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Original Article

Evaluation of Some Physical and Frictional Properties Necessary for Optimum Kernel Recovery in the Dry-Cracking of Ogbono (*Irvingia)* Nuts

Egbe Ebiyeritei Wisdom[1], Tariebi Karikarisei[2], Ifiemi Tulagha[3]

[1,2,3] *Department of Agricultural and Environmental Engineering, Faculty of Engineering, Niger Delta University Wilberforce Island Amassoma, Bayelsa State, Nigeria.*

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Abstract *- Since cracking nuts requires a lot of labor and frequently results in damaged kernels, this strategy typically reduces the product's market value. In order to examine the possibilities of developing their equipment for handling and processing, the physical and frictional properties were determined for moisture contents of 8.1, 9.7, 10.2, 11.0, and 11.4% wet basis. The size of the seed was measured using a Venier caliper. Investigated were the aspect ratio, seed surface area, seed volume, bulk density, true density, and angle of repose. The results demonstrate that its major, intermediate, and minor diameters ranged from 3.60 cm to 5.0 cm, 4.50 cm to 2.70 cm, and 3.20 cm to 2.0 cm, respectively. Additionally, its seed volume ranged from 8.55-26.86 cm^3, surface area ranged from 19.11 cm to 47.94 cm^2, and equivalent diameter ranged from 4.22 cm to 8.49 cm, and true and bulky density polynomially increased from 3.64 g/cm^2 to 4.33 g/c. As the frictional properties were investigated, it was discovered that the coefficient of static friction increased from 0.60-0.90 (plywood), 0.50-0.82 (mild steel), 0.37-0.70 (glass), and 0.30 to 0.64 (plastic), with plywood providing the highest range of values. This implies that mild steel construction equipment used the most power, followed closely by plywood-built machinery. Designers should use this study's results to qualitatively produce effective and efficient equipment for Dika seeds handling, processing, drying, storing, and cracking kernels.*

Keywords *- Irvingia nut, Regression equation, Moisture content, Physical properties, Frictional properties.*

1. Introduction

A species of African tree in the genus Irvingia called Irvingia Gabonensis is also referred to as "Dika" or "Ogbono." They produce palatable mango-like fruits and are highly prized for their nuts' high glycemic and protein content. The wild mango (Irvingia spp.), commonly known as the dika tree, is an economically and socially significant fruit tree in West and Central Africa. It is a member of the plant family Irvingiacea. The tediousness of its extraction is the main obstacle and issue in using the dika kernel. In rural areas, women handle the wet or dry fruit one at a time and use a machete to split it apart along the fruit's natural cleavage or when it has properly dried.

2. Literature Review

The tree has been identified as one of the essential fruit trees for domestication in the region because of its relative importance to the food industry [1][2][3]. The kernel contains 5.3% dietary fiber, 8.9% protein, 19.7% carbs, 62.8% fats, and 3.2% ash [4][5] and has been integrated into human nutrition to prevent weight gain and regulate dietary lipids [2] [6] [7].

Particularly for its capacity to thicken cuisine, dika kernels are extensively marketed regionally, nationally, and among West African nations. The kernel usage as a foundation material in the production of soap, cosmetics, confectionery, and edible fats, as well as a medicinal binder, further emphasizes its economic significance [6][9][10]. The tree's natural habitat is the moist lowland forests of tropical Africa, despite the fact
it is frequently planted throughout Central and Western Africa [9] [3].

Due to its semi-stony shell, the irvingia nut requires more time to dry before the nut and kernel are completely separated, as opposed to the other nuts like palm, cashew, peanut, and African nutmeg, which dry more quickly when exposed to direct sunlight and need two to three days to dry. Since the kernel and nut were not dried apart before the breaking process, researchers recently built cracking machines but could not achieve 100% efficiency.

3. Materials And Methods

3.1. Materials Used for Drying the Irvingia Nut

Dika nuts collected and skin dried in large quantities were purchased from Swali Market in Bayelsa State, Nigeria. By hand, the nuts were cleaned. The Niger Delta University Department of Agricultural Engineering Processing Lab provided the tools and equipment needed for this operation during drying. Vernier Caliper, Air Oven, Mental Dishes, Weighing Balance, and Intron Universal Testing Machine comprised the equipment.

