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PROPERTIES OF COCONUT *(COCOS NUCIFERA L.)* RELEVANT TO ITS DEHUSKING

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ABSTRACT Coconut seed (*cocos nucifera L.*) is a tropical plant valuable for its oil and fat fractions for the production of soap and milk which are used for making soap, as diesel fuel, for lighting, for making candles. In developing, processing and handling the seeds, some engineering properties such as size, sphericity, roundness, volume, surface area, density, coefficient of friction against different materials and compression tests were studied. One hundred seeds were randomly selected for the physical properties tests, such as the shape, size, volume, density, surface area experiments. The three principal dimensions were measured using a Vernier Calliper with an accuracy of 0.02 mm. Major diameter varied from 17.36 cm to 19.70 cm; surface area varied from 4724 mm^2 to 5797 mm^2, seed volume varied from 600 cm^3 to 800 cm^3 with an average density of 1.065 g/cm^3, which shows that it floats in water because the density is greater than that of water. The coefficient of friction is high for plywood and minimum for glass. The average modulus of elasticity is 153.625 N/mm with an average load at yield and deformation at yield at 5390.6 N and 35.22 mm respectively on the major axis.

Keywords: Physical, Properties, Coconut, Dehusk, Friction, Processing

INTRODUCTION Coconut palm (*cocos nucifera L*) is of the botanical family name called palmacea. Coconut palm is one of the most important cultivated trees and it is also referred to as the "tree of life" because of its different uses. Coconut is of great important in almost all areas of life. Coconut sap (toddy) as a source of sugar, vinegar or alcoholic, coconut water as a delicious, non- alcoholic beverage and substituted for blood plasma in emergency surgical operation. Coconut oil for cooking, as milk and cream, which are used for making soap, as diesel fuel, for lighting and for making candles.

Coconut coir fibre for ropes and mals, coconut peal for horticulture, shell for buttons, decorative carving, burnt as a fuel and for charcoal. Activated carbon manufactured from coconut husk has one of the largest activated surfaces areas combined with a high percentage of micro pores in the size range 5-10A° (Angstoms), making it ideal for removal of odorous compounds, gases from volatile organic compounds and gases of a low molecular weight. Wood from the coconut stem for furniture and construction purposes leaves for decoration and as a thatching material and finally the heart of the palm as vegetable salad (Harries *et al*. 2002).

Dehusking of coconut is a process whereby the husk of a coconut is removed. It is an age old practice and it is manually done by impaling the fruit on a sharp- pointed shard of steel positioned vertically with the point up and the border part firmly placed on the ground. The farm operator impales the coconut on the sharp point with a strong-determined movement. A few impaling stokes loosen the husk; making it come off in one piece, although it requires accuracy.

In recent years, efforts have been made to develop improved methods and machinery to dehusk coconut fruit more economically and that is why there is need to know the engineering properties of coconut in order to design a dehusking machine. This paper presents some properties of coconut relevant to its dehusking. There has been no much work done on the engineering properties of coconut relevant to dehusking. However, work has been done on the engineering properties of some grains and seeds relevant to dehusking. Such crops are Rice, Soyabean, Cowpea and pigeon pea.

MATERIALS AND METHODS

The coconut seeds used for this project were obtained from Eti-Oni, Ilesha, Nigeria. They were cleaned manually to eliminate foreign materials. One hundred seeds were randomly selected and used for the physical properties test, such as the shape, size, volume, density, surface area experiments. The following are the procedures used to determine the properties of the seed:

Colour and appearance of the coconut seed

This was done by direct visual observation of the seeds. The colour is green when mature and brown when ripe, consisting of a light brown fibrous husk, a hard brown shell and one very large hollow seed with whitish oily edible flesh.

Size determination

The whole seed that was randomly selected and their sizes determined by the use of vernier calliper. Measurements of three mutually perpendicular axes were made: namely; major, intermediate and minor diameters. Figure 3 shows the three principal dimensions.

