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Determination of Some Physical and Mechanical Properties of Bitter Kola Nuts

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Abstract

Bitter Kola (Garcinia Kola) is an important crop that has medicinal and economic values and is commonly utilized traditionally in the treatment of several ailments. Thus, research was carried to investigate the physical and mechanical properties of bitter kola nut, namely length, width, thickness, mean diameters, sphericity, porosity, angle of repose and static coefficient of friction. The average length, width and thickness varied between 20.5 and 35.0mm, 15.6 and 21.0mm, and 14.0 and 17.0mm. The average sphericity, aspect ratio, surface area volume, 1000 unit mass bulk and true densities of bitter kola nut revealed 73%, 66%, 1182mm^2, 750kg/m^3 and 1274kg/m^3. While the coefficient of static friction for various surfaces (glass, plywood, galvanized steel and rubber) were found to be 0.465, 0.532, 0.466 and 0.582 respectively. The results obtained will be useful in the design and development of machines to mitigate against stress involved in handling and processing bitter kola (Garcinia kola) nut.

1. Introduction

Bitter Kola (Garcinia kola) is a monocotyledonous plant of the clusiaceae family. An average tree of about 33m high. It has a thick slash and grayish-brown bark and a buttressed trunk. It bears a greenish-white flower and orange colour fruits with brownish seeds embedded in the pulp. It is found in Benin, Cameroon, Democratic Republic of Congo, Ivory Coast, Gabon, Ghana, Liberia, Senegal, Sierra Leone and Nigeria. It habitat is subtropical or tropical most low land forest [1].An average of four seeds is contained in a fruit. A part from the all other parts are also important to human being in various ways. Its common names in Nigeria include Akuilu or Agbuilu (IgboO, Orogbo (Yoruba), Namigingoro (Hausa), Edu (Bini), etc [2-8]. Bitter Kola (Garcinia Kola) has been reported as one commonly used medicinal plant and this can be adduced to basic information regarding the ethnopharmacology, pharmacology, toxicological and phytochemistry properties of bioactivities from natural source and their ability to manage different diseases. Fundamental physical and mechanical information on biomaterial is essential for optimal design of machines for handling, transportation, cleaning, sorting, separation, drying, aeration, storing and processing. The information on the geometrical characteristics of size, shape, sphericity, volume surface area, weight density, and porosity are importantly needed by engineers as well as food scientific processors and breeder [9, 10]. Data on physical properties are important in the design of a particular machine or analysis of the behaviour of produce in order to perform various post harvest operations [11]. Grading of grains seeds and fruits relies on the physical characteristics such as size and shape. The handling losses during threshing, separation, cleaning and grading operations are influenced by the size and shape of agricultural materials [12].

Density is commonly used to separate impurities from agricultural products and estimate floor space during transportation and storage in food industries. These parameters such as surface area, volume and porosity of biomaterials are imperative in estimations correlated to spray coverage, removal of residues, respiration rate, light reflectance, colour determination, evaluation of the diffusion coefficient f shrinking systems heating and cooling processes and rate of reaction airflow, heat flow and drying. The coefficient of static and dynamic friction on various surfaces is also essential to design the conveying, transporting, and storing machinery. The angle of repose is imperative in designing and development of machinery for mass flow and structures for storage [13 – 17]. This paper provides a detailed information on useful data essential for design and development of machines to mitigate against stress involved in handling and processing bitter kola (Garcinia kola) nut.

2.0. Materials and Methods

a. Sample Preparation and Moisture Content Determination

1000 bitter kola seeds were purchased from the same source (to ensure unbiased estimate). The seeds were cleaned to a devoid of sand or any other foreign bodies. The sample was packed inside polythene bags and air sealed. The moisture contents of the bitter kola nut was determined by oven drying method as described by ASABE (2003).

