

# Some Engineering Properties of Kariya (*Hildegardia barteri*) Kernel as Influenced by Moisture Content

Adeyanju, J. A<sup>1</sup>, Adekunle, A. A<sup>2</sup>, Abioye, A. O<sup>1\*</sup>, Olokoshe A. A<sup>3</sup>, Ibrahim, T. H<sup>2</sup>, Ajagun, E. J<sup>2</sup>, Adeniran, H. A<sup>1</sup>

<sup>1</sup>Ladoke Akintola University of Technology, Ogbomoso, Nigeria

<sup>2</sup>Bioresources Development Centre, National Biotechnology Development Agency, Ogbomoso, Nigeria

<sup>3</sup>Project Development and Design Department, Federal Institute of Industrial Research, Oshodi, Nigeria

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\*Corresponding author: Abioye, A. O

## Abstract

The knowledge of engineering properties is vital in designing postharvest equipment. In this research work, some physical and thermal properties of kariya (*Hildegardia barteri*) kernel were studied with respect to moisture content in the range of 8.83 to 27.42 % dry basis (d.b). The surface area, geometric mean diameter, arithmetic mean diameter, bulk density, true density, aspect ratio, sphericity, volume and porosity ranged between 154.09 and 200.29 mm<sup>2</sup>, 7.75 and 8.64 mm, 144.40 and 216.66 mm, 0.65 and 0.72 kg/m<sup>3</sup>, 1.01 and 1.29 kg/m<sup>3</sup>, 0.64 and 0.69 mm<sup>3</sup>, 12.40 and 14.59, 226.94 and 340.23 cm<sup>3</sup> and 40.28 and 98.46, respectively. The static coefficient of friction ranged from 0.42 and 0.53; 0.40 and 0.51; 0.42 and 0.52 for galvanized steel, stainless steel and glass surface respectively. Thermal properties were found to increase from 0.17 to 0.51 kJ/kgK, 1.2 to 2.0 x 10<sup>-7</sup>m<sup>2</sup>/s and 1.43 to 2.73 W/m<sup>2</sup>°C, for specific heat, thermal diffusivity and thermal conductivity respectively. Models were established for all the parameters measured for the kariya kernel as a function of moisture content, with high correlation coefficients. These models can adequately predict the properties within the moisture range examined.

**Keywords:** Engineering properties, *kariya*, moisture content, axial dimension, static coefficient of friction.

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## 1. INTRODUCTION

Kariya (*Hildegardia barteri*) which is also called Krobo Christmas tree is predominantly a decorative tree in the western part of Africa, grown for its bright and attractive flowers [1]. These flowers develop into one-seed pod of approximately 50 mm length around December to March every year [2]. Kernel extracted from Kariya pod have been reported to be processed and consumed as snacks and also as condiments in local foods [1].

Report from [1] stated that the proximate composition of kariya kernels to be 17.5%, 6.5%, 37.5% and 2.8% for protein, crude fiber, crude fat and ash respectively. Researchers have reported that investigations on Kariya have been restricted to the physical properties of the seeds, physicochemical and functional properties of kariya flours [1, 2].

Engineering properties of biological materials, known to be suitable for analyzing and determining the efficiency of a machine or an operation, products and

equipment development and the final quality of products have been reported to establish a vital and crucial data for design of machines, structures, processes and controls [3, 4] reported that size and shape of seeds which are characterized by its dimension, are critical in determining the method of separation and clearing. Reports by some researchers have shown that seed dimensions, arithmetic and geometric mean diameter, surface area, volume, sphericity, aspect ratio, bulk density, true density, porosity, coefficient of friction, angle of repose, heat capacity, thermal conductivity and diffusivity are the most vital physical and thermal properties of agricultural products [3, 5]. These properties according to [4] are contingent on the moisture content and temperature of different agricultural products.

Studies on some engineering properties of kariya seed will afford equipment engineers the opportunity to design equipments to harvest, transport, sort, clean, separate, size, package and process the seeds, which in turn have impact on work efficiency

and the extent of product loss. Therefore, this work is aimed at studying the influence of moisture on the engineering properties of kariya kernel.

## 2. MATERIALS AND METHODS

### MATERIALS

Kariya seed was obtained from Obafemi Awolowo University, Ile-Ife, Osun State. Other materials used in this work include distilled water and toluene (C<sub>7</sub>H<sub>8</sub>). The equipment used are weighing pans (aluminium), micrometer screw gauge, circular wooden plate, beaker, tilting table apparatus, measuring cylinder, electronic balance, protractor.

