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# Determination of some Physical Properties, Angles of Repose and Frictional Properties of a Local Variety of Kernel and Nut of Oil Palm

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**Abstract**
*The study was to determine the moisture content, size, volume, sphericity, solid density, bulk density and porosity, angle of repose, coefficient of static friction and compressive strength of oil palm kernel and nut. The results show that the moisture contents were 7.94% and 25.31% for the kernel and nut respectively. The arithmetic and geometric mean diameters were 1.56 cm and 45.79 cm (kernel) and 0.87 cm and 1.27 cm (nut). The average volumes were, 1.75 cm3 (kernel) and 0.79 cm3 (nut). The average sphericities were 66.37 % (kernel) and 64.36 % (nut). The average solid densities, bulk densities and porosities of the samples were 1.63 g/cm3, 0.00053 g/cm3 and 61.32 % (kernel) and 2.13 g/cm3, 0.0008 g/cm3 and 46.91 % (nut). The average values for the angles of repose on wood were 20.8 0 (fresh), 22.81 0(boiled), 19.09 0 (kernel) and 60.71 0 (nut). On glass, the angles of repose were 17.53 0 (kernel) and 64.08 0 (nut). Those on metals were, 18.55 0 (kernel) and 62.3 0 (nut). The coefficients of static friction on wood were 0.35 (kernel) and 1.89 (nut). On glass, coefficient of static friction was 0.32 (kernel) and 2.18 (nut). Those on metals were 0.34 (kernel) and 2.0 (nut).*

**Keywords:** Oil palm; Kernel Nut; Physical Properties

## 1.0 INTRODUCTION

The oil palm (Elaeis guineensis) belongs to the family of palmae and is a major tropical tree crop in Nigeria. Palm oil is the most important product of the oil palm fruits and is also used for soup making [1]. The oil palm fruit embedded hard-shelled nut containing the palm kernel which is rich in palm kernel oil [2].

Many products are derivable from the oil palm plant. These are palm oil, palm kernel oil, palm kernel cake, fiber, palm wine, fatty alcohol, broom and wood plank. Harvested palm bunches undergo processing stages of stripping sterilization, digestion and palm oil extraction. The meal obtained after oil extraction from the palm kernel nut is useful in formulating animal feed. Two types of oil are produced from the oil palm. These are red palm oil from the fruit and white oil from the kernel. The kernel oil content of is about 47% [3]. The fatty acid composition of the palm oil is very different from that of the palm kernel oil. Typically, for tenera fruit, 100 tons of fresh fruit bunches will yield 21 tonnes of oil and 6 tonnes of decorticated palm kernel oil [4]. This palm kernel oil represents 12% of total oil production.

Inadequate knowledge of engineering properties of biomaterials will lead to poor design and construction of handling equipment especially for fresh and boiled materials which in turns reduces its availability as so much will be lost during processing and storage. Selected engineering properties such as physical, mechanical, rheological, etc, are very important in the design of handling machines for major agricultural crops. Oil yield and quality have been reported to depend on design parameters [5]

Improvement of technology for processing palm fruit, nut and kernel requires accurate information on the engineering properties of the crop. Physical properties such as moisture content, size, shape, sphericity, mass, volume, solid density, bulk density and porosity and mechanical properties such as angle of repose, coefficient of friction and compressive strength are very important in the design of processing machines for agricultural crops. The objective of this study is to determine some engineering properties of fresh and boiled palm fruits, the kernels and nuts.

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## 2.0 MATERIALS AND METHODS

The local variety of palm fruits used for this study was sourced from Apumiri Ubakala Market Umuahia South L.G.A, Abia State, Nigeria. One thousand (1000) samples of the fresh fruits were selected, cleaned manually to remove all foreign materials and conditioned for two days. From the 1000 samples, 100 of the fresh fruits were selected at random and weighed. From the weighed sample, 10 fresh fruits were again selected at random and the moisture contents were determined. The 10 samples were boiled and allowed to cool for 30 minutes. The same sample was processed and the moisture contents of the kernel determined. The kernels were cracked manually and the moisture content of the nuts determined. Oven drying method was used at 105$^0$C for 20 hrs in all the cases. The average moisture contents of the samples M in % (wet basis) were calculated using the relationships as described by [6] as below:

$$\text{Mc (Wb)}\% = \frac{Ww - Wd}{Ww} \times 100\% \qquad (1)$$

where: $w_w$ = Weight of wet samples (g) $w_d$ = Weight of dried samples (g) and $w_b$ = Wet basis