3.2. Determination of Moisture Content

The original weights of fifteen (15) samples of Irvingia nuts were 8.1, 9.7, 10.2, 11.0, and 11.4; these samples were then divided into three (3) groups and dried at 100, 125, and 150°C. Before drying, the samples were weighed, and weight loss was monitored every ten minutes with an electronic balance until the seed was freed from the shell. The sample's moisture content was calculated, utilizing the proportion of weight loss, which was reported as a percentage of the beginning weight.

$$M_{cwb} = \frac{(wi-wf)}{wi} \times 100 \quad (1)$$

3.3. Seed Dimension

With an accuracy of 0.02mm, a Venier Caliper was used to measure the seed's three main dimensions (L_1, L_2, and L_3).

3.3.1. The arithmetic mean diameter (F_1), geometric mean diameter (F_2), Square mean diameter (F_3), equivalent diameter (D_e)

This was calculated using 2 through 5 [11].

$$F_1 = \frac{(L_1+L_2+L_3)}{3} \quad (2)$$

$$F_2 = (L_1 \times L_2 \times L_3)^{\frac{1}{3}} \quad (3)$$

$$F_3 = \frac{L1L2+L2L3+L3L1\; L_1L_2+L_2L_3+L_3L_1}{3} \quad (4)$$

$$De = \frac{(F_1+F_2+F_3)}{3} \quad (5)$$

where
L_1= major
L_2= intermediate
L_3 = and minor diameters

3.3.2. The aspect Ratio. (Ar)
This was calculated using equation (6) [12].

$$A_r = \frac{L_1}{L_2} \quad (6)$$

3.3.3. Seed Surface Area (A_s) and Seed Volume
This was calculated using equation 7&8 [13].

$$A_s = \frac{\pi BL12}{2L_1-B} \quad (7)$$

$$V = \frac{\pi B2L12}{6(2L_1-3)} \quad (8)$$

3.3.4. Bulk Density
The formula (9) [13] [14]

$$p_b = \frac{Bsam}{Bv} \quad (9)$$

where Bsam is the bulk nut mass, and Bv is the beaker volume

3.3.5. True density (P_t)

The true density was ascertained using the toluene displacement method in place of water. In a graduated measuring cylinder with a 100ml capacity, 500ml of toluene was placed. Five duplicates of the toluene immersion procedure were performed on the seeds from each batch after they had been weighed with an automated weighing balance. The volume was calculated as the amount of displacement. So, using equation 10, determine the true density.

$$P_t = \frac{weight\ of\ seed}{v2-v1} \quad (10)$$

3.3.6. porosity (ε)

Fy=Pb/Pt is a formula that describes how porosity is determined. Equation 11 was used to calculate the porosity in percentage terms [14] [15] [16] [17]

$$\varepsilon = (1-f_y)\times 100\% \quad (11)$$

3.3.7. sphericity (ϕ)

This is calculated using expression (12) [18] [28]

$$\phi = \frac{(LWT)^{\frac{1}{3}}}{L} \quad (12)$$

3.3.8. Angle of Repose ($\emptyset r$)

Using the square box method, this was determined at various moisture concentrations. This technique used a specially created square box with a detachable front cover. Each batch of seeds was placed inside the box, with its front immediately removed so the seeds could flow with their inherent inclination. In order to calculate the angle of repose for the various moisture contents, the height (H) and length (L) of the seeds were both measured together. The equation shown below (13) was employed [20]

$$\emptyset r = \tan^{-1}\left(\frac{H}{L}\right) \quad (13)$$

Where H= maximum height of the seeds in mm; L= spread length in mm

3.4. Frictional Properties
3.4.1. Determination of Static Coefficient of Friction

The static coefficient of friction for distinct sample batches was determined for three different structural materials: steel metal plate, plywood, plastic, and fiber glass. The samples from each batch were placed and full to the brim in a carton of St. Louis sugar dimension, which was then flipped over and placed on the surface of the adjustable tilling table in order to keep the edges from coming into touch with the structural component surface, a little portion of the carton was removed. The tilt angle was subsequently determined using a protractor. [21][22].