2.1. Geometric Properties

In order to determine mean of bitter kola (Garcinia Kola) nut dimension, 100 seeds were randomly selected for axial dimension length (L), width (W) and thickness (T) were measured using digital vernier caliper with an accuracy of 0.01mm. The average length of bitter kola nut was investigated using the three axial dimensions. The arithmetic mean diameter (D_a), geometric mean diameter (D_g), sphericity (%), surface area (s), aspect ratio (R_a) of bitter kola nut were calculated by using the following relationships [9, 18-20].

$$D_a = \frac{L+W+T}{3} \quad (1)$$

$$D_g = (LWT)^{-3} \quad (2)$$

$$D_{cm} = \frac{(LW+WT+LT)^{0.5}}{3} \quad (3)$$

$$D_e = \frac{D_a + D_g + D_{sm}}{3} \quad (4)$$

$$\emptyset = \sqrt[3]{\frac{(LWT)}{L}} \quad (5)$$

$$R_a = \frac{W}{L}\ 100 \quad (6)$$

$$A\int = \frac{\pi B L^2}{(2L-B)} \quad (7)$$

$$V = \frac{\pi B^2 L^2}{6(2L-3)} \quad (8)$$

$$B = (LW)^{0.5} \quad (9)$$

2.2 Determination of Weight, Bulk VolumeSpecific Volume, Density and Porosity

1000 seeds were divided into twenty equal parts of 50 seeds. Each part was weighed separately with the digital weighing balance. The sum of the twenty weights was taken to be the equivalent weight (W_{1000}) of 1000 seeds. Bulk volume (V_b) of 100 seeds was measured directly with a graduated cylinder. Specific volume (Vs) was evaluated using liquid displacement method. True density (e_t), bulk density (e_b) were derived using the following relationships [9].

$$e_t = \frac{M}{V_s} \quad (10)$$

$$e_b = \frac{M}{V_b} \quad (110$$

$$P = \frac{e_t - e_b}{e_t} \text{ X } 100 \quad (12)$$

2.3 Determination of Specific Surface Area, Angle of repose and coefficient of Static Friction

The specific area was determined using the relationship given by [9]

$$A_s = \frac{\pi D_g^2}{V_s} \quad (13)$$

The static angle of repose (ϕ) was determined using a flat tilting drafting wooden table as described by [21]. Some seeds were placed on tilted table. The table was gently tilled until the seeds start to slide on the inclined surface. The angle of repose was taken as the angle of inclination of the table read from the attached protractors. The static and dynamic coefficient of friction was determined with respect to four structural materials namely: glass, plywood, galvanized steel and rubber sheet in accordance with [22].The mean force required to initiate rupture in bitter kola nut the horizontal and vertical were measured using an Instron Testing Machine equipped with 5kg load cell at a compressive rate of 20mm min^{-1}.

3.0. Results and Discussion

The average length, width and thickness varied between 20.5 and 35.0mm, 15.6 and 24.0mm and 14.0 and 17.0mm as revealed in Table 1. Arithmetic and geometric mean diameter was evaluated as 16.0mm. The dimensional characteristics are significant in providing essential engineering data necessary for design and development of appropriate machines for grading, sizing, sorting, cleaning and packaging. These parameters determine the natural resting position of any biomaterials.

The average sphericity and aspect ratio of bitter kola seed as shown in Table 1 reveals 73% and 66%. The sphericity value indicated that the bitter kola seed is not spherical in shape and will tend to slide rather than roll [23]. These parameters are very useful in the design of processing and storage equipment, principally in handling operation such as conveying and discharge from chutes for any grain, fruit and seed [11].

On the other hand, the surface area of bitter kola seed revealed 1182mm^2. This parameter is very valuable tool in decisive the shape of any grain, fruit and seed. This is imperative in the way the grains, fruits and seeds will act upon oscillating surfaces for the period of processing operation [24].

The 1000 unit mass of bitter kola seeds was 547.8. 1000 unit mass was reported for japtropha seed and kernel, arigo seed, simarouba fruit and kernel, maize, red gram, wheat, green grain, chickpea, faba bean, pigeon pea were 1322.41g, 688g, 1124.7g, 1120g, 330.26g, 68.30g, 102g, 346g, 30.15g, 120g and 75g accordingly [25-28]. The practical application of this property is found in the design of equipment for cleaning using aerodynamic forces, separation, conveying and elevating unit operations is useful in cleaning. The porosity, bulk and true densities were given in Table 2.