### Sample Preparation

Kariya seed was cleaned by picking foreign materials such as stones and broken seeds. Five (5 g) samples of the seeds were heated in an electric oven for 48 h at 103 °C to investigate the initial moisture content of the kariya seeds [6]. Samples of the kariya seeds were conditioned using equation 1 to elevate the moisture content to the anticipated different levels considered in this study [7].

$$Q = w_i \left( \frac{mf - m_i}{100 - mf} \right) \dots \dots \dots (1)$$

Where; Q, is the mass of added water (kg); w<sub>i</sub>, is the initial mass of the sample (kg); m<sub>i</sub>, is the initial moisture content of the sample (% d.b.) and m<sub>f</sub>, is the final moisture content of the sample (% d b.).

Five levels of 8.83, 13.72, 17.97, 23.01 and 27.42% moisture contents were obtained for the kariya seeds after which the samples were packed in Ziploc polythene bags and kept in a refrigerator for uniform moisture distribution until used.

### Physical Properties Determination

#### Dimensional properties

The length, width and thickness dimensions were recorded with the micrometer screw gauge. The data generated from the length, width and thickness was used to generate the surface area (S), geometric mean diameter (D<sub>g</sub>), arithmetic mean diameter, volume (V) and sphericity (Φ).

#### Surface Area

The surface area (S) was investigated using the equation reported by [8]

$$S = \frac{\pi(\sqrt{WT})L^2}{2L - \sqrt{WT}} \dots \dots \dots (2)$$

#### Geometric mean diameter

The equation given by [9] was used to evaluate the geometric mean diameters of the kariya seeds. The equation is expressed as:

$$D_g = (LWT)^{1/3} \dots \dots \dots (3)$$

#### Arithmetic mean diameter

The arithmetic mean diameter was evaluated using the expression below:

$$D_{am} = \frac{LWT}{3} \dots \dots \dots (4)$$

Where; D<sub>am</sub>, arithmetic mean diameter; D<sub>g</sub>, geometric mean diameter; L, length; W, width; T, thickness

#### Volume

The volume of the kariya seeds was calculated using the expression below:

$$\text{Volume} = \frac{\pi}{6} D_g^3 \dots \dots \dots (5)$$

#### Determination of sphericity

Equation 9 as described by [8] was used to investigate the sphericity of kariya seeds.

$$Q = \frac{LWT^{1/3}}{L} \dots \dots \dots (9)$$

#### Determination of aspect ratio

Aspect ratio was calculated as described [3].

$$R_a = \frac{W}{L} \dots \dots \dots (10)$$

### Gravimetric properties

#### Bulk density

Investigation of the bulk density was done using the standard test weight procedure. A known weight of the seeds was filled in standard container (beaker) of 500 ml. The seeds were filled to the top of the container. Bulk density was calculated to be the ratio of the mass of seeds filled in the container to the volume of the container.

#### True density

100 seeds of known mass were randomly picked. Toluene, which is used as a replacement to water because seeds absorb it less than water, was poured into a calibrated measuring cylinder. The seeds were then poured in the cylinder and the volume of displaced toluene recorded. The true density was found to be the ratio of the mass of the seeds to the volume of the displaced toluene [10].

#### Porosity

The porosity of the seeds was calculated using the mathematical expression below.

$$\varepsilon = \frac{\rho_p - \rho_b}{\rho_b} \times 100 \dots \dots \dots (6)$$

Where; ρ<sub>b</sub> is the bulk density and ρ<sub>p</sub> is the true density

### Frictional properties

#### Determination of static coefficient of friction

The coefficient of static friction was investigated on plywood, mild steel and rubber. Seeds of kariya was placed on the three surfaces and was gradually raised until the seed began to slide. The angle at which the seeds begin to slide was recorded. The coefficient of static friction was calculated using the following expression:

$$C_{SF} = \tan A \dots \dots \dots (8)$$

Where;  $C_{SF}$  is the coefficient of external static friction,  $\tan A$  is the external static friction

### Thermal Properties Determination

#### Determination of specific heat capacity, thermal conductivity and thermal diffusivity

The specific heat capacity, thermal conductivity and thermal diffusivity of the kariya kernel was determined using equipment called KD2 Pro analyser. The analyser which consists of a controller and sensor kit uses the transient line heat source method in measuring the thermal conductivity, diffusivity and specific heat of the kariya seeds.