$$\mu = \tan\alpha \quad (14)$$

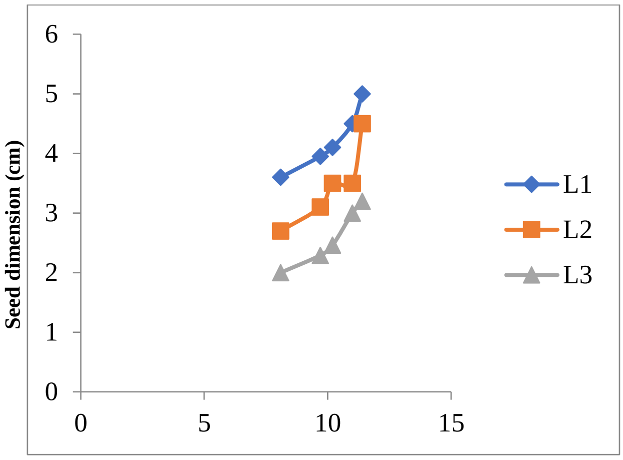
4. Results and Discussions
4.1. Physical Properties

The almonds were separated into five (5) batches, each of which had their moisture content measured at 8.1-12.0% (wet basis). By averaging the replicate data as shown in Table 1, the averages of each batch volume, major, intermediate, and minor diameters were calculated.

Table 1. Batch average of dimensions

MC	L1(cm)	L2(cm)	L3(cm)	F1(cm)	F2(cm)	F3(cm)
8.1	4.61	3.71	3.1	3.78	3.45	8.45
9.7	4.96	4.11	3.30	4.12	3.73	10.24
10.2	5.11	4.51	3.47	4.36	3.92	11.08
11.0	5.51	4.51	4.01	4.67	4.19	12.26
11.4	6.1	5.51	4.22	5.24	4.62	15.66

4.2. Seed Dimensions



MOISTURE CONTENT %

Fig. 1 Effect of moisture content on seed dimensions

The typical major, intermediate, and minor diameters range from 8.1% to 11.4% wet basis, depending on the moisture content, were found to vary between 4.61 - 5.0 cm, 3.71 - 5.51 cm, and 3.00 - 4.22 cm, respectively. The diameter of each seed increased nonlinearly when moisture content rose, as shown in Fig. 1. The following regression models (Equations 15-17) were created to account for the impact of seed dimension on moisture content. It is advised that the best connection between these qualities and moisture content be a linear one.[12][13][14][23] all suggested a linear relationship between seed size and moisture rise.

$$L_1 = 1149.4M^2 - 196.82M + 9.69 \quad R^2 = 0.9862 \qquad (15)$$

$$L_2 = 1417.5M^2 - 217.31M + 13.563 \quad R^2 = 0.9817 \qquad (16)$$

$$L_3 = 1432M^2 - 232.70M + 13.174 \quad R^2 = 0.9514 \qquad (17)$$

4.3. Seed Volume and Surface Area

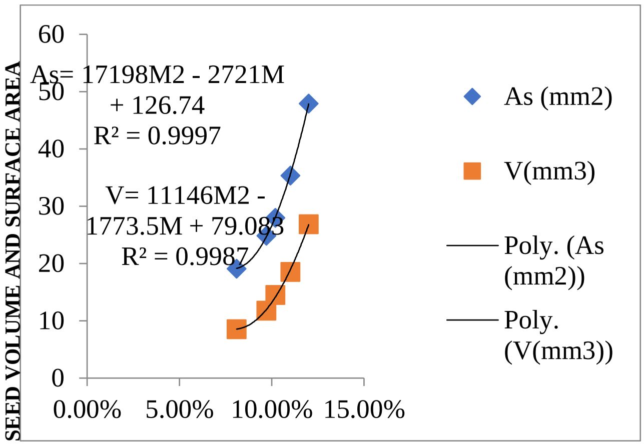
Table 2. Seed volume and surface area are impacted by seed moisture content.

MC LEVEL	V(cm^3)	As (cm^2)
8.1%	8.55	19.11
9.7%	11.80	24.88
10.2%	14.52	27.97
11.0%	18.56	35.35
11.4%	26.86	47.94

From Table 2, the size of the seeds varied from 8.55 cm^3 to 26.86 cm^3 in volume and from 19.11 cm^2 to 47.94 cm^2 in surface area. The subsequent 18 and 19 of the polynomial regression models

$$As = 17198M^2 - 2721M + 126.74 \quad (R^2 = 0.9997) \qquad (18)$$

$$V = 11146M^2 - 1773.5M + 79.083 \quad (R^2 = 0.9987) \qquad (19)$$



MOISTURE CONTENT (%)

Fig. 2 Shows the volume and surface area of seeds as a result of moisture.

With a rise in moisture content, the size of the seed and its surface increased polynomially, as seen in Figure 2 above. It contrasts with the findings of certain researchers, such as [12], who hypothesized that seed volume and area would grow linearly as corn's moisture content rose. [24].

