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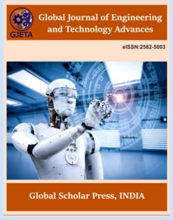

(RESEARCH ARTICLE)

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Some physical properties of kariya (*Hildegardia barteri*) nut/ kernel relevant to the design of its processing equipment

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Abstract

Kariya kernel is very rich in essential fats, oils and other valuable nutrients which may find applications in many food formulations. To harness these nutrients, processing equipment and machines are to be used. In order to effectively design these machines, the values of some physical properties of kariya nut and kernel are needed. In this study, some physical properties of the kariya nut and kernel were investigated. Results showed that mean major diameter, intermediate diameter, minor diameter and unit mass obtained at the nut moisture content of 19.83 ± 3.71 (w.b.) were 14.16 ± 0.79 mm, 10.17 ± 0.36 mm, 9.78 ± 0.28 mm and 0.503 ± 0.05g, respectively while the corresponding values obtained at the kernel moisture content of 8.89 ± 2.22% (w.b.) were 9.07 ± 0.72 mm, 7.32 ± 0.49 mm, 7.08 ± 0.41 mm and 0.328 ± 0.03 g, respectively. The values of calculated geometric mean diameter were 11.20 ±0.33 mm and 7.77 ± 0.36 mm, for the kariya nut and kernel, respectively. The skewness value of the sample distribution of 0.08 and -0.24 were recorded for the kariya nut and kernel, respectively. The sphericity, surface area, volume, density, bulk density and porosity were 79.27 ± 3.07%, 394.75 ± 23.13 mm^2, 738.37 ± 64.96 mm^3 , 681.1 ± 20 kg/m^3, 440.24 ± 0.04 kg/m^3 and 36.65 ± 0.74% ; and 85.97 ± 5.27%, 189.85 ± 17.34 mm^2, 246.71 ± 33.60 mm^3, 1342.1 ± 136.23 kg/m^3, 773.06 ± 0.06 kg/m^3 and 42.28 ± 4.10% for the kariya nut and kernel respectively.

Keywords: Physical properties; Kariya nut/ kernel; Design; Processing equipment

1. Introduction

Kariya tree (*Hildegardia barteri)* is cultivated majorly for its ornamental purposes. Its origin is traced from West Africa. It produces flowers during the dry season. Flowers are borne on branches which have no leaves and matured into mono-seeded pods [1]. Each pod is about 50 mm in length, bearing a peanut-like seed. The ripen pods drop and dispose as soon as they are dried. The kernels are always eaten raw or roasted like groundnuts in some parts of West Africa. They are used as ingredients in some local food recipes [2]. Kernel has proximate composition of 17.5% crude protein, 37.5% crude fat, 2.8% ash and 6.5% crude fibre. The crude protein content of kariya kernel competes reasonably with 19.8% for both sunflower and pistachio seeds, 15.6% for walnut kernel; whereas, it is less than 20% for mustard, 20.3% for linseed, 20.8% for almond seeds and 21.2 % for cashew nuts [3]. This protein content can be explored in many food applications. The crude fat content of kariya kernel comprises of 77% of saturated and 23% of unsaturated fatty acids. Almost the same composition is found in palm kernel oil with 82% saturated and 18% unsaturated fatty acids [4]. These oils are practically stable and will turn into solid at room temperature. Its fat content has approximately the same amount of linolenic, palmitic, myristic and stearic acid, which is not common among oil seeds. Traditional processing of kariya nut involves sun drying of the pods, manual dehulling of the leaf-like coverage and cracking of the nut using hands or stones to obtain kernels and shell fragments (Figure 1). However, the operations involved in traditional

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methods of processing are yet to be mechanized which could reduce drudgery and create opportunity for large scale operation [5].

Figure 1 Kariya pod, nut, kernel and shell fragment

Many researchers have carried works on some physical and engineering properties of seeds, nuts, grains, tuber crops, and vegetables in order to provide useful information likely to be employed in the design of crop and food processing equipment [6, 7, 8, 9]. Some researches were studied with respect to variation of nut, seeds and grains moisture content [8, 10, 11], while others were carried out at initial moisture content [13, 14]. These physical and engineering properties include geometric mean diameter (which is a function of major diameter, minor diameter and intermediate diameter), sphericity, static and dynamic angles of repose, coefficient of friction, specific gravity, unit weight/mass, volume, surface area, porosity, aspect ratio, true, solid and bulk densities, bio yield, stiffness, elastic deformation, hardness, shear resistance, compressibility, tensile strength, rupture, toughness, thermal conductivity, thermal diffusivity, specific heat capacity, etc [15, 16, 17, 18]. In order to tap these essential nutrients found in kariya kernels for commercial purpose, efficient processing equipment and vessels are needed. But there is scanty information on the physical and engineering properties of kariya nut/ kernel for rational design and fabrication of these machines. Therefore, there was need to provide these pieces of information. Hence, the objective of this study was to determine some physical properties of kariya nut and kernel such as size, shape, geometric mean diameter, sphericity, surface area, volume, unit mass, solid density, bulk density, and porosity with respect to their initial moisture content, so that Food scientists and processors could also exploit these data in their various disciplines for further researches and processing.

