STUDY OF THE PHYSICAL PROPERTIES OF PALM KERNELS AND SHELLS RELEVANT THEIR HANDLING

Eje, B.E.
Department of Agricultural and Bioresource Engineering,
Enugu State University of Science and Technlogy, Enugu

Chiwetalu, U.J.
Department of Agricultural and Bioresource Engineering,
Enugu State University of Science and Technlogy, Enugu

Ogbuagu, N.J.
Department of Agricultural and Bioresource Engineering,
Enugu State University of Science and Technlogy, Enugu

Abstract.
Relevant physical properties of Palm Kernels and shells were determined as a basis for designing a palm kernel and shell separator. The physical properties determined were the characteristic dimensions, moisture content (wet basis), bulk density, specific gravity and angle of repose.. The shells were found to have distinctive size distribution pattern from the kernels as identified through sieve analysis. The kernels have tendency of being spherical, with sphericity of 0.8 while the shells have a sphericity of 0.6 which makes them hemispherical. These distinctive shapes are characteristics that can be utilized in the mechanical separation of kernels from the shells.

Keywords: Physical Properties, Palm Kernels, Shells, Handling

1.0 Introduction

The oil palm fruit is produced by oil palm tree. The oil palm tree is an erect single stemmed tree of fairly uniform column growing up to 8m or more at maturity. The ovaries of the female inflorescence develop into large bunches and each bunch may contain about 800-1000 fruits (Food and Agricultural Organisation (FAO), 1970). The sizes of the fruits or the nuts depend mainly on the thickness of the shell. As a drupe, each fruit is made up of three major layers: an outer exocarp, a middle fibrous mesocarp and finally, a hard breakable endocarp or shell. The kernel however consists of a small embryo embedded in a mass of hard oily endosperm, surrounded by a tough black integument, the testa (Corley et al, 1976, Wood et al, 1976).

The palm kernels are very important products of the palm produce industry in Nigeria. In addition to being a good source of foreign exchange earnings, the kernel and its products are widely used in the local industries for the production of edible oil, margarine, confectionary fats, soaps, animal feeds and candles. Palm kernel cake has been identified as one of the cheapest source of protein in the formulation of animal feeds while the lauric acid constituent of the oil make the soap produced from it the best quality soap due to its superior lathering quality.(Elaine Moore, 1968, Vegetable oil of Nig.(VON), 1987).The shells have been successfully used as coarse aggregate in wide range of concrete mix (Acheampong et al.,2013,Mahmud et al.,2009)

It is then evident that palm kernel and its products are of great economic importance to the nation. However, before it gets to this final stage of usefulness, it passes through series of post-harvest processing and handling activities such as nut cracking, kernel/shell separation, washing and cleaning, kernel milling, kernel oil extraction etc. Mohsenin (1970) in his work noted that an understanding of the physical laws governing the responses of the biologicalto various handling and processing methods is a fundamental requirement to the design of machines required for handling them. Henderson and Perry (1976) also specified cleaning, sorting, partial or perhaps final grading or classification of agricultural products as being based upon their sizes, shapes, specific gravity and surface characteristics. This study is therefore aimed at determining some of the physical properties of the kernels and shells relevant to the design of machines for their processing and handling.

2.0 Materials and Methods

The palm kernel nuts used for the experiments were obtained from the local farmers in the surrounding communities of Nsukka, Ehalumona, Ibagwa,Obukpa and Orba during the 2015 harvesting season. The study was carried out about two weeks after the palm oil extraction and nut drying processes. A total of 80kg of the palmnuts were obtained from these areas. 30kg of the nuts were left uncracked while the remaining 50kg were cracked using a locally fabricated hammer mill specially designed for palmnut cracking. The kernels were finally separated from the shells by manual handpicking method. All measurements were taken in the laboratory at a room temperature of 31°c and 42% relative humidity.

5okg of the sample was dried in an oven at a temperature of 103°c for 72 hours and the moisture content of each sample was also calculated according to the ASAE (1984) standards.

The sizes and shapes were determined by measuring the weight and axial dimensions (major, intermediate and minor diameters) of the shells, kernels and nuts. An electronic weighing balance with 0.Olg calibration was used for all weighing while a vernier caliper of 0.01cm calibrations was used for all linear dimensions. The geometric mean diameter is calculated using the formular:

$D_G = (ABC)^{½}$ ……………………………………………………………………………..(1).