The linear dimensions of the kernels and nuts referred to as major (A), intermediate (B) and minor (C) diameters were measured using a vernier caliper (Kanon Instrument, Japan) with reading accuracy of 0.01mm. Hence the measurement of the 100 samples of all size indices was replicated for both boiled, kernel and nut of palm fruit. The arithmetic and geometric mean diameter were calculated from the following relationship as described by [7].

$$D_a = \frac{A + B + C}{3} \qquad (2)$$

$$D_g = (A \times B \times C)^{\frac{1}{3}} \qquad (3)$$

where: $D_a$ = arithmetic mean diameter (cm), $D_g$ = geometric mean diameter (cm), A= major diameter (cm), B= intermediate diameter (cm) and C= minor diameter (cm)

For the sphericity ($S_C$), the dimensions obtained for the 100 samples were used to compute the index as described in [8]:

$$Sc = \frac{(A \times B \times C)^{1/3}}{L} \times 100 \qquad (4)$$

Where symbols still remain the same as described above.

The mass of individual sample for both the kernel and nut of palm fruit was determined using electronic weighing balance (Scout Pro SPU 40L, China) to an accuracy of 0.1g and the volume of the individual sample for kernel and nut was determined by taking the dimensions of the three linear axes and it was estimated using the following relationship given by [9]:

$$V = \frac{\pi AB\backslash C}{6} \quad \text{in } cm^3 \qquad (5)$$

The solid density, $\rho_s$, was determined using the relation:

$$\rho_s = \frac{M}{V} \quad \text{in g}/cm^3 \qquad (6)$$

The bulk fruit was put into containers whose weight and volume were known and was weighed with three replications and average values were recorded.

The porosity (P) was determined using the density (bulk and solid) parameter as described by [7] as:

$$\text{P} = 1 - \left(\frac{\rho_b}{\rho_s}\right) \times 100 \quad in \quad \% \qquad (7)$$

where: M= mass (g), V= volume (cm$^3$), $\rho_s = solid\ density$ and $\rho_b = bulk\ density$

Each sample was placed on plywood for the angle of repose which rests on a table in a conical form. The plywood was then tilted until the sample began to slide freely. The height the plywood made with the tape as at the time of free flow and horizontal distance taken. The experiment was replicated for both the glass and metal.

Angle of repose was then determined using the relationship:

$$\alpha = tan{-}^1 \, {}^{h_1}/_{h_2} \qquad (8)$$

Where $\alpha$ = angle of repose ($^0$), $h_1$ = vertical height (cm) and $h_2$ = horizontal length (cm)

The coefficient of friction of the sample was determined by using the angle of repose found against three structural materials (plywood, glass and metal). It was estimated using the following relationship as described in [10].

$$\mu = Tan\alpha \qquad (9)$$

Where: $\mu$ = coefficient of friction and $\alpha$ = angle of repose

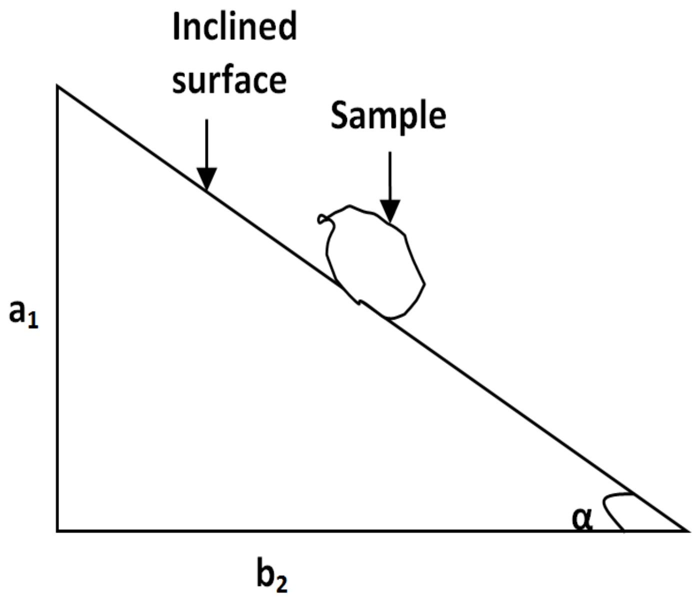


**Figure 1:** Determination of angle of repose of kernel and nut samples

## 3.0 RESULTS AND DISCUSSION

### *3.1 Physical Properties*

The moisture contents of the samples as shown in Table 3.1 were 7.94 % (kernel) and 25.31 % (nut). From the result, the nut gave higher moisture content than the kernel. This could probably be as result of the presence of the shell. The diameters (major, intermediate and minor) of the samples were given in the Table. From the Table, the major diameters were 2.24 cm (kernel) and 1.27 cm (nut). The intermediate diameters were 1.28 cm (kernel) and 0.78 cm (nut) and the minor diameters were 1.15 cm (kernel) and 0.55 cm (nut). The average arithmetic mean diameters were 1.56 cm (kernel) and 0.87 cm (nut), while the geometric mean diameters were 45.79 cm (kernel) and 0.23 cm (nut). From the results, removal of endocarp decreased the size of kernel from 1.56 cm to 0.87 cm (nut).