Sphericity

A direct measurement of the major, intermediate and minor axis of the seeds using a vernier caliper. Calculation of sphericity was carried out using the formula below;

$$\text{Sphericty} = (abc)^{1/3}/a$$

where a, b, c are major, intermediate and minor axes (Mohsenin, 1970)

Roundness

Roundness was determined from the seed traced after it was enlarged by photocopying the area of the smallest circumscribing circle. This was found using the formula below;

$$\text{Area} = \pi r^2 \quad \text{where r = radius of the circle}$$

The projected area (Ap) to the area of circumscribing circle (Ac) gives the roundness of each seed. Roundness = Ap/Ac

where Ap = Projected area of traced seed, Ac = Area of smallest circumscribing circle

Density

Ten samples were randomly selected. The samples were first weighed to get the mass, and the volume was determined for each sample by immersing in water to get the volume of the water displaced using a measuring bucket. It is important to note that the readings were taken immediately the seeds were immersed into the bucket. Error due to parallax was avoided at the same time in taking readings. The ratio of each mass of the sample obtained from the volume gives the density.

Volume

The volume of ten samples of randomly selected seeds was determined by water displacement method using a measuring bucket. The difference between the final volume of water displaced and the initial volume gives the volume of the seeds. As practiced by Shepherd and Bhardwaj (1986). The volume of the ten seeds can also be determined in the units by use of the formula given below:

$$\text{Volume} = \pi D^3/6$$

where D = the three axes i.e. major, intermediate, and minor axis.

Surface Area Determination

The surface area of the seeds was determined using the formula of Dutta *et al.* (1988) given below and all the measurements of the principal areas as variables.

Surface Area $S = 2b^2 + 2ab\text{Sin}^{-1}e$

where $e = [1 - [a/b]^2]^{½}$, a= semi major axis of solid in mm, b= semi minor axis of solid in mm

Coefficient of Friction

The coefficient of static friction of coconut seeds was determined on several surfaces of structural materials. The materials used were galvanized steel, glass, and plywood with grains perpendicular to the direction of movement of seeds. The structural material was fastened to an adjustable tilting surface. The adjustable surface was gradually raised with a screw device until seed starts to slide down. The angle of slope was then measured directly from a protractor attached to the tilting table.

Moisture Content Determination

The moisture content of coconut seed was determined by oven drying method as described in ASABE (2006) standards.

Crushing and Compressive Force on Seed

The compressive and crushing force test was carried out with a Tensiometer. The machine is meant for testing tensile strength of materials, but under compression arrangement. It was made suitable for this purpose. The machine has a maximum load at 200 kN yield. To determine the load applied the force of compression and complete rupture of seeds were recorded using the computer system attached to it. The test was carried out along the major and the minor axes and a trial for the intermediate axis with moisture content of 42.68%.

RESULTs AND DISCUSSION

The results obtained after determining some engineering properties of coconut seed relevant to dehusking of the seed are as follows:

The principal dimensions, major, intermediate and minor areas were measured for twenty seeds with a venier caliper. The results obtained are presented in Table 1 and

Appendix B respectively. The values of the major diameter ranges from 17.36 cm to 19.70 cm, with mean of 18.493 cm and standard deviation of 0.52 cm. The values of the intermediate diameter range from 13.22 cm to 15.4 cm, with mean value of 14.059 cm and standard deviation of 0.591 cm. The value of the minor diameter ranges from 13.22 cm to 15.40 cm, with mean value of 14.059 cm and standard deviation of 0.591 cm.

It was observed that the intermediate diameter and the minor diameter has the same mean value and standard deviation value, hence the intermediate diameter is equal to the minor diameter. The intermediate diameter and the minor diameter have the longest standard deviation of 0.591 cm, which indicates that the values of these diameters have the largest spread about the mean and hence the highest variability compared with other diameter. Table 1 shows the mean values of the three principal diameters.

The mean of the principal dimensions of the seeds in the twenty samples were used to compute the sphericity as shown in Appendix B. The sphericity of the coconut seeds vary from 0.7734 to 0.9085 with standard deviation of 0.032. The sphericity value indicates that the shape of the seed approximates that of a sphere because of the mean sphericity value is 0.834 (83.4%) with a very little deviation among the seeds. The mean value is shown in Table 1.