The sphericity which is a measure of how close a material is to being spherical is given by the formular:

$S = (bc/a^2)^{½}$………………………………………………………………………………(2) where D_G is the geometric mean diameter, S is the sphericity, a is the major diameter, b is the intermediate diameter and C, the minor diameter (Mohsenin 1970).

A cylindrical container with a volume of $3.23x10^4$ m^3 was used for the bulk density measurement. For each measurement, the container was freely filled with the sample material and leveled. The bulk density was then calculated using the frmular:

$BD = W_s/V_s$……………………………………………………………………..……..(3) where BD is the bulk density, W_s is the weight of the sample and $V_s$is the volume of the sample in the container.

The specific gravity was determined using the specific gravity balance (analytical balance). The samples were weighed in the air and then weighed submerged in water. The specific gravity was calculated Using the expression $(SG)_s = W_a{}^X (SG)_b/W_a{}^- W_w$…………………………………………………….…….(4) where $(SG)_s$ is the specific gravity of the sample, $(SG)_b$ is the specific gravity of water W_a is weight of sample in air and W_w is the weight of sample in water.

The angle of repose was determined using a circular platform placed in a box filled with the sample material and with a glass window on one side (mohsenin 1970, Onuegbu 1982.) The sample was allowed to discharge from the box leaving a free standing cone on the platform. Agraduated meter rule attached to the apparatus was used to measure the constant height of the platform and height of the sample profile as shown in Fig 1. The angle of repose was calculated using the formular:

θ = arc tan((H_c - H_p) x^2) D_p……………………………………………………..(5) where θ is the angle of repose, H_p and H_c are the constant heights of the platform and the crest of the material respectively from the datum point and D_p is the diameter of the platform.

In determining the kernel to shell weight and volume ratio of cracked palm nuts, the weight and volume of the kernels and shells in the sample were separately measured. The percentage weight or volume of the kernel or shell fraction was ‘then calculated using the following equations:

PW_f = (W_f x 100) W_T…………………………………………………………………..(6)

PV_f = V_f/V_T……………………..…………………………………………………….(7)

Where PW_f is the percentage weight of fraction, W_f is the weight of fraction in the sample, W_T is the weight of the sample, PV_f is the percentage volume of fraction, V_f is the total volume of fraction in the sample and V_T is the Volume of the sample.

The kernel and shell size distribution was determined by subjecting them individually to a standard sieve analysis. A set of sieves were arranged in a Ro-Tap shaking machine and the machine was allowed to run for five minutes. The weight fraction and axial dimensions of thekernels or shells retained on each sieve was measured with electronic weighing balance and vernier caliper respectively.

3.0 Results and Discussion

Results obtained from palm nut size measurements and shape determination show that the nuts have varying shapes and sizes. Most of them were found to have irregular shapes with a good number having a higher tendency to being spherical or elliptical. The kernels are somewhat more spherical with the cross section close to being round while the shells which have hard hairy structure and fragmented into several pieces by the nut cracker are more irregular in shape though with a greater tendency to being hemispherical. Results of the mean values of measurements of the axial dimensions taken for 100 samples of the nuts, kernels, and shells are as presented in Table.1 the values of the sphericity are 0.8 for kernels and nuts and 0.6 for shells.

Results obtained from the sieve analysis used in determining the size distribution of kernels and shells are presented in Table 2 and 3. The Tables give a clear picture of the mean axial dimensions of various fractions in the sieve analysis and the weight percent of such actions that can pass through a given aperture.

The values of the percentage weight of the individual components in the kernel and shell mixture were 23.43% and76.57% for kernels and shells respectively. Likewise, the percentage volumes of the components in the mixture were 34.9% for kernels and 65.1% for shells.

The results obtained from the study of other physical properties (relevant to the design of palm kernels and shells post-harvest handling machines) such as moisture content, bulk density, specific gravity and angle of repose are as summarised in Table 4.

Conclusion

This study has successfully identified some of the physical properties of palm kernels, nuts, and shells and these properties can be directly or indirectly employed in the design of post-harvest handling machines for these materials. The distinctive shapes and sizes of kernels and shells as identified by the values of the sphericity, and their size distribution pattern can be effectively utilised for the selection of sizes and shapes of screens that can be employed in mechanical separation of kernels from shells. The difference in specific gravity of the shells (1.24) and kernels (1.05) can also be utilised in kernel-shell separation by using or simulating a fluid medium with an intermediate specific gravity. However, some problems could be encounter using the principle because of the closeness of the specific gravity values of the two materials. The angle of repose can as well aid the design of hopper, spouts, chutes and surfaces encountered in handling the kernels or shells.