The sphericity indices of the samples were also presented in Table 1. From the Table, the average sphericity indices were 66.37 % (kernel) and 64.36 % (nut). From the result, the nut had a lower sphericity. This shows that the sample is neither round nor spherical, but will always tend to roll when they are on a particular orientation. This agrees with the result realized in [11-12] for dura variety as also reported by Adama, *etal*, 2022.

The masses of the samples as shown in the Table were (kernel) and 0.58 g (nut). From the results, the nut gave lower mass which could be because of the low shell.

The volumes of the samples were presented in the Table 3.1. The volumes were 1.75 $cm^3$ (kernel) and 0.79 $cm^3$ (nut). From the result, the nut sample gave the lower value. These help to know the three dimensional measure of space in the design of the handling units of the machinery.

The solid density and bulk density of the samples were presented in Table 3.1. From the table, the solid densities were 1.66 g/ $cm^3$ (fresh), 1.32 g/ $cm^3$ (boiled), 1.62 g/ $cm^3$ (kernel) and 2.13 g/ $cm^3$ (nut). This shows that there is much compaction in the nut sample compared to others. The bulk densities were 0.00054 g/ $cm^3$ (fresh), 0.00054 g/ $cm^3$ (boiled), 0.00053 g/ $cm^3$ (kernel) and 0.0008 g/ $cm^3$ (nut). Mijinyawa and Omoikhoje in [12] studied the true density of dura palm kernel and nut. The values ranged from 0.8 g/$cm^3$ to 2.0 g/$cm^3$ for palm nut while kernel density ranged from 0.93 g/$cm^3$ to 1.33 g/$cm^3$. The present result is within the mentioned range.

The porosity of the samples was presented in Table 3.1. From the table, the porosities were 60.21 % (fresh), 75.72 % (boiled), 61.32 % (kernel) and 46.91 % (nut). From the result, the boiled sample gave the highest porosity while the nut gave the lowest porosity.

Statistical analysis performed on the data showed that the coefficient of variation for kernel, the length, thickness, AMD, and sphericity are in very good range while the width and solid density are in good range. The mass falls under acceptable range but the range for the moisture content is within unacceptable range indication high variation in the data obtained. For the nut, the mass and solid density fell within acceptable range while AMD, width, thickness volume, spherity, fell under good range. The length and GMD are within very good range.

**Table 3.1:** The results obtained show that differences exist between the mechanical and physical properties of the palm fruit [11-12]

| **Properties** | **Kernel** | **Nut** |
|---|---|---|
| **Mass(g)** | | |
| Mean | 2.78 | 0.58 |
| Std. Dev | (±0.6) | (±0.13) |
| Co. Variance **(%)** | 21.58 | 22.41 |
| **Length(cm)** | | |
| Mean | 2.24 | 1.27 |
| Std. Dev. | (±0.16) | |
| Co. Variance **(%)** | 7.14 | 7.99 |
| **Width(cm)** | | |
| Mean | 1.28 | 0.78 |
| Std. Dev. | (±0.18) | (±0.12) |
| Co. Variance **(%)** | 14.06 | 15 |
| **Thickness(cm)** | | |
| Mean | 1.15 | 0.55 |
| Std. Dev. | (±0.09) | (±0.1) |

| Properties | Kernel | Nut |
|---|---|---|
| Co. Variance **(%)** | 7.82 | 18.80 |
| **AMD** | | |
| Mean | 1.56 | 0.87 |
| Std. Dev. | (±0.14) | (±0.09) |
| Co. Variance **(%)** | 8.97 | 10.34 |
| **GMD** | | |
| Mean | 45.99 | 23.00 |
| Std. Dev. | (±0.14) | (±0.23) |
| Co. Variance **(%)** | 0.31 | 10.00 |
| **Volume($cm^3$)** | | |
| Mean | 1.5 | 0.79 |
| Std. Dev. | (±0.47) | (±0.1) |
| Co. Variance **(%)** | 31.00 | 12.65 |