2. Material and methods

About 800 dried kariya pods were sourced from University of Uyo Town Campus, Uyo, Nigeria. The bulk pods were winnowed to remove foreign materials. Exactly 100 pods were picked at random and dehulled to obtain the nuts. After the first phase of the experiment with the nuts, the nuts were manually cracked and cleaned to obtain kernels for the second phase. The initial moisture content of the nuts and kernels (20 samples each) was determined using gravimetric method as described by ASABE [19], Antia *et al.* [20], Alonge and Etim [21] and Alonge *et al.* [11]. The nut and kernel masses were measured using digital weighing balance, while their axial dimensions (major, minor and intermediate diameters) were taken using digital vernier calipers of 0.01 mm calibration. The dimensions were used to determine some physical properties of kariya nuts and kernels using Equations 1 to 9. For the purpose of assessing the nut and kernel size distribution, they were classified each, based on GMD, into three size ranges: small (10.5 mm ≤ GMD < 11.0 mm), medium (11.0 mm ≤ GMD < 11.5 mm), large size ranges (11.5 mm ≤ GMD < 12.0 mm); and small (6.0 mm ≤ GMD < 7.0 mm), medium (7.0 mm ≤ GMD < 8.0 mm), large size ranges (8.0 mm ≤ GMD < 9.0 mm) for the nuts and kernels, respectively. Their mean and standard deviation of each parameter were calculated through the aid of Data Acquisition Template powered by Microsoft Excel ™. Their skewness values were also determined. The experiment was conducted in three replicates.

2.1. Determination of Some Physical Properties Kariya Nut and Kernels

2.1.1. Nut Moisture Content (MC) Determination

The initial moisture content was found using Equation 2.1.

$$\% \, MC_{wb} = \frac{M_i - M_f}{M_i} \times 100\% \qquad (2.1)$$

where $\% \, MC_{wb}$ = percent moisture content wet basis, M_i = initial mass of nut or kernel (g) and M_f = mass of nut or kernel at bone dry condition (g).

2.1.2. Nut and Kernel Size, Sphericity and Shape

Nut or kernel geometric mean diameter, as function of the axial dimensions, according to Irtwange and Igbeka [22] was calculated thus:

$$GMD = (d_1 \times d_2 \times d_3)^{1/3} \qquad (2.2)$$

where GMD = nut or kernel geometric mean diameter (mm), d_1 = nut or kernel minor diameter (mm), d_2 = nut or kernel intermediate diameter (mm), d_3 = nut or kernel major diameter (mm).

Skewness of the sample size distribution was calculated using Equation 2.3:

$$\text{Skewness } (Đ) = 3 \times \left(\frac{\text{Mean} - \text{Median}}{\text{Standard deviation}}\right) \qquad (2.3)$$

The sphericity of the nut or kernel was determined by using the relationship [22]:

$$\text{Sphericity } (\psi) = \frac{GMD}{d_3} \times 100\,\% \qquad (2.4)$$

When the sphericity of a grain/seed is ≥ 0.6 (i.e. 60%), the shape of such a seed is regarded as a sphere [13, 23].

2.1.3. Nut or Kernel Surface Area

Based on this study, the shape of the kariya nut and kernel are described as a sphere; hence, the nut or kernel surface area was calculated using Equation 2.5 [15, 23].

$$S_a = \pi \times (GMD)^2 \qquad (2.5)$$

where S_a= nut surface area (mm^2)

2.1.4. Nut or Kernel Volume

Nut or kernel volume was found using Equation 2.6 [15].

$$V_{n/k} = \frac{\pi \, (GMD)^3}{6} \qquad (2.6)$$

where $V_{n/k}$= nut or kernel volume (mm^3) and π (pie) = 3.142

2.1.5. Nut or Kernel Unit Mass

The nuts and kernels were weighed using electronic weighing balance.

2.1.6. Nut or Kernel Density

The density of the nut or kernel was calculated by dividing individual sample mass by its corresponding volume [15].

$$\rho_{n/k} = \frac{M_{n/k}}{V_{n/k}} \qquad (2.7)$$

where $\rho_{n/k}$= nut or kernel density (g/mm³), $M_{n/k}$ = nut or kernel mass (g) and $V_{n/k}$= nut or kernel volume (mm³).

