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Determination of Some Engineering Properties of Fresh and Boiled Oil 6 Palm Fruits

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Abstract

Palm fruit is a product of oil palm and consists of the nut, the kernel, the fibre, oil and water. These components are separated by way of processing to get the desired products. For rational design of the handling systems, the engineering properties of the products are very important. A research was carried out to determine some engineering properties of fresh and boiled palm fruits. The properties determined are moisture content, sphericity solid and bulk densities, porosity, angles of repose and coefficients of friction. One thousand samples of the products were selected, conditioned and used for the experiments. The geometric and arithmetic mean diameters, volume, size and spherisity were calculated from the axial dimensions. The moisture contents were determined using gravimetric method. The angles of repose and coefficients of friction were determined on wood, glass and metal surfaces. The solid and bulk densities, porosity and compressive strength were determined using standard procedure. Results gave average moisture content of the fresh fruits to be 24.63 % and that of the boiled as 15.25 %. For the arithmetic and geometric mean diameters, the results were 1.9 cm and 580.6 cm respectively (fresh); 2.05 cm and 965.77 cm respectively (boiled), The average sphericities were calculated to be 70.7 % (fresh), and 73.28 % (boiled),. The average solid and bulk densities were 1.66 g/cm^3 and 0.00054 g/cm^3 respectively for fresh fruits, 1.32 g/cm^3 and 0.00054 g/cm^3 for the boiled product. The porosities of the samples were 60.21 % (fresh), and 75.73 % (boiled), The average values for the angles of repose on wood were 20.8 ^{0} (fresh), 22.81 ^{0}(boiled), On glass, the angles of repose were 18.09 ^{0} (fresh), 21.99 ^{0} (boiled), On the metal surface, the angles of repose were 19.45 ^{0} (fresh), 21.7 ^{0} (boiled), The coefficients of static friction on wood were 0.38 (fresh), and 0.42 (boiled), On glass surface, the coefficient of static friction were 0.33 (fresh), 0.44 (boiled) while that of metals surface gave the coefficient of static friction were 0.35 (fresh), 0.4 (boiled).

Keywords: Oil Palm; Palm nuts; Engineering Properties; Fresh Palm Fruits; Boiled Palm Fruits

1.0 INTRODUCTION

Oil palm fruit is a product of oil palm (Elaeis guineensis) and consists of the nut, the kernel, the fibre, oil, water, etc. The constituents are separated by way of processing to get the desired products. The fruit grow in massive clusters and in bunches which weighs between 5 kg to 10kg [1]. The fruits range in sizes from less than I inch to 2 inches and are red and black when ripe [2]

In the sixties, palm produce was the major source of income for the government of the old Eastern region whose economy was then adjudged to be the fastest growing in the whole world. Palm produce is seen as a mortgage lifter and a big income earner. The economy of Malaysia today depends on palm produce.

Some of the processes involved in processing operation for palm produce include; boiling, cooling, digestion, pressing/squeezing, separation, etc. In palm fruit processing, two basic methods are involved. These are traditional and mechanized. Traditional method is full of drudgery, time consuming, slow rate and increase in losses. For increased palm oil yield, reduced drudgery, high efficiency, mechanization of palm fruits processing is imperative. Mechanization in agricultural production and processing is the introduction of some forms of mechanical assistance to human power in carring out operations in agriculture.

Over the years, there have been calls for indigenous designs and manufacture of agricultural machines to handle local products since imported machines from the temperate regions are not suitable in the environment [3]. The machines from the temperate regions are seen to be too costly beyond the financial reach of the poor farmer. The machines are also known to be technically too complex and do not suit the tropical environment. Rational design and manufacture of local

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machines requires engineering properties of the products to be handled. Knowledge of engineering properties of agricultural products to process will reduce waste of materials of construction, cost of manufacture of the machinery, mechanical injury on the materials being handed by ensuring precision in the process.