#### Statistical Analysis

Analysis of Variance (ANOVA) was used to analyze the results. The mean was separated with the use of Duncan's multiple range to detect significant difference ( $p < 0.05$ ) among the sample using Statistical Package for the Social Science (SPSS).

## 3. RESULTS AND DISCUSSION

### Influence of Moisture Content on the Dimensional Properties of Kariya Kernel

Table-1 shows the result of influence of moisture content on surface area, arithmetic mean, geometric mean diameter, sphericity, aspect ratio and volume of kariya kernel. ANOVA revealed the effect of moisture variation at significant level of 5% on dimensional properties of the kariya kernel within the moisture range considered. The dimensional properties ranged from 154 – 200.29 mm<sup>2</sup>, 12.40 - 14.59, 144.40 - 216.66 mm, 7.75 - 8.64 mm, 0.64 – 0.69 mm and 226.94 – 340.23 cm<sup>3</sup> for surface area, sphericity, arithmetic, geometric mean diameter, aspect ratio and volume respectively. Correlation coefficient,  $R^2$  revealed that moisture content has significant positive quadratic influence on the surface area, sphericity, geometric mean diameter, arithmetic mean, and volume and, linear effect on the aspect ratio of the kariya kernel (Table-1). The  $R^2$  value ranged between 0.9174 and 0.9544, an indication that the equation can be used to explain the connections of moisture and the dimensional properties measured for the kariya kernel

as shown in Table-1. Report from [11] stated that during reconstitution, moisture is absorbed by the food material through the available interspace connecting the cotyledons and the coat which eventually diffuse into the cotyledons thereby, increasing the dimension of the food material hence the increase in the dimensional properties of the kariya kernel.

### Influence of Moisture Content on the Gravimetric Properties of Kariya Kernel

Results of gravimetric properties of kariya kernel is presented in Table 2. True density, bulk density and porosity ranged between 1.01 to 1.29 kg/m<sup>3</sup>, 0.65 - 0.72 kg/m<sup>3</sup> and 40.28 to 98.46 % within the moisture range studied. The regression equations for the gravimetric properties are shown in Table 2. According to [11], the data generated from bulk density may be useful in hoppers and silo design which in turn are useful for storage and handling of grain for essential determination of weight of food products that would be held in the container. From the regression equation, the bulk density was found to decrease as moisture content increases. This may possibly be linked to the fact that, as volume increases, the mass of the bulk seed increase a little higher, thereby causing a decrease in the bulk density. Several researchers have reported the decreasing trend for bulk density on varieties of seeds such as [12] for lentil seeds [13], for neem nuts [14], for sunflower seeds and [11] for bambara ground nut. True density has been reported to have its practical application of separating undesirable materials from of its product [15]. The true density shows an increasing effect on the kariya kernel as moisture increases. Reports for sunflower [16]; guna seeds [17] and sweet corn [7] show a related increasing trend. The cause of the increase in the true density as moisture increases may be attributed to increase in the mass of the kernel as related to the volume expansion on moisture gain. As moisture content increase, porosity increase linearly (Table-2). The reports from previous researchers such as [12, 18-20] on lentil seeds, traditional black hull sunflower, pigeon pea and chickpea seeds, respectively shows similar trend.