2.1.7. Nut or Kernel Bulk Density

Bulk density is simply the density of a material when stacked in a container. It was determined as described by Rao *et al.* [15]:

$$\rho_b = \frac{M_{cnk} - M_c}{V_c} \quad (2.8)$$

where ρ_b= nuts or kernel bulk density (g/ml), M_c = mass of empty container (g), M_{cnk}= mass of container plus nuts or kernels (g), V_c = volume of empty container (mm³)

2.1.8. Porosity

Based on the relationship given by Mohsenin [24], the porosity of the nut or kernel was calculated thus:

$$P_{n/k} = \left(1 - \left[\frac{\rho_b}{\rho_{n/k}}\right]\right) \times 100\ \% \quad (2.9)$$

where $P_{n/k}$= nuts or kernel porosity (%)

3. Results and discussion

The results of the findings are presented in Table 1 and Figure 2.

Table 1 Some physical properties of kariya (*Hildegardia barteri*) nut and kernel at 19.83 % and 8.89% moisture content (w.b.) respectively.

Properties	Total No. of Observations	Nut	Kernel
Moisture content (% w.b.)	60	19.83± 3.71	8.89± 2.22
Major diameter, d_3 (mm)	300	14.16 ± 0.79	9.07 ±0.72
Intermediate diameter, d_2 (mm)	300	10.17 ± 0.36	7.32 ±0.49
Minor diameter, d_1 (mm)	300	9.78 ± 0.28	7.08 ± 0.41
Geometric mean diameter, GMD (mm)	300	11.20 ±0.33	7.77 ± 0.36
Sphericity (%)	300	79.27 ± 3.07	85.97 ± 5.27
Surface area (mm²)	300	394.75 ± 23.13	189.85 ± 17.34
Volume (mm³)	300	738.37 ± 64.96	246.71 ± 33.60
Unit mass (g)	300	0.503 ± 0.05	0.328 ± 0.03
Density (kg/m³)	300	681.1 ± 20	1342.1 ± 136.23
Bulk density (kg/m³)	300	440.24 ± 0.04	773.06 ± 0.06
Porosity (%)	300	36.65 ± 0.74	42.28 ± 4.10

Note: The values of mean and standard deviation are designated as Mean ± S.D.

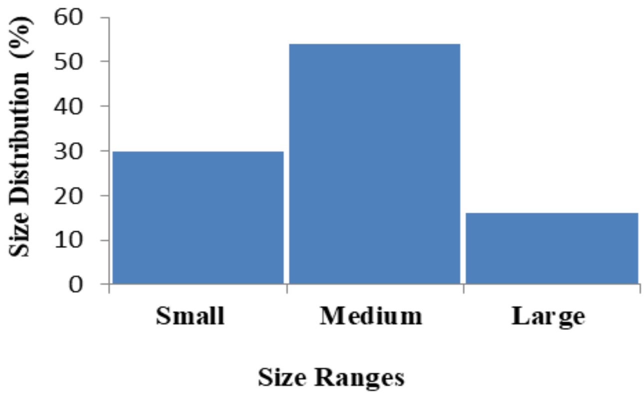

Figure 2 Histogram showing the % size distribution of kariya nuts.

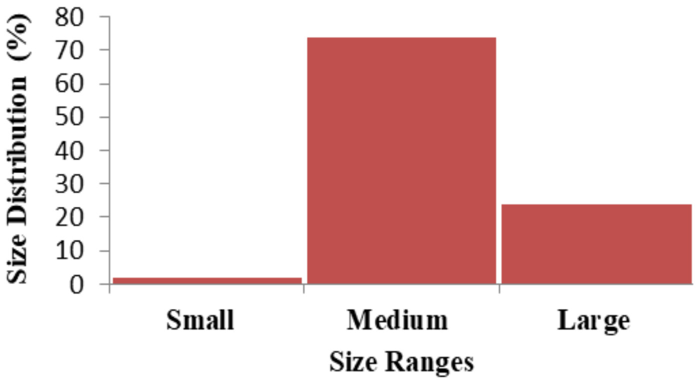

Figure 3 Histogram showing the % size distribution of kariya kernels.

3.1. Moisture Content of Kariya Nut and Kernel

Moisture content of kariya nut and kernel were found to be 19.83 $\pm$3.71% and 8.89 $\pm$2.22% (w.b.), respectively. It was observed that the moisture content of kariya nut was greater than that of kernel. The shell fragment was discovered to behave like an elastic material when torn by hand. This might have been the reason it was able to harbour almost 50% of the nut moisture content.