Researchers have been carryng out studies on engineering properties of oil palm fruits. For instance, [4], investigated the physical and mechanical properties of two varieties of oil palm fruit. The varieties investigated were dura and tenera. And the properties studied are size, sphericity index, aspect ratio, true density, bulk density, porosity, cracking force, pressure, dynamic angle of repose and coefficient of friction. Morakinyo et al (2019) [5] determined some engineering (mechanical, physical and thermal) properties of palm nuts, kernel shell, fibre and woods for effective mill equipment design. The properties determined were maximum deflection, hardness value, and energy of at breaking and young modulus. Some of the results were 9.62, 2.76, and 26.18 mm; 2,707.28, 3,156.00 and 15,383.14N; 2.80, 1.65 and 7.29Nm; 39,622.89, 23, 810.44 and 76,199,60Nm^2 for palm nuts, kernel shells and fibre of dura cultivars respectively.

The objective of this paper is to present an experiment conducted to determine selected engineering properties of local variety of fresh and boiled oil palm fruits. [6] investigated physical and mechanical properties of palm fruit, kernel and nut. The parameters investigated were linear dimensions, mean diameters, sphericity, surface area, volume, true and bulk densities, porosity, angle of repose and static coefficient of friction. [7], proposed average values of some engineering properties of palm kernels. [8], determined some engineering properties of palm nuts, kernel shell, fibre and woods for effective mill equipment design.

Most the works as reviewed were done on improved varieties of palm fruits. Again, some of the works did not state whether the fruits worked were fresh or boiled. The ones that gave the state of the products indicated that the works were for fresh fruits. In as much as we encourage adoption improved varieties of palm fruits, local varieties are still being processed in many towns and villages in Nigeria. Also, many unit operations on palm fruits processing are done on boiled ones. These call for the need for continued studies on Engineering properties of fruits.

The objective of this study is to determine some engineering properties of local variety of palm fruits in Ubakala areas of Umuahia South Abia state Nigeria.

2.0 MATERIALS AND METHODS

2.1 Sourcing and Conditioning of the Palm Fruits

The local variety of palm fruits used for this study was sourced from a local market at Ubakala in Umuahia South Local Government Area of Abia state. One thousand (1000) samples of the fresh fruits were selected, and cleaned manually. This was done to remove all foreign matters such as dusts, pebbles, broken and rotten fruits. One hundred samples of the fresh fruits were selected at random from the one thousand fruits and weighed.

2.2 Determination of the Moisture Content of the Palm Fruits

Ten fresh fruits were further selected at random from the conditioned and weighed samples. Another set of 10 samples were selected at random, boiled and allowed to cool for 30 minutes and the weight determined. The sets were oven dried for 20 hours at 105^{0}C. The moisture contents of the two sets of samples were determined using the relationships as described by [9] as below:

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

Where:
M_c = Moisture content, %, w_w= Weight of wet samples (g); w_d= Weight of dried samples (g) and W_b =Wet basis

2.3 Determination of the Arithmetic and Geometric Mean Diameters

For each fruit, the linear axial dimensions; major (L), intermediate (W) and minor (T) 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 fresh and boiled fruits. The arithmetic and geometric mean diameter samples were calculated from the following relationships as described by [10]

$$D_a = \frac{L + W + T}{3} \quad (2)$$

$$D_g = (L \times W \times T)^{\frac{1}{3}} \quad (3)$$

where:
D_a= arithmetic mean diameter (cm),
D_g= geometric mean diameter (cm),
L= major diameter (cm),
W= intermediate diameter (cm) and
T= minor diameter (cm)

2.4 Determination of the Sphericity and Volume

The average sphericity and volume of the sample were calculated from the values obtained from the axial dimensions.