4.4. Equivalent Diameter

Table 3. Effect of moisture content on equivalent diameter

MC LEVEL(%)	De (cm)
8..1	5.21
9.7	6.08
10.2	6.79
11.0	7.8
11.4	9.48

The equivalent diameter in Table 3 and Figure 3 exhibited a quadratic growth with increasing moisture content, as demonstrated in (equation 20).

$$DE = 0.431M^2 - 7.2172M + 34.436 \quad R^2 = 0.965 \qquad (20)$$

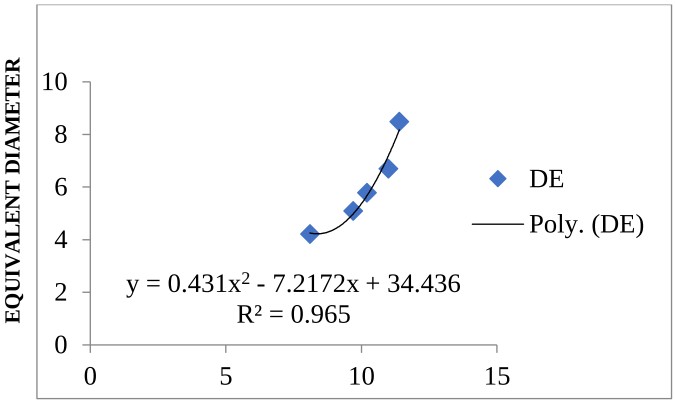


Fig. 3. Moisture content's impact on equivalent diameter

4.5. Aspect Ratio and Sphericity

As moisture increased, a quadratic drop in seed sphericity happened gradually, as seen in Table 4 below. It shows that when the seed's basic dimensions rise in relation to the moisture content, the seed is getting closer to being a sphere. A third polynomial growing trend was visible in the aspect ratio, on the other hand. To achieve this, the 21 and 22 regression models were created.

$$A_r = 0.0008x^2 + 0.0246x + 0.4919 \quad R^2 = 0.9137 \qquad (21)$$

$$\emptyset = -0.0003x^2 - 0.0042x + 0.9938 \quad R^2 = 0.9921 \qquad (22)$$

Table 4. Effect of moisture content on aspect ratio and sphericity

MC LEVEL	A_r	∅
8.1	0.76	0.76
9.7	0.79	0.78
10.2	0.86	0.81
11.0	0.88	0.85
12.0	0.91	0.86

[12] proposed a linear for the sphericity and aspect ratio of corns. For the parkia fillicoidea specie of paddy grain and locust bean, respectively, [13][24] [25] suggested a linear behavior as well. [25] proposed a power model for African breadfruit seeds, [6] offered a model for the quadratic polynomial regression that accounts for how moisture affects the sphericity of Roselle seeds.

4.6. Angle of Repose

Table 5. Angle of repose is affected by moisture content

MC	θr
8.1	23.00
9.7	27.00
10.2	30.00
11.0	34.00
12.0	35.00

The moisture content of Dika nut seeds rose from 8.1% to 11.4% wet basis, causing the angle of repose ($\emptyset r$) to increase from 23.00° to 35.00°.

It might result from the seeds becoming more cohesive when moisture content rises because they weigh more, have higher inertia, and are less flowable. Seeds cannot slide on each other due to the increased flow resistance, which raises the angle at which the seed rests. Figure 4 illustrates this in [27] for green grain, [13] for lentil seeds, and [29] for dried pomegranate seeds. It was created in Equation 23.