Table 1: Some Physical Properties of Bitter Kola Nut and Shell

Properties	No. of Sample	Maximum	Minimum	Mean
Length (mm)	100	35.0	20.5	26.6
Width (mm)	100	21.0	15.5	17.5
Thickness (mm)	100	17.0	14.0	15.6
Arithmetic mean diameter (mm)	100	24.2	15.6	19.9
Equivalent mean diameter (mm)	100	24.7	14.1	19.4
Geometric mean diameter (mm)	100	24.7	14.1	19.4
Square mean diameter (mm)	100	16.8	15.2	16.0
Sphericity (%)	100	68.0	78.0	73.0
1000 unit mass (g)	100	646.3	449.3	547.8
Surface area (mm^2)	100	1344.0	1020.0	1182.0
Bulk volume (cm^3)	100	77.0	690.0	730.0
Specific volume (cm^2)	100	465.0	395.0	430.0
Aspect ratio (%)	100	50.0	82.0	66.0

The mean bulk and true densities of bitter kola seed were 750kg/m^3 and 1274kg/m^3. The bulk and true densities of agricultural products play a major role in the design of silos, calculating thermal properties in heat transfer problems, in estimating Reynolds number in pneumatic and hydraulic handling of materials, calculation of floor space during transportation and storage bins, maturity and quality evaluation of products which are fundamental to grain marketing and in predicting physical structure and chemical composition [11]. The mean porosity for the bitter kola nut and shell was 41%. The porosity of any biomaterial provides information on airflow, heat flow, Reynolds number in pneumatic and hydraulic handling and thermal diffusivity in drying.

Table 2: Mechanical Properties of Bitter Kola Nut and Shell

Properties	Mean
Bulk density (kg/m^3)	750
True density (kg/m^3)	1274
Porosity (%)	41
Bio-yield force (N)	176.13
Deformation (mm)	2.47
Rapture force (N)	197.23
Compressor force (MPa)	5.23

The mean static coefficient of friction of bitter kola nut and shell with four different structural materials including plywood, rubber sheet, mild steel and glass were 0.532, 0.582, 0.466 and 0.465

accordingly (Table 3). Mild Steel and Rubber sheet had the lowest and highest static coefficient friction. This property is central for designing pneumatic conveying systems, screw conveyors, hoppers. this parameter is essential in calculating compressibility and flow behaviour of biological materials used for designing seed bins and storage [29]. The average angle of repose of bitter kola nut and shell was 34%. The angle of repose is pertinent for the design of conveyor and hoppers for planting machines.

Table 3: Frictional Properties of Bitter Kola Nut and Shell

Properties	Mean
Angle of repose (o)	34
Plywood	0.532
Rubber sheet	0.582
Mild steel	0.466
Glass	0.465

4.0. Conclusion

Some engineering properties of bitter kola nut and shell such as length, width, thickness, arithmetic and geometric mean diameter, sphericity, surface area, 1000 unit mass, aspect ratio, porosity, true and bulk densities, angle of repose, coefficient of static friction on different surface were evaluated. These are very essential in the selection of materials, design and fabrication of machines and equipment for handling, storage and processing of biomaterial for bitter kola nut and shell.

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Nomenclature

D_a	Arithmetic Mean diameter (mm)
D_g	Geometric Mean diameter (mm)
D_{sm}	Square mean diameter (mm)
D_e	Equivalent mean diameter (mm)
R_a	Aspect ratio (%)
A_s	Surface area (mm^2)
V	Volume (cm^3)
P	Porosity (%)
V_b	Bulk volume (cm^3)
V_3	Specific volume
L	Length (mm)

W	Width (mm)
T	Thickness (mm)
Greek Letters	
ϕ	Angle of repose (°)
e_t	True density (kg/m^3)
e_b	Bulk density (kg/m^3)

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