For the sphericity (S_C), the dimensions obtained for the 100 samples were used to compute the index as described by [11].

$$Sc = \frac{(L \times W \times T)^{1/3}}{L} \times 100 \quad (4)$$

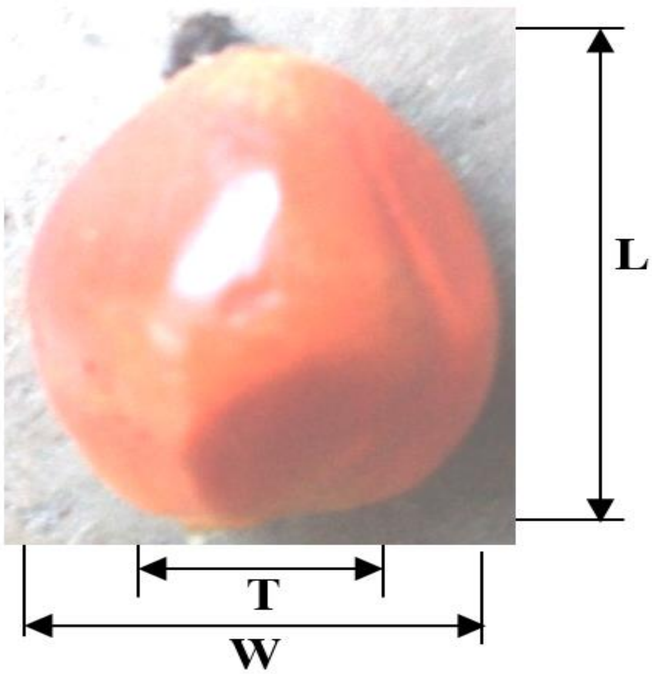

Fig. 1: Determination of axial dimensions of palm fruit

Where symbols still remain the same as described above.

For the volume, the mass of individual sample for both fresh and boiled palm fruit was first determined by using electronic weighing balance (Scout Pro SPU 40L, China) to an accuracy of 0.1g and the volume of the individual sample for both fresh, boiled fruits was determined by taking the dimensions of the three linear axes and it was estimated using the following relationship given by [10]

$$V = \frac{\pi LWT}{6} \quad (5)$$

where: V= Volume of sample (cm^3), L =Major diameter of sample (cm), W= Intermediate diameter of sample (cm) and T= Minor diameter of sample (cm)

2.5 Determination of the Solid, Bulk Densities, Porosity Angles of Repose and Coefficient of Frictions

Solid density was determined for the products using:

$$\rho_s = \frac{M}{V} \; in \; \frac{g}{cm3} \quad (6)$$

The bulk fruit was put into containers whose weight and volume were known and was weighed. Both the fresh and boiled of the sample were replicated three times and their average values recorded.

Porosity (P) was determined using the relation of densities (bulk and solid) parameter as described by [10] as:

$$\mathrm{P} = 1 - \left(\frac{\rho_b}{\rho_s}\right) \times 100 \quad (7)$$

where: M= mass (g), V= volume (cm^3), ρ_s = solid density and ρ_b = bulk density

For the angle of repose, 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 (opposite side) of the plywood was measures with the tape as at the time of free flow and horizontal distance (adjacent) taken. The experiment was replicated for both the glass and metal.

Angle of repose was then calculated using the relationship:

$$\theta = tan{-}^1 \left({}^{h_1}/_{h_2}\right) \quad (8)$$

Where: θ= angle of repose (^{0}), h_1= vertical height (cm) and h_2= horizontal length (cm)

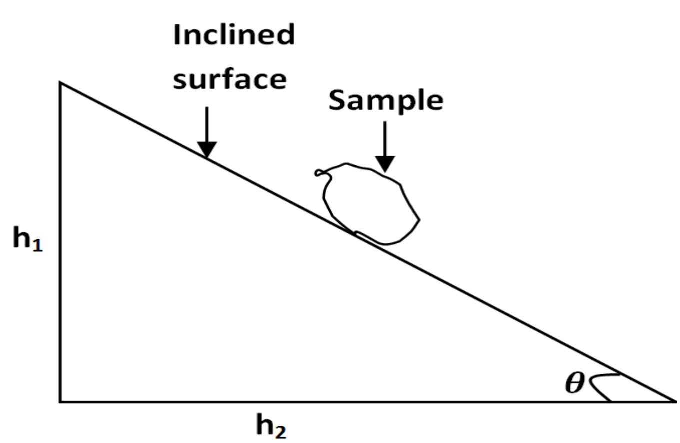

Fig. 2: Determination of angle of repose of the samples

The coefficients of friction of the samples were determined by using the angle of repose found against the three structural materials (plywood, glass and metal). It was estimated using the following relationship as described by [12]:

$$\mu = Tan\theta \quad (9)$$

Where: μ= coefficient of friction and θ= angle of repose

Compressive strength test was determined at Federal Institute of Industrial Research, Oshodi, Lagos State, Nigeria (FIIRO). Ten (10) samples of the products for both lateral and longitudinal positions were determined using an Instron Universal Testing Machine, Testometric make and model M500-25KN. Each sample was placed between the compression plates of the testing equipment. The sample was compressed at a constant deformation rate of 0.33 cm/min. The force and stress at peak deformation, energy at yield point, young modulus etc. were recorded by the data logger attached to the machine. The average mean and standard deviation were recorded as obtained data.

Fig. 3: Experimental set up using Instron Universal testing machine

3.0 RESULTS AND DISCUSSION

The engineering properties (measured and calculated) of the fresh and boiled palm fruits were grouped into two, physical and mechanical. These properties were presented in two tables (Tales 3. 1 and 3.2).

3.1 *The Physical Properties of Fresh and Boiled Fruits*

The physical properties of the fresh and boiled palm fruits determined in this study are shown in Table 3.1. The properties presented in the Table are, mass, length, width, thickness, volume, arithmetic and geometric mean diameter, spherecity, solid and bulk densities, porosity and moisture content. However, only the major physical properties are discussed and these are; the, mass, the arithmetic and geometric mean diameters, the spherecity, bulk density, porosity and moisture content.

3.1.1 *The masses*

The masses of the samples were 4.74 g for fresh and, 4.88 g for the boiled. From the results, the boiled fruits gave higher mass than the fresh fruits. This could probably be as a result of water absorbed during the boiling process. The increase was 1.14g.

3.1.2 *Sphericity*

The sphericity indices of the samples gave the average sphericity indices 70.7 % for the fresh fruits and 73.28 % for the boiled fruits. 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 results obtained by [4] for dura variety.

3.1.3 *Arithmetic mean diameters*

The arithmetic mean diameters of the products were 1.9 cm for the fresh fruits and 2.5 cm for the boiled registering an increase of 0.6 cm. 3.1.4. Geometric mean diameters. The geometric mean diameters samples were 580.6 cm for the fresh fruits and 965.77 cm for the boiled fruits. The geometric mean diameter of the boiled fruits was significantly higher than that of the fresh. The result was 385.17 cm (66.34%).

3.1.4 *Bulk density*

For the bulk density, results show that the bulk densities of the fruits are 0.00054 g/cm^3 (fresh) and 0.00053 g/cm^3 (boiled).

3.1.5 *Porosity*

The porosities of the samples as calculated were 60.21 % (fresh) and 75.72 % (boiled).

3.1.6 *Moisture content*

The mean moisture contents of the samples were 24.63 % for the fresh fruit and 15.25 % for the boiled.

Table 1: Physical Properties of Fresh and Boiled Dura Palm Fruits

Properties	Fresh	Boiled
Mass(g)		
Mean	4.74	4.88
Std. Dev	(±1.09)	(±1.09)
Co. Variance (%)	23.00	22.24
Spherecity (%		
Mean	70.7	73.28
Std. Dev.	(±7.55)	(±8.82)
Co. Variance (%)	10.68	12.04
Length(cm)		
Mean	2.59	2.74
Std. Dev.	(±0.33)	(±0.33)
Co. Variance(%)	12.74	14.54
Width(cm)		
Mean	1.72	1.79
Std. Dev.	(±0.33)	(±0.33)
Co. Variance(%)	19.19	18.44
Thickness(cm)		
Mean	1.47	1.6
Std. Dev.	(±0.33)	(±0.32)
Co. Variance(%)	22.49	20.00
AMD		
Mean	1.9	2.05
Std. Dev.	(±0.30)	(±0.28)
Co. Variance(%)	15.79	13.66
GMD		
Mean	580.6	965.77
Std. Dev.	(±940.96)	(±1482)
Co. Variance(%)	162.07	153.45
Volume(cm3)		
Mean	3.49	4.35
Std. Dev.	(±1.84)	(±1.94)
Co. Variance(%)	52.72	44.60
Bulk Density (g/cm3)	0.00054	0.00053
Solid Density (g/cm3)		
Mean	1.66	1.32
Std. Dev.	(±0.77)	(±0.59)
Co. Variance (%)	4.64	4.4.7
Porosity (%)	60.21	75.72
Moisture Content (Wb)		
Mean	24.63	15.25
Std Dev.	(±7.99)	(±2.79)
Co. Variance (%)	31.63	18.30