The mean roundness of the sample is given in Appendix B. The roundness ranges from 0.463 cm to 0.749 cm with a standard deviation of 0.066 cm and a mean value 0.581 as shown in Table 1. The mean surface area of the seeds in each sample is given in Appendix C. The surface area ranges from 4724 mm^2 to 5797 mm^2 with a standard deviation of 311.290 mm^2 and a mean value of 5329.9 mm^2 as shown in Table 1. The volume of ten seeds measured by water displacement method is given in Appendix D. The volume ranges from 600 cm^3 to 800 cm^3 with a mean volume of 675 cm^3 as shown in Table 1. The density of the samples ranges from 0.964 g/cm^3 to 1.171 g/cm^3 with a mean value of 1.065 g/cm^3 as shown in Table 1. The density of the ten seeds measured is given in Appendix D.

The mean of experimental results obtained for coefficient of static with respect to three structural surfaces (wood, galvanized steel and glass) are shown in Table 1. The experiment was performed ten different times for each structural surface as shown in Appendix E and the mean coefficient of friction was found to be 0.449, mean coefficient of friction for galvanized steel was found to be 0.392 while that for glass was found to be 0.342. The coefficient of friction for plywood is higher compare to the other surfaces.

Compressive and Crushing Force

The compressive force was taken for both the major axis and the minor axis; graphs were plotted for five different seeds. It was observed that the minor or intermediate axis test does not give a yield. This indicates that it cannot be dehusk through the minor or intermediate axis. The results are shown in Figures 1 and 2 respectively. The maximum modulus of elasticity (ratio of load to deformation) needed to crush the coconut seed is 184.632 N/mm^2 as shown in Appendix F. The maximum load required to dehusk the coconut is 6840 N as shown in Figure 1 and the energy absorbed at during this load is 107.09 Nm

On the intermediate or minor axis, the load at break is the same as the load at peak. This indicates that the coconut cannot be dehusked using the intermediate or the minor axis because the seeds will be damage using these axes. Therefore, it is better dehusked using the major axis. Also, more force is needed to crush the coconut seed when placed in the intermediate position and the minor position than when placed along the major axis.

Table 1: Some Engineering Properties of Coconut

Property	Mean Value	Standard Deviation
Major diameter (cm)	18.493	0.520
Intermediate diameter (cm)	14.059	0.591
Minor diameter (cm)	14.059	0.591
Sphericity	0.834	0.032
Roundness	0.581	0.066
Surface area (mm^2)	5329.9	311.290
Volume (cm^3)	675.000	81.777
Density (g/cm^3)	1.065	0.127
Coefficient of friction on plywood	0.449	0.069
Coefficient of friction on galvanized steel	0.392	0.027
Coefficient of friction on glass	0.342	0.021
Modulus of elasticity (N/mm)	153.621	23.707
Load at yield (N)	5390.6	1040.8
Load at break (N)	5701.1	688.3
Load at peak (N)	6167.7	801.2
Deformation at Yield (mm)	35.219	4.539
Deformation at break (mm)	42.111	2.530
Deformation at peak (mm)	40.151	2.000
Energy at yield (Nm)	83.94	18.98
Energy at break (Nm)	122.88	23.03
Energy at peak (Nm)	111.15	12.99