3.2. Size Distribution

From Table 1, the mean of values of major diameter (d_3), intermediate diameter (d_2), minor diameter (d_1), and geometric mean diameter (GMD) for kariya nut and kernel were 14.16 $\pm$ 0.79 mm, 10.17 $\pm$ 0.36 mm, 9.78$\pm$ 0.28 mm and 11.20 $\pm$ 0.33 mm; and 9.07 $\pm$ 0.72 mm, 7.32 $\pm$ 0.49 mm, 7.08$\pm$ 0.41 mm and 7.77 $\pm$ 0.36 mm, respectively. The mean % decrease of d_2 and d_1 with respect to d_3 were 28.20% and 30.93%, respectively for the kariya nut while the corresponding values for kernel were 19.30% and 21.90%, respectively. Hence, the mean values of d_2 and d_1 of the kernel were closed. This might be attributed to the fact that the kernel is spherical in shape. It was also found that the % nut and kernel sizes distribution based on GMD and the total sample used in the experiment were 30% small, 54% medium and 16% large size ranges; and 2% small, 74% medium and 24% large size ranges, respectively. The calculated skewness value for the nut size distribution was 0.08 (i.e. positive skewness). The observed value was almost closed to zero which indicates that the size distribution was relatively symmetrical. Besides, from Figure 2, the skewed distribution is towards the left side. This implies that the mean, mode and median of the data set were slightly different. Hence, greater portion of data was between the small and medium size ranges (10.0 mm $\leq$ GMD < 11.5 mm). On the other hand, the calculated skewness value for the kernel size distribution was -0.24 (i.e. negative skewness). The observed value was also closed to zero. Figure 3 shows that the skewed distribution is towards the right side which still implies that the mean, mode and median of the data set were not the same. Hence, greater portion of data was between the medium and large size ranges (7.0 mm ≤ GMD < 9.0 mm). Thus, the observed values of geometric mean diameter could be incorporated in the design of sorting and screening system for the cracked mixture or in cleaning systems.

3.3. Sphericity and Shape of Kariya Nut and Kernel

From Table 1, the mean of values of sphericity (ψ) for kariya nut and kernel were 79.27 $\pm$ 3.70 % and 85.97 $\pm$ 5.27 %, respectively. The sphericity values prove that the nuts and kernels are almost a sphere and can freely roll on any surface without resistance. This information could be used in the design of kariya nutcracker, separating system for cracked mixture of kernels / shell fragments and milling machine for kariya seeds.

3.4. Surface Area of Kariya Nut and Kernel

The mean surface area of kariya nut and kernel were found to be 394.75 $\pm$ 23.13 mm^2 and 189. 85 $\pm$ 17.34 mm^2, respectively. The values obtained could be employed in the design heat and mass transfer equipment when considering the known surface area that would be exposed to heat treatment processes during oil extraction or transient heat process.

3.5. Unit Mass of Kariya Nut and Kernel

The mean unit mass of kariya nut and kernel were obtained as 0.503 $\pm$ 0.05 g and 0.328 $\pm$ 0.03 g, respectively. It was observed that shell fragment was about 0.272 $\pm$ 0.04 g. The observed weight of shell fragment could suggest the pneumatic method of separating the cracked mixture. Unit mass could also be employed in the design of handling and weighing system for large scale kariya kernel processing.

3.6. Volume and Density of Kariya Nut and Kernel

The mean volume of kariya nut and kernel were found to be 738.37 $\pm$ 64.96 mm^3 and 246.71 $\pm$ 33.60 mm^3, respectively. Volume of the nut was found to be higher than that of kernel. The values of volume might be useful in screening solids and sorting systems. Mean values of density for the nut and kernel were 681.1 $\pm$ 20 kg/ m^3 and 1342.1 $\pm$ 136.23 kg/ m^3, respectively. As observed, the nuts could not sinked in water which might be due to the void space between the shell and kernel. Hence, water displacement method of volume determination was not possible. The implication of density values is that the kernels would sink in water, which makes it possible to separate them from foreign materials while the nuts could float on water. The observed density values could assist in process calculation and product characterization.

3.7. Bulk Density

The mean values of kariya nut and kernel bulk density were 440.24 $\pm$ 0.04 kg/ m^3 and 773.60 $\pm$ 0.06 kg/ m^3, respectively. Kernel bulk density was higher than that of the nut. These values are useful in containerization, transportation and in the designing a suitable packaging or storage system e.g. silo, bins, etc.

3.8. Porosity

The mean values of kariya nut and kernel porosity were found to be 36.65 $\pm$ 0.74% and 42.28 $\pm$ 4.10%, respectively. The implication is that the kernels would create more air-spaces (spores) among their particles than the nuts when stacked in a container. Hence, for the purpose of process calculation, it should be noted that spores inside the kernels are not included in the air volume; hence, the values are useful in storage system design.

4. Conclusion

In this study, some physical properties of kariya nut and kernel were investigated at the moisture content of 19.83$\pm$ 3.71% and 8.89$\pm$ 2.22%, respectively. Data collected could assist in the rational design of kariya nut and kernel processing, and handling equipment for efficient unit operations.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest.

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