**Table-1: Surface area, geometric mean diameter and arithmetic mean diameter of kariya kernel**

Moisture (X, %)	Surface area (mm <sup>2</sup> )	Geometric mean diameter (mm)	Arithmetic mean diameter (mm)	Aspctratio (mm <sup>3</sup> )	Sphericity	Volume (cm <sup>3</sup> )
8.83	154.09±5.21 <sup>a</sup>	7.57±0.07 <sup>a</sup>	144.40±6.70 <sup>a</sup>	0.64±0.01 <sup>a</sup>	12.40±0.61 <sup>a</sup>	226.94±10.46 <sup>a</sup>
13.72	166.80±7.45 <sup>b</sup>	7.86±0.10 <sup>a</sup>	161.99±10.72 <sup>a</sup>	0.65±0.01 <sup>a</sup>	12.49±0.62 <sup>a</sup>	254.51±16.98 <sup>a</sup>
17.97	172.48±3.54 <sup>c</sup>	7.99±0.01 <sup>a</sup>	170.56±0.94 <sup>a</sup>	0.67±0.06 <sup>a</sup>	13.30±0.33 <sup>ab</sup>	267.75±1.53 <sup>b</sup>
23.01	175.62±11.64 <sup>c</sup>	8.14±0.15 <sup>b</sup>	180.06±17.19 <sup>b</sup>	0.67±0.09 <sup>a</sup>	13.48±0.91 <sup>ab</sup>	282.99±27.23 <sup>c</sup>
27.42	200.29±27.40 <sup>d</sup>	8.64±0.33 <sup>b</sup>	216.66±40.98 <sup>c</sup>	0.69±0.01 <sup>a</sup>	14.59±1.89 <sup>b</sup>	340.23±64.46 <sup>d</sup>
Regression	0.068X <sup>2</sup> - 0.30X+153.83	0.0014X <sup>2</sup> +0.001 X+7.50	0.13X <sup>2</sup> - 1.08X+147.27	0.0026X+0.6 173	0.0047X <sup>2</sup> - 0.06X+12.51	0.20X <sup>2</sup> - 1.72X+231.63
R <sup>2</sup>	0.9174	0.9544	0.9486	0.9372	0.9505	0.9494

Means with different superscripts are significantly different ( $p < 0.05$ )

**Table-2: Bulk density and true density of kariya kernel**

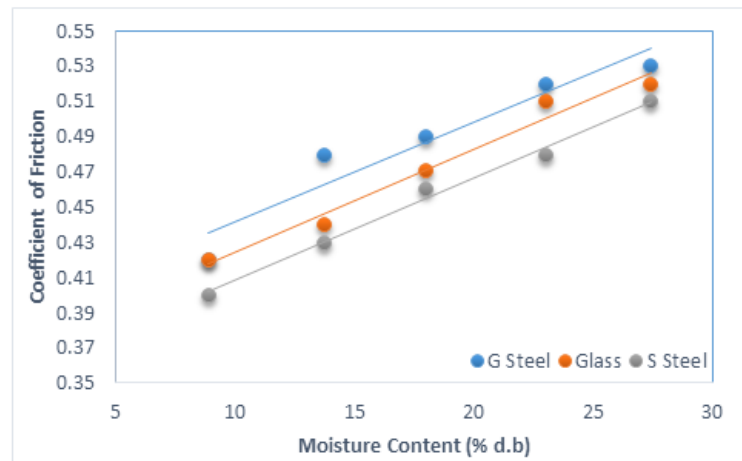
Moisture (X, %)	Bulk density (kg/m <sup>3</sup> )	True density (kg/m <sup>3</sup> )	Porosity
8.83	0.72±0.04 <sup>b</sup>	1.01±0.14 <sup>a</sup>	40.28±0.00 <sup>d</sup>
13.72	0.71±0.00 <sup>b</sup>	1.20±0.16 <sup>b</sup>	69.01±4.77 <sup>a</sup>
17.97	0.69±0.05 <sup>a</sup>	1.20±0.01 <sup>b</sup>	73.91±5.18 <sup>b</sup>
23.01	0.67±0.01 <sup>a</sup>	1.27±0.06 <sup>b</sup>	89.55±0.0 <sup>c</sup>
27.42	0.65±0.01 <sup>a</sup>	1.29±0.00 <sup>c</sup>	98.46±1.96 <sup>d</sup>
Regression	-0.0039X <sup>2</sup> +0.758	-0.0009X <sup>2</sup> +0.0465X+0.687	2.9559X <sup>2</sup> +20.474
R <sup>2</sup>	0.9857	0.9305	0.9431

Means with different superscripts are significantly different ( $p < 0.05$ )

### Influence of Moisture Content on the Frictional Properties of Kariya Kernel

Figure-1 shows the effect of moisture content of the kariya kernel on the frictional properties against galvanized steel, glass and stainless steel surfaces. The values ranged between 0.43 - 0.53; 0.48 - 0.53; 0.48 -

0.52. In all the surfaces under consideration, it was noticed that the coefficient of friction increased linearly with moisture content. The relationship among the regression equations, coefficient of friction and moisture content is presented in Table-3.