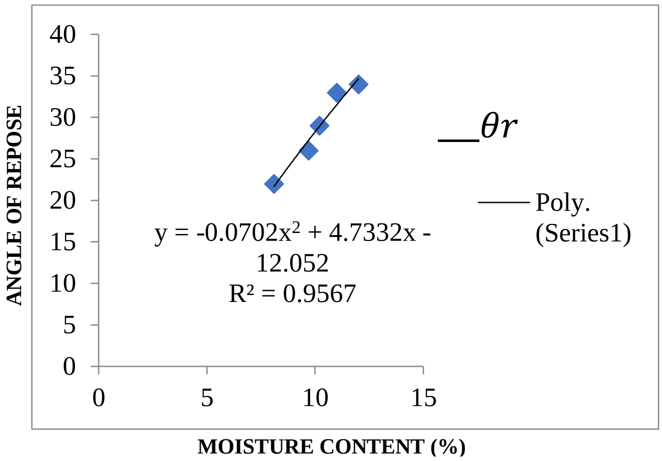


Fig. 4 Effect of moisture content on the angle of repose

$$\phi r = -0.0702x^2 + 4.7332x - 12.052 \quad R^2 = 0.9567 \qquad (23)$$

4.7. Density

Table 6. Effect of bulk and true density on moisture content

Moisture content (%)	Bulk density g/cm^2	True density g/cm^2
8.1	3.64	10.31
9.7	3.80	10.72
10.2	4.10	11.0
11.0	4.22	11.63
12.0	4.33	12.26

$$\text{Bulkdensity} = 0.0919M^2-1.3306M+15.042 \quad R^2=0.9923 \qquad (24)$$

$$\text{True density}= 0.0001M^2+0.1933M+2.0617 \quad R^2=0.9234 \qquad (25)$$

Figure 5 illustrates this relationship, showing that true density rises polynomially from 10.31 g/cm^2 to 12.26 g/cm^2, while bulk density increases polynomially from 3.64 g/cm^2 to 4.33 g/cm^2. According to [14], lentil seeds' true and bulk density should behave linearly regarding the moisture content variable. According to [30], the true and bulk densities for the average safe storage density of the yam bean should be 1.01779g/cm^2 and 1.0036g/cm^3, respectively. [27] proposed a linear rise in green gram density from 1363 kg/m^3 to 1292 kg/m^3 (true density) and from 807 kg/m^3 to 708 kg/m^3 (bulk density). Regression models are created in equations 24 and 25.

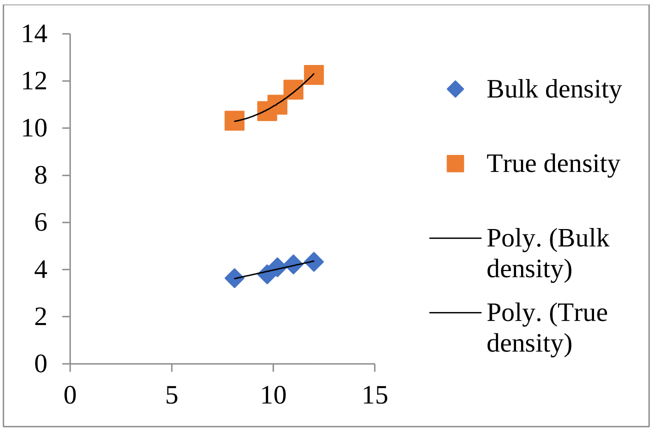


Fig. 5 Effect of moisture content on Bulk density and True density

4.8. Frictional Properties

Table 7. Effect of moisture content on static coefficient of friction

MC %	Plywood	Mild steel	Plastic	Glass
8.1	0.61	0.51	0.31	0.38
9.7	0.69	0.57	0.36	0.43
10.2	0.75	0.73	0.48	0.57
11.0	0.86	0.79	0.59	0.66
11.4	0.93	0.84	0.65	0.74

Plywood has a higher coefficient of static friction than mild steel, plastic, or glass because its material grains are rougher. As a result, both a rise in moisture content and an increase in the coefficient of static friction increase the power needed for machinery that processes friction. It suggests that more power will be needed for machines made of plywood than for equivalent machines made of mild steel.

5. Conclusion

The embedded kernel in a dika nut is roughly elliptical, and the nut is reasonably spherical, although the sizes of the two are unrelated. Within the analyzed moisture content range (8.1, 9.7, 10.2, 11.0, and 12.0% (at a wet basis), it was discovered that every property under investigation responded to an increase in moisture content polynomially. According to the moisture content, the seed volume and surface area rose from 8.55 to 26.86 cm^3 and 19.11 to 47.94 $cm^{2,}$ respectively. Within the moisture content range investigated, the aspect ratio, sphericity, and porosity increased from 0.75 to 0.90, 0.89 to 0.86, and 0.41 to 0.61, respectively.

Plywood has a higher static coefficient of friction, followed by mild steel. The angle of the ratio increased from 23.00 to 35.00. The following suggestions are given for more research on this topic based on what was observed throughout the experiment. The pertinent information gathered is valuable for designing and creating devices that can crack kernels. It is advised that designers use this study's findings to build high-quality tools that are reliable and practical for working with processing and storing Dika seeds.

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