3.1.7 Angles of repose

The angles of repose of the fresh and boiled samples on the three surfaces are presented in Table 3. 2. From the Table, the angles of repose of the fresh sample was 20.8 ^{0} on wood surface, 18.09 ^{0} on glass surface and 19.45 ^{0} on metal surface. For the boiled samples, the results were 22.81 ^{0} on wood surface, 21.90 ^{0} glass surface and 21.70 ^{0} on metal surface. These results are in line with the results of the studies in [4], stated that the dynamic angle of repose 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 angle of repose values obtained on the three surfaces may indicate that samples have neither very smooth nor rough surface.

3.1.8 Coefficients of static friction

The coefficients of static friction of the samples were also given in Table 2. From the Table, the coefficients of static friction of the fresh palm fruit were 0.38 on wood, 0.33 on glass and 0.35 on metal steel. For the boiled fruit, the results were 0.42 on wood, 0.44 on glass and 0.40 on metal sheet. From the results, there was a small difference in the coefficient of friction obtained on wood, glass and metal sheet for each of the sample. [13] observed similar trend in the static coefficient of friction of wheat. 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.

3.1.9 Compressive strength

The compressive strengths of the samples at lateral and longitudinal positions were also given in Table 3.2. From the Table, the average forces at break for both the fresh and boiled fruits at lateral was 973.9 N and at longitudinal positions the strengths for the fresh and boiled samples was 1208.6 N. The significance of this result is that boiling has no effect on the compressive strengths of the palm fruits when measured at lateral and longitudinal positions. However, it is observed that average force at break at longitudinal position was higher than the average force at lateral position. This could probably be due to the fact that the force at break for a material on lateral position is always lower than the force at break on longitudinal positions.

Table 2: Mechanical Properties of Fresh and Boiled Oil Palm Fruits on Three Surfaces (Dura Variety)

Dynamic Angles of Repose	Fresh	Boiled
Wood		
Mean	20.8	22.81
Std. Dev.	(±3.40)	(±4.68)
Co. Variance (%)	16.35	20.52
Glass		
Mean	18.09	21.99
Std. Dev.	(±3.18)	(±8.33)
Co. Variance (%)	17.58	37.88
Metal		
Mean	19.45	21.7
Std. Dev.	(±3.11)	(±3.87)
Co. Variance (%)	15.99	17.83
Coefficient of Static Friction		
Wood		
Mean	0.38	0.42
Std. Dev.	(±0.07)	(±0.1)
Co. Variance (%)	18.42	23.81
Glass		
Mean	0.33	0.44
Std. Dev.	(±0.06)	(±0.41)
Co. Variance (%)	18.18	93.18
Metal		
Mean	0.35	0.4
Std. Dev.	(±0.06)	(±0.08)

Co. Variance (%)	17.14	20.00
Compressive Strength		
At Lateral Position	Force at Break (N)	Stress at break(N/cm^2)
Mean	973.9	973. 9
Std. Dev.	(±212.6)	(±212.6)
Co. Variance (%)	21.83	21. 83
At Longitudinal Position		
Mean	1208.6	1208.6
Std. Dev.	(±802.8)	(±802.8)
Co. Variance (%)	66.43	66.43

4.0 CONCLUSION

The following conclusions can be drawn from the results of this study:

The essential engineering properties of a local variety of fresh and boiled oil palm fruits have been determined.

The results are in agreement with some studies of earlier researchers;

There are no significant differences between the properties of varieties tested for fresh and boiled fruits.

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