**Table 3.2:** Physical Properties of Palm Kernels and Nuts sphericity (%)

| Properties | Kernel | Nut |
|---|---|---|
| Mean | 66.37 | 64.36 |
| Std. Dev. | (±3.59) | (±7.05) |
| Co. Variance **(%)** | 5.40 | 10.95 |
| **Solid Density (g/$cm^3$)** | | |
| Mean | 1.63 | 2.13 |
| Std. Dev. | (±0.3) (±0.53) | |
| Co. Variance **(%)** | 18.40 | 24.88 |
| **Bulk Density (g/$cm^3$)** | 0.00052 | 0.0008 |
| **Porosity (%)** | 61.32 | 46.91 |
| **Moisture Content ($W_b$)** | | |
| Mean | 7.94 | 25.31 |
| Std Dev. | (±3.79) | (±4.21) |
| Co. Variance **(%)** | 47.73 | 16.87 |

### *3.2 Angles of Repose*

The angles of repose of the samples were presented in Table 3.2. From the Table, the angles of repose of the kernel samples on the surfaces were $19.09^0$ (wood), $17.53^0$ (glass) and $18.45^0$ (metal), while that of the nut samples were $60.70^0$ (wood), $64.08^0$ (glass) and $62.30^0$ (metal). Based on studies in [11], the dynamic angle of repose values obtained on plywood, aluminum, mild steel and galvanized steel were found to be $22.01^0$, $21.01^0$, $19.91^0$ and $22.23^0$, respectively. These variations in the angles of repose values obtained on the three surfaces may indicate that samples have neither very smooth nor rough surface.

The coefficients of static friction of the samples were also given in Table 3.2. From the Table, the coefficients of static friction of the kernel samples, the results were 0.35 on wood, 0.32 on glass and 0.34 on metal sheet. For the nut sample, the results were 1.89 on wood, 2.18 on glass and 2.0 on metal sheet. From the results, there was a small and insignificant difference in the coefficient of friction obtained on wood, glass and metal sheet of each of the samples. But the nut samples gave the highest coefficient of static friction which might have been due to the moderating influence of the rough surface compared to the other samples. According to Tabatabaeefar in [12], *Adama etal, 2022* observed similar trends in the static coefficient of friction of wheat and local variety of fresh and boiled palm fruit respectively. He recorded lowest static coefficient of friction on glass surface followed by galvanized iron and lastly plywood. The reason for higher coefficient of friction on the boiled samples might have been due to the increase in moisture content.

**Table 3.3:** Angles of Repose and Frictional Properties of Palm Kernels and Nuts [12, 14].

| Angle of Repose on Wood Surface | Kernel | Nut |
|---|---|---|
| Mean | 19.09 | 60.71 |
| Std. Dev. | (±4.78) | (±6.74) |
| Co. Variance **(%)** | 3.99 | 9.0 |
| **Angle of Repose on Glass Surface** | | |
| Mean | 17.53 | 64.08 |
| Std. Dev. | (±4.44) | (±6.19) |
| Co. Variance **(%)** | 25.32 | 9.65 |
| **Angle of Repose on Metal Surface** | | |
| Mean | 18.55 | 62.3 |
| Std. Dev. | (±4.5) | (±6.05) |
| Co. Variance **(%)** | 24.25 | 9.71 |
| **Coefficient of Friction on Wood Surface** | | |
| Mean | 0.35 | 1.89 |
| Std. Dev. | (±0.1) | (±0.52) |
| Co. Variance **(%)** | 28.57 | 27.51 |
| **Coefficient of Friction on Glass Surface** | | |
| Mean | 0.32 | 2.18 |
| Std. Dev. | (±0.09) | (±0.61) |
| Co. Variance **(%)** | 28.12 | 27.98 |
| **Coefficient of Friction on Glass Surface** | | |
| Mean | 0.34 | 2.0 |
| Std. Dev. | (±0.09) | (±0.52) |
| Co. Variance **(%)** | 26.47 | 26.00 |

## 4.0 CONCLUSIONS

The following conclusions are drawn from the results of this study:

The angles of repose and frictional properties of kernel and nut of a local variety of oil palm have been determined.

For all the properties determined, the palm nut recorded higher values than the kernel. The implication of this is that the cover has effects on the properties of the products (kernel and nut). In other words separate machines are to be used in handling the different products.

The coefficients of variation for all the properties except for moisture content and volume are within acceptable range.

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