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Table 1 The axial dimensions of palm kernels, nuts and shells

Sample		Axial dimensions (mm) Mean	standard deviation
100 Nuts	Major diameter	26.8	3.4
	Intermediate diameter	19.7	3.3
	Minor diameter	15.7	2.0
	Geometric mean diameter	20.2	
	Sphericity	0.8	
100 kernels	major diameter	15.7	2.25
	Intermediate diameter	12.07	1.62
	Minor diameter	9.2	1.62
	Geometric mean diameter	12.04	
	Sphericity	0.8	
100 shells	Major diameter	13.9	5.02
	Intermediate diameter	9.4	3.03
	Minor diameter	4.8	2.15
	Geometric mean diameter	8.5	
	Sphericity	0.6	

Table 2. Result of the sieve Analysis of palm kernels

Sieve aperture Size	Weight retained		Sample axial dimensions (mm)					
			Major diameter		Intermdiameter		minor diameter	
Size	(g)	(%)	Mean	Standard Deviation	Mean	Standard deviation	Mean	Standard deviation
13.2	32	5.3	17.46	1.8	14.89	0.88	11.44	1.97
12.7	21.8	3.7	16.47	1.75	13.94	0.68	11.05	1.02
9.5	459.66	78.10	15.50	2.14	12.36	1.27	9.15	1.42
6.35	85.13	14.46	14.45	2.80	9.39	1.05	7.48	1.05

Table 3. Result of the sieve Analysis of palm kernels

aperture Size (mm)	Weight retained		Sample axial dimensions (mm)					
	(g)	(%)	Major diameter Mean	Stddevi.	Interm diameter Mean	stddevu.	minor diameter Mean	Stddevi.
13.2	41.9		9.79	24.9	4.8	17.43	2.12 10.01	1.9
12.7	11.54		34.53	18.46	3.8	16.08	1.08 9.50	2.1
6.35	147.78		32.36	13.5	2.3n	9.6	1.40 4.9	1.04
4.76	58.32		13.63					
2.4	24.4		5.70					
Pan	5.5		1.29					

Table 4. Other physical properties of palm kernels, shells and nuts,
Material physical properties

	Mosit. Cont. Wet basis (%)	Bulk density (kgm^2)	specific gravity	Angle of reposes (degree)
Kernels	9.5	572.8	1.052	37.8
Shell	8.5	439.86	1.244	47.97
Nuts	9.1	594.31	1.147	43.20

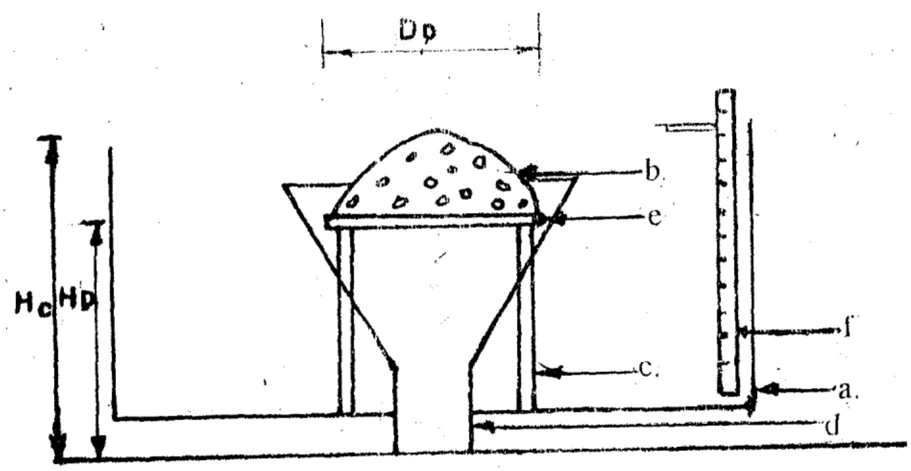

Fig.3.4: Apparatus for determination of static angle of repose.

A Box; b, sample material; c, adjustable legs; d, funnel; e, circular platform; f, meter rule $D_p$diameter of platform; $H_p$and H_c, heights of the platform and the crest of the test sample respectively.