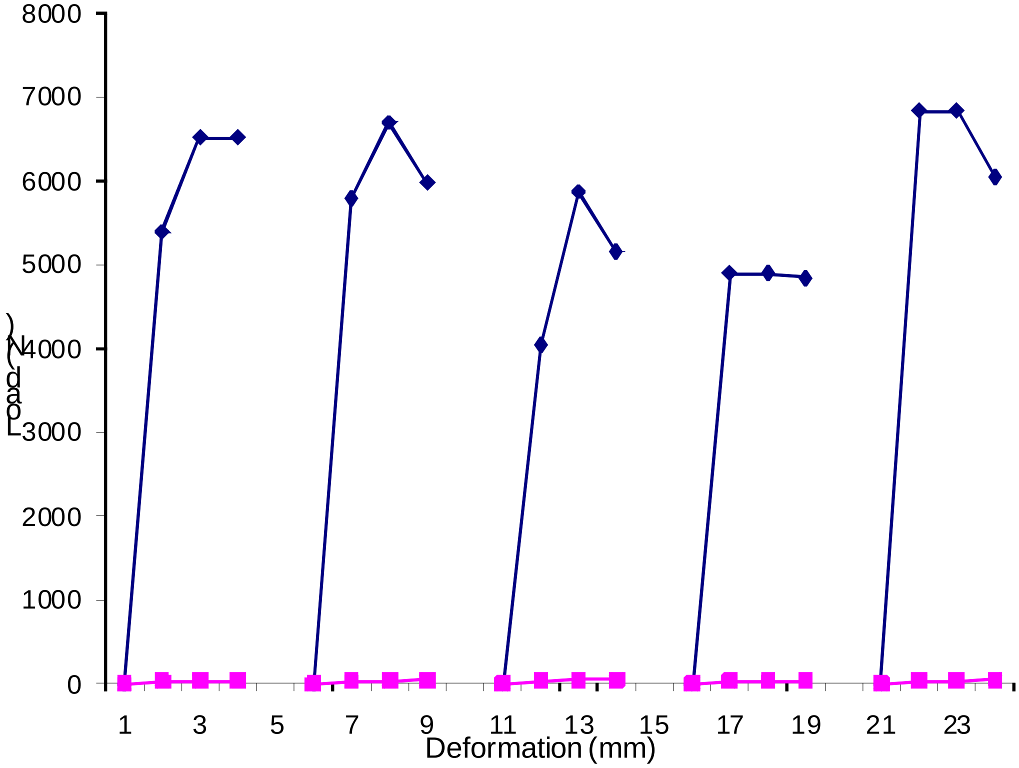

Figure 1: Graph of Load against Deformation on Major axis

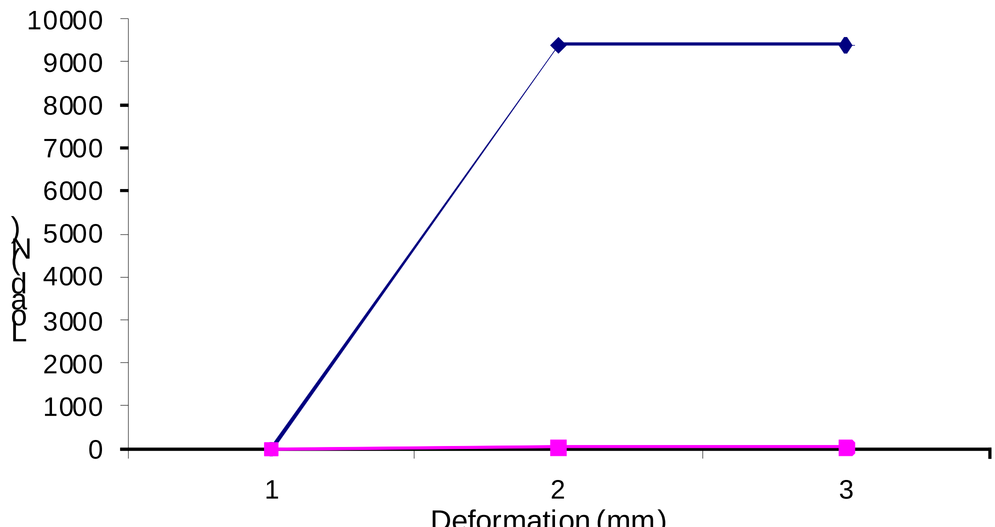

Figure 2: Graph of Load against Deformation on intermediate axis

CONCLUSION

The various investigations on some engineering properties of coconut seed revealed the following:

(a) That the major diameter of the seed is between 17.36 cm to 19.70 cm and it mean is 18.49 cm. The intermediate diameter of the seeds ranges between 13.22 cm to 15.40 cm and its mean is 14.05 cm while the minor diameter of the seeds ranges between 13.22 cm to 15.40 cm and its mean is 14.06 cm. It was observed that the intermediate diameter and the minor diameter are approximately the same for coconut seed.

(b) The shape of the coconut seed was found to be approximately described as that of a spheroid

(c) The average density and volume of seeds were found to be about 1.065 g/cm^3 and 675 cm^3 respectively

(d) Good and nature seeds have their surface area increasing as weight increases. Average surface area of seed was found to be 5329.9 mm^2

(e) The coefficient of friction for wood, galvanized steel and glass was found to be 0.449, 0.392, and 0.342 respectively. Therefore, the hopper need not be built steeply because of the relatively low coefficient of friction.