**Fig-1: Coefficient of friction of kariya kernel at different moisture content****Table-3: Regression friction using galvanize, stainless and glass of kariya kernel**

Moisture (X, %)	Galvanize Steel	Glass	Stainless Steel
Regression	0.0056X + 0.3858	0.0058X + 0.3662	0.0058X + 0.3505
R <sup>2</sup>	0.9115	0.9767	0.9936

### Influence of Moisture Content on the Thermal Properties of Kariya Kernel

Specific heat capacity of kariya kernel showed a positive linear relationship with moisture content. R<sup>2</sup> value was found to be 0.9381 as shown in Figure 4. Several researchers have observed similar trend between the specific heat capacity and moisture content for Lentil seeds [21]; Borage seeds [22]; Locust beans [23] and Bambara groundnut [11]. The regression equations showing the correlation between the specific heat and moisture content within moisture level considered is as presented in Table-4.

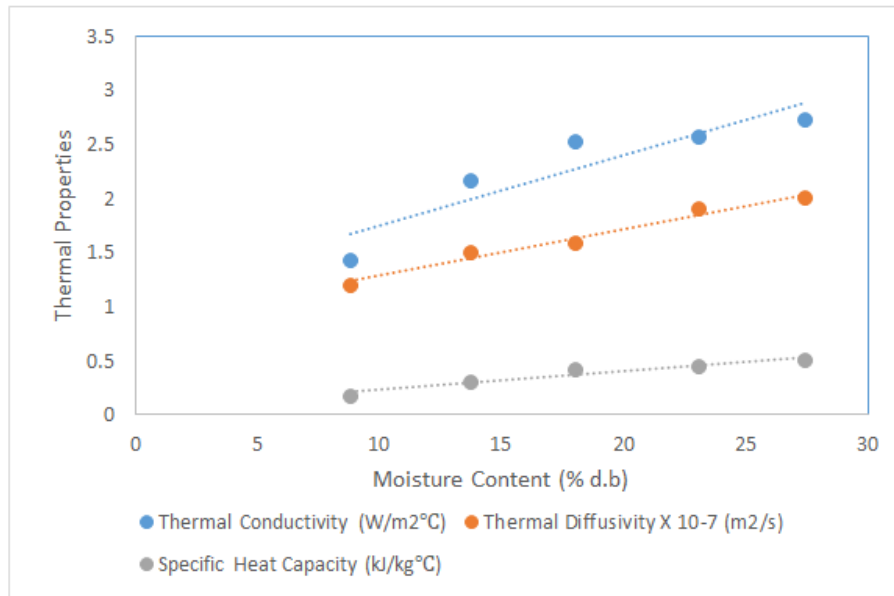
The results of thermal diffusivity was found to increase from  $0.12 \times 10^{-7}$  to  $0.20 \times 10^{-7}$  m<sup>2</sup>/s as moisture content increases. The increase could be as a result of decrease in bulk density of kariya kernel with respect to increase moisture content. Both moisture content and

thermal diffusivity exhibited a positive linear relationship as revealed in Figure-2. The R<sup>2</sup> value for the thermal diffusivity of kariya kernel is 0.9777. The relationship between moisture content and thermal diffusivity is expressed by the regression equations shown in Table-4.

Thermal conductivity of kariya kernel which was found to increase with increase moisture content ranged between 0.17 and 0.51 W/mK (Fig-2). A positive linear relationship explaining the interaction between the thermal conductivity of the kariya kernel and moisture content was observed as shown in Table-4. Linear correlation of thermal conductivity with moisture content for different food materials such as Pistachios, African yam bean and Bambara groundnut have also been documented by various researchers [24,

25, 11]. Table-4 shows the regression equation between

the interactions.



**Fig-2: Variation of thermal properties with moisture content**

**Table-4: Effect of moisture content (X) on the thermal properties of kariya kernel**

Thermal properties	Regression	R <sup>2</sup>
Thermal conductivity	$0.0650X + 1.1021$	0.8393
Thermal Diffusivity	$0.0432X + 0.8546$	0.9777
Specific Heat Capacity	$0.0176X + 0.053$	0.9381

#### 4. CONCLUSION

Some engineering properties which may influence the design and development of postharvest equipment were studied. The findings revealed that the engineering properties of kariya kernel understudied vary significantly with moisture content. The information gathered is important for designing storage equipment, optimization of milling operations and processing machinery which makes the kernel more relevant to postharvest processors.

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