ºC
T_{t2} = final temperature, ºC

2.4 Statistical analysis

The different results were analyzed statistically using GenStat Discovery Edition software. The cashew plantations identified as samples *A, B* and *C* respectively served as the treatment. This test was done for the observed data. This test was used to determine if there is any significant difference

between the location as regard their different properties. If there was a significant difference, Least Significant Difference (LSD) was conducted to detect the difference between the means.

3. RESULTS AND DISCUSSIONS
3.1 Physical properties
The values of the physical properties of the samples considered were as shown in Table 2 where the superscripts represent the level of significance at 5% levels of probability level. The same letter means the difference in means are not significant. As expected all the properties considered had varying values for different replications of cashew kernels samples.

This is in agreement with literature which recorded varying values for a particular physical property [3, 16]. However, when subjected to statistical analysis, it was found that the physical properties were all significantly the same at 5% probability level. This then implies that the cashew kernels can be handled and processed using the same machine/mill.

3.2 Mechanical properties
Table 3 showed the mechanical properties of the cashew kernels where the superscripts represent the level of significance at 5% levels of probability level in means of the properties in descending order '*a*'

representing the highest in value. The same superscript letter signifies that there is no significant difference among the value means. It can be observed that porosity, angle of repose and deformation were significantly the same while terminal velocity, coefficient of friction, compressive force and stress were significantly different. This shows that with the application of different and appropriate amounts of force to the kernels during processing and handling operations the same level of result, that is, deformation and porosity will be actualised.

3.3 Thermal Properties
The differences between mean values of the thermal properties of the kernels are equally shown in Table 3 where the superscripts represent the level of significance at 5% levels of probability level. The same letter indicates that the difference in means is not significant. As can be observed, there were variations in the values of any given property. This is in agreement with literature which recorded varying values for a particular property [3, 16]. However, when the values were statistically evaluated, it was observed that of the two thermal properties there was no significant difference among them. From this result, it can be said that the effect of heat on kernels are the same.

Table 2: Mean values of the physical properties of Cashew kernels

Properties	A	B	C
Length (mm)	26.7±0.31 [a]	24.5±0.30 [a]	25.6±0.54 [a]
Width (mm)	11.6±0.17 [a]	10.71±0.11[a]	9.8±0.06 [a]
Sphericity(%)	53.66±0.16[a]	52.47±0.28[a]	53.21±0.73[a]
Bulk density (kg/m^3)	559.3±11.34[a]	640.6±3.37[a]	719.6±18.18[a]
True density(kg/m^3)	1176.5±9.38 [a]	1250±1.56 [a]	1117.6±3.89 [a]
Specific gravity	0.893±0.01 [a]	0.893±0.05[a]	0.893±0.08 [a]

Table 3: Mean values of the mechanical and thermal properties of cashew kernels

	A	B	C
Mechanical properties			
Porosity (%)	52.1±1.26 [a]	48.8±0.3 [a]	39.6±1.82 [a]
Angle of repose (º)	35.30±0.06 [a]	35.30±1.01[a]	35.30±0.54 [a]
Terminal velocity (m/s)	2.180±0.07[b]	3.839±0.10[a]	3.224±0.01 [a]
Coefficient of friction	0.5286±0.01[b]	0.6316±0.01[a]	0.5441±0.01[b]
Compression force (N)	675±21.6 [b]	875±11.21[a]	975±6.12 [a]
Stress (N/mm^2)	0.91±0.07[b]	1.75±0.05[b]	1.66±0.04 [a]
Deformation (mm)	5.50±0.04 [a]	5.75±0.05 [a]	6.00±0.18 [a]
Thermal properties			
Specific heat capacity (J/Kg/K)	1688.9±27.89[a]	1644.5±50.13[a]	1627.3±37.05[a]
Thermal conductivity (W/mK)	0.2423±0.01[a]	0.2019±0.02[a]	0.2173±0.01[a]

4. CONCLUSION

From the analysis of properties of cashew kernels obtain from different plantations within Nsukka area it can be concluded that since there was no significant different among the physical properties then a processing system developed using the property values of kernels processed from a particular plantation can conveniently be used with any other kernel from other plantations. However varying force applications are to be used depending on the characteristics of the kernel of a given plantation. This is because there were significant differences in the values of the mechanical properties examined and the end-product of the processing operation will be the same due to the fact that deformation in all cases was significantly the same. Equally the thermal response of different samples of kernel will be the same since no significant difference was observed in the cashew kernels' thermal properties.

Hence, a cashew kernel processing system/machine designed using the properties of a given cashew kernel as design parameters can conveniently be used for processing of any other sample of cashew kernel grown in Nsukka.

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