(f) During the compression test it was observed that load, deformation, and energy absorbed at yield is 5390.6 N, 35.219 mm, 83.94 N/m. Load, deformation and energy absorbed at break is 5710.1 N, 42.11 mm and 122.88 Nm respectively.

Average load, deformation and energy absorbed at peak are 6164.7 N, 40.151 mm, 111.15 Nm. All these are the test carried out on the major diameter. The compression test on the intermediate axis was observed to have the same load at break and peak. The value of the deformation of break and peak are also the same but no yield was observed. The energy absorbed at break is also the same with the energy absorbed at peak. The max load at which there will be a yield at the major axis of the coconut is 6800 N.

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Appendix A

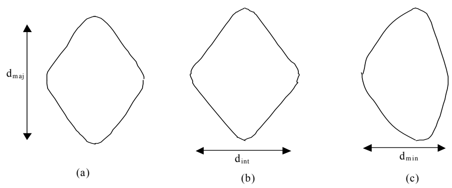

Figure 3: The three principal dimensions (Major, Intermediate and Minor axes)

Appendix B: Showing the three principal axes, Sphericity and Roundness

Test Code	Major Diameter (cm)	Intermediate Diameter (cm)	Minor Diameter(cm)	Sphericity $(Abc)^{1/3}/A$	Roundness
1	19.700	13.400	13.400	0.7734	0.4627
2	18.130	15.400	15.400	0.9085	0.7499
3	18.450	13.190	13.190	0.7995	0.5111
4	19.200	14.450	14.450	0.8274	0.5664
5	18.070	14.250	14.250	0.8556	0.6219
6	18.730	14.300	14.300	0.8353	0.5829
7	18.150	14.550	14.550	0.8630	0.6426
8	18.420	14.350	14.350	0.8467	0.6069
9	18.300	13.800	13.800	0.8285	0.5687
10	17.360	13.900	13.900	0.8623	0.6411
11	18.750	13.980	13.980	0.8223	0.5559
12	18.510	13.220	13.220	0.7990	0.5101
13	17.860	14.230	14.230	0.8594	0.6348
14	18.500	14.300	14.300	0.8423	0.5975
15	19.240	13.820	13.820	0.8021	0.5159
16	18.300	13.920	13.920	0.8333	0.5786
17	18.760	14.220	14.220	0.8313	0.5746
18	17.500	14.340	14.340	0.8757	0.6715
19	19.400	14.060	14.060	0.8068	0.5253
20	18.520	13.200	13.200	0.7979	0.5080

Appendix C: Surface Area

Sample	Surface Area (mm^2)
1	4982
2	5694
3	5609
4	5162
5	5797
6	5339
7	5347
8	4724
9	5431
10	5214

Appendix D: Volume and Density

Sample	Weight (g)	Volume (cm^3)	Density (g/cm^3)
1	825	800	1.031
2	750	700	1.071
3	775	700	1.171
4	625	600	1.042
5	650	600	1.083
6	700	700	1.000
7	575	500	1.150
8	675	700	0.964
9	800	750	1.067
10	750	700	1.071

Appendix E: Coefficient of Friction for three surfaces

Sample	Plywood	Galvanised Steel	Glass
1	0.3541	0.3640	0.3739
2	0.4142	0.3839	0.3346
3	0.5774	0.4142	0.3443
4	0.4557	0.4452	0.3153
5	0.4663	0.3839	0.3640
6	0.4040	0.3640	0.3640
7	0.3640	0.4245	0.3541
8	0.5430	0.3600	0.3346
9	0.4877	0.3879	0.3250
10	0.4245	0.3939	0.3057

Appendix F: Modulus of Elasticity

Test No	Load (N)	Deformation (mm)	Modulus of Elasticity (N/mm)
1	5394.0	33.459	161.212
2	5786.0	31.338	184.632
3	4037.5	31.124	129.723
4	4895.7	39.902	122.693
5	6840.0	40.272	169.845