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DETERMINATION OF SOME PHYSICAL PROPERTIES OF AFRICAN OIL BEAN KERNEL RELEVANT FOR DESIGN OF THE PROCESSING MACHINE

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ABSTRACT

This study investigated some physical properties of African oil bean kernel such as size, sphericity, surface area, bulk density, true density, weight, porosity, volume, angle of repose and the coefficient of friction on various material surfaces. Standard methods from the literature were adopted in carrying out the experiment. The properties were investigated at moisture content of 14.63% wet basis. The results obtained showed that the average values of major, intermediate and minor diameters of the kernels were 47.34, 30.13 and 9.99 mm, respectively. The volume, sphericity, porosity, surface area, bulk and true densities were obtained as 23.34cm^3, 0.51, 45.23 %, 18.45 cm^2, 0.64g/cm^3 and 0.85g/cm^3, respectively. The coefficient of friction of the kernels on wood, glass and metal were gotten as 0.88, 0.72, and 0.77, respectively while the angle of repose is 14.57^o. The data obtained will be useful in the design of postharvest machines for African oil bean kernel.

Keywords: *African oil bean, kernel, physical properties, design data, postharvest, processing.*

1.0 INTRODUCTION

The African oil bean (*Pentaclethra macrophylla Benth*) is a tropical tree crop found mostly in the Southern part of Nigeria and in other coastal parts of West and Central Africa. The tree is grown either in wild or semi-wild with no organized cultivation or plantations (Igbozulike et al., 2021). It is a highly valued cash crop in Nigeria that brings good returns. The seed is glossy brown and requires heat treatment to ease the dehulling. The kernel is extracted upon dehulling, and every other processing of African oil bean is done on the kernel. Osabor et al. (2017), Osagie-Eweka and Alaiya (2013), Mbah et al (2013), Balogun (2013) and Okwu and Aluwuo (2008) have highlighted the phytochemical, mineral, vitamin and economic potentials of African oil bean seed. Their works showed that African oil bean, which is often eaten as snack, is a rich food supplement. Processing of the seeds is encouraged because of the high postharvest losses due to the seed's high moisture content at harvest and lack of optimum storage facilities (Igbozulike et al., 2023). African oil bean seed is usually dehulled before other processing like slicing, fermentation, and packaging take place.

The physical properties of crops are needed to generate data that will facilitate the design of processing machine, storage structures, and quality control of agricultural products. Consequently, researchers have determined these properties for crops like guna seed (Aviara et al., 1999), Canarium schweinfurthii (Ehiem et al. 2016), fluted pumpkin seed (Igbozulike and Amamgbo, 2019), okra fruits and seeds (Davies, 2020), yellow passion fruit seeds (de Araujo et al., 2020), peanut seed (Gojiya et al., 2020), jamun (Syzgium cuminii) seed (Bajpai et al., 2020), spindle seed (Kaliniewicz et al., 2021), lemon seed (Benestante et al., 2023), among many others. There is no data on the physical properties of African oil bean kernel currently available in literature. Researchers like Asoegwu et al (2006), Alonge and Etim (2011) and Ndukwu (2013) have determined the properties of African oil bean seeds but they failed to determine that of the kernel which is the main component that is consumed. Oje and Ugbor (1991) opined that the physical properties of oil bean seed are relevant for designing dehulling machine. The properties of African oil bean kernel are necessary for the design of postharvest processing systems and operations such as slicing, handling, storage, oil expression and extraction. It follows then that there is need to study the physical properties of the African oil bean kernel in order to obtain empirical data needed for the design of efficient postharvest processing machines and handling equipment.

Therefore, the focus of this work is to determine the physical properties of Africa oil bean kernel in order to obtain relevant data that would be used for the design of machines with high efficiency for the processing and general handling of the kernels. This study will guide the engineers, designers, scientist etc. in the designing and construction of the machine and equipment to be used in the processing and handling of the African oil bean kernels.

2.0 MATERIALS AND METHODS

2.1 Sample Sourcing

Fifty (50) freshly harvested Africa oil bean pods were purchased from Oriagu market in Ehime Mbano Local Government of Imo State, Nigeria. The geographical coordinate of Oriagu market is latitude 5.6348° N and longitude 7.3194° E.

2.2 Sample Preparation

The dicotyledonous pods were manually opened and the seeds were removed from the pods. The seeds were carefully cleaned and sorted to remove the unwholesome ones. A total of 120 seeds were randomly selected from the sorted lot and 10 of them were used to determine the moisture content of the seeds. The physical properties of the seeds were determined using a total of 100 seeds. Then, the seeds were parboiled at 100℃ for 10 minutes to extract the kernels. After extraction, the kernels were washed in tap water, dabbed with paper cloth and kept in a jute bag under the laboratory ambient condition for 24 hours prior to experiment. The moisture content of the kernel was determined prior to the experiment using ASAE standard (S352.2).

2.3 Determination of the Physical Properties

2.3.1 Seed dimensions

The principal axes of the kernels - major, intermediate and minor diameters, were determined using a digital Vernier caliper (Greprufte Sicurhele, Germany) with sensitivity of 0.01 mm.

2.3.2 Arithmetic and geometric mean diameters

The arithmetic and geometric mean diameters were found using Equations (1 & 2) respectively (Mohsenin, 1986):

$$D_a = \frac{L+W+T}{3} \quad (1)$$

$$D_g = [LWT]^{\frac{1}{3}} \quad (2)$$

where $\mathrm{D_a}$ is the arithmetic mean diameter (mm), $\mathrm{D_g}$ is the geometric mean diameter (mm), L is the major diameter of the kernel (mm), W is the intermediate diameter of the kernel (mm) and T is the minor diameter of the kernel (mm).

The sphericity of the kernels was calculated using Equation (3) following the relationship given by Igbozulike and Aremu (2009):

$$\psi = \frac{[LWT]^{\frac{1}{3}}}{L} = \frac{D_g}{L} \quad (3)$$

where ψ is the sphericity (dimensionless), other parameters are as previously defined.

2.2.3 Surface area

The surface area of the kernel was computed using the following equation (Ixtaina *et al*., 2008):

$$A_s = \pi {D_g}^2 \quad (4)$$

where $\mathrm{A_s}$ is the surface area (mm²) and D_g is the geometric mean diameter of the kernel

2.4True and Bulk densities

The water displacement method was used to find the true density (ρ_t) (Igbozulike and Amamgbo, 2019). Water was poured into a graduated cylinder to a certain level. The sample's seeds were counted and the weight was measured. The amount of water displaced after the seeds were poured into the graduated cylinder was noted. Ten replications in total were taken and the true density was calculated thus:

$$\rho_t = \frac{M_t}{V_t} \quad (5)$$

Here, ρ_t= true density (g/cm³), M_t= true mass (g), V_t= true volume (cm³)

For the bulk density, the method described by Akaaimo and Raji (2006) and Igbozulike and Aremu (2009) was used in determining and calculating the bulk density of the sample. The bulk density equation is given as follows:

$$\rho_b = \frac{W_k}{V_k} \quad (6)$$

where W_k is the weight of kernels (g) and V_k is the volume of kernels (cm³)

2.4 Porosity

The porosity (ε) of the kernels was calculated from the values of bulk density and true density using the Mohsenin (1986) equation as applied by Igbozulike and Aremu (2009):

$$\varepsilon = \left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad (7)$$

where ε is the porosity (in percentage), ρ_b is the bulk density (kg/m³) and ρ_t is the true density (kg/m³)

2.5 Angle of repose of kernels

The angle of repose was determined using a topless and bottomless cylinder that was placed on the top of a circular base. The cylinder was filled with the sample and was gradually removed. The diameter of the base and the height of the cone formed by the kernels were measured. The angle of repose was calculated thus: (Igbozulike and Amamgbo, 2019).

$$\varphi = tan^{-1}\frac{2h}{b} \quad (8)$$

where φ is the angle of repose (°), *h* is the height of the pile formed by the kernels (cm) and b is the base formed by the kernels (mm).

2.6 Coefficient of friction

The coefficient of friction was determined using an inclined plane. The plane was gradually raised until the sample starts to roll. The tangent of the angle of inclination is the static coefficient of friction of the kernel on the material surface used. Three different materials - galvanized steel, plywood, and glass were used. Coefficient of friction was computed thus:

$$\mu = tan \propto \quad (9)$$

where μ is the coefficient of friction and $\propto$ is the angle of repose

3.0 RESULTS AND DISCUSSIONS

3.1 Physical properties of Africa oil bean

Tables 1 and 2 show the physical properties of African oil bean seed and kernel, respectively.

Table 1: Physical properties of the African oil bean seeds.

Physical properties	Minimum	Maximum	Average	SD
Major diameter, mm	36.01	84.51	53.31	8.81
Intermediate diameter, mm	24.75	56.90	34.58	5.18
Minor diameter, mm	8.21	19.34	12.23	1.99
Geometric mean diameter	22.27	37.91	12.23	3.19
Arithmetic mean diameter	7.42	12.64	9.35	1.06
Sphericity	0.15	0.69	0.53	0.70
Surface area (cm^2)	1.73	45.14	24.72	6.31

SD = standard deviation

The major diameter of the seed ranged from 36.01 mm to 84.51 mm with an average value of 53.31 (Table 1). The intermediate diameter is in the range of 24.75 mm and 56.90 mm while the diameter was found to be within 8.21 mm and 19.34 mm. These values are in agreement with the values obtained for the seeds by Asoegwu *et al*. (2006), Alonge and Etim (2011), and Ndukwu (2013). The reason for this could be because there is no known variety for African oil bean. The values of the physical properties of African oil bean kernel are different from those of the seeds as shown in Table 2.

Table 2:Physical properties of the African oil bean kernel.

Physical properties	Minimum	Maximum	Average	SD
Major diameter, mm	27.09	76.98	47.34	9.13
Intermediate diameter, mm	21.40	54.40	30.13	5.00
Minor diameter, mm	4.56	15.10	9.99	1.61
Geometric mean diameter	16.80	33.14	24.03	3.02
Arithmetic mean diameter	5.60	11.05	8.01	1.01

Sphericity	0.35	0.71	0.51	0.66
Surface area (cm^2)	8.86	34.49	18.45	4.66
Porosity (%)	37.04	53.21	45.23	0.35
Weight (g)	1.70	24.01	9.27	3.87
Volume(cm^3)	10.00	35.00	23.34	7.52
Buk density (g/cm^3)	0.49	1.82	0.64	0.25
True density (g/cm^3)	0.60	2.10	0.85	0.30
Angle of repose, degree	8.21	18.94	14.57	0.21
Coefficient of friction				
Wood	0.53	1.60	0.88	0.19
Glass	0.30	1.60	0.72	0.17
Metal	0.30	1.70	0.77	0.21

SD = standard deviation

The result shows that the kernel major diameter ranged from 27.09 to 76.98 mm, intermediate diameter ranged from 21.40 to 54.40 mm and the minor diameter is in the range of 4.56 to 15.10 mm with a standard deviation 9.13, 5.00, and 1.61 respectively. The implication of varied values of physical properties of African oil bean seed and kernel is that the data from each of them is unique and important for design of effective processing machines. The average value of the sphericity of African oil bean kernel is 0.51. According to Mohsenin (1986) as reported by Igbozulike and Amamgbo (2019), the sphericity value of most agricultural products falls within 0.32 and 1.0. The African oil bean kernel sphericity value of 0.51 implies that it will not roll about its axis since it is not close to 1.0. The sphericity value is lesser that of simarouba fruit and kernel found to be 0.69 and 0.65, respectively (Dash *et al*., 2008). The African oil bean kernel's geometric mean diameter is 24.03 mm and the arithmetic mean diameter is 8.01 mm. These values are lesser than the values obtained by Ehiem and Simonyan (2012) for wild mango nuts.

Table 3: Physical properties of African oil bean seed and kernel reported by researchers

Researcher	*Component*	*Moisture content (% db)*	*Moisture Content (% wb)*	*Major diameter (mm)*	*Intermediate diameter (mm)*	*Minor diameter (mm)*
Asoewguetal. (2006)	*Seed*	*8.73*	*8.03*	*56.18*	*37.69*	*12.01*
Alonge and Etim (2011)	*Seed*	*10.43*	*9.44*	*62.79*	*40.20*	*10.98*
Ndukwu (2013)	*Seed*	*16.41*	*14.10*	*70.87*	*55.23*	*44.24*
Present study	Seed	9.74	9.16	53.31	34.31	12.23
Present study	Kernel	17.14	14.63	47.34	30.13	9.99

The dimension of the principal axes of African oil bean kernel is lower than that of the seeds despite the fact that the kernel has a higher moisture content value (Table 3). The reason for this is because boiling of the seed to facilitate removal of the seed coat (husk) may have increased the moisture level of the kernel. The porosity of the kernel which is the function of true density and bulk density has is 45.23%.Alonge and Etim (2011) found the porosity of African oil bean seed to be 0.49, which is slightly above the result gotten for African oil bean kernel. The seeds volume of African oil bean kernel was found to be 23.34 cm^3while the weight ranged from 1.70 to 24.01 g with a mean of 9.27g and a standard derivation of 3.87g.

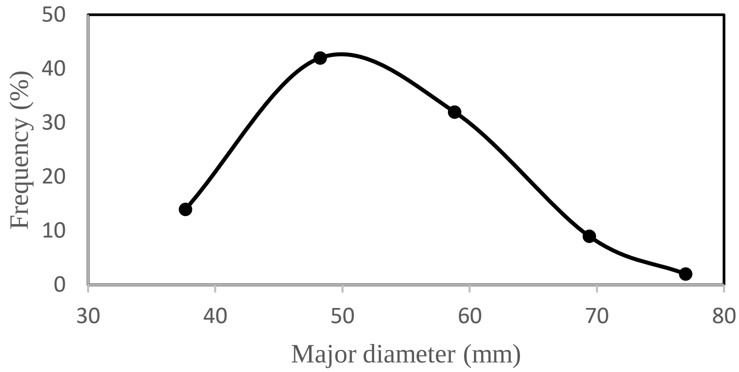

Fig. 1: Frequency distribution of the kernel major diameter

The coefficient of friction of African oil bean kernel against three types of material surfaces was found to be highest on wood surface (0.88), followed by metal (0.77) and glass surface with the least value (0.72). The fairly large value of coefficient of static friction for the kernel may be attributed to the high moisture content as well as the stickiness of the surface of the kernel. The seed of African oil bean has lower coefficient of friction (Alonge and Etim, 2011), and this is due to the smooth nature of the seed.

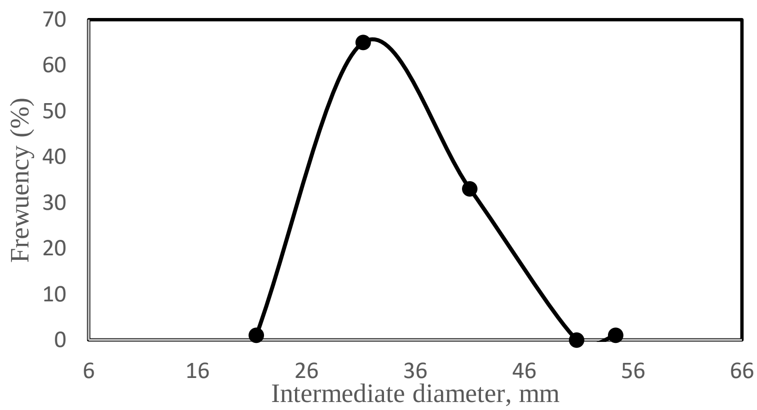

Fig. 2: Frequency distribution of the kernel intermediate diameter

The coefficient of friction property is very important in the design of storage container, hopper or any other loading and unloading device for the kernel. The angle of repose of African oil bean kernel was obtained as 14.57°. This value is lesser than that of African oil bean seed. Ndukwu (2013) obtained 17.20° whereas Alonge and Etim (2011) got 18.77° as angle of repose for African oil bean seed.

Figures 1 through 3 display the frequency distribution of the main axes of the African oil bean kernel. The kurtosis and skewness analysis of the frequency distribution curves for the axial dimensions shown in Figures 1 – 3 are presented in Table 4 below. Kurtosis describes how peaked or flat a distribution is in relation to the normal distribution.

Table 4: Kurtosis and skewness for the principal axes of African oil bean kernel

	Major diameter (mm)	*Intermediate diameter*	*Minor diameter*
Kurtosis	0.5112	0.5193	1.1534
Skewness	-1.8156	-1.5220	1.0926

The primary axes of the African oil bean kernel have positive kurtosis, which suggests a highly peaked distribution as opposed to a relatively flat distribution for negative kurtosis. On the other hand, skewness describes how asymmetrically a distribution is centered around the mean. The distribution of the minor diameter, which has a positive skewness, has an asymmetric tail that extends more in the direction of more positive values, whereas the distribution of the major and intermediate diameters has an asymmetric tail that extends more in the direction of more negative values.

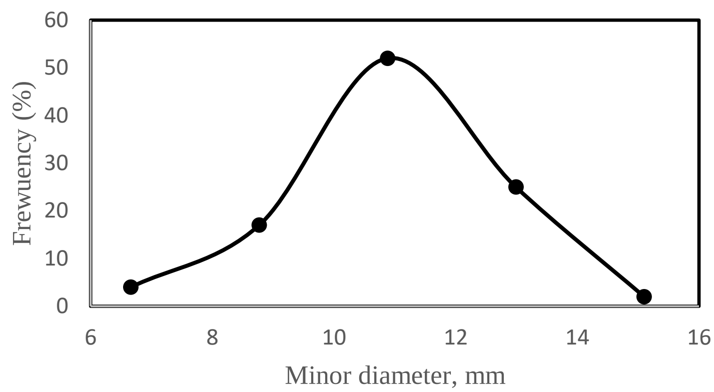

Fig. 3: Frequency distribution of the kernel minor diameter

The variation in the physical characteristics of African oil bean seed and kernel (Table 3) makes it impossible for the data obtained by Asoegwu *et al*. (2006), Alonge and Etim (2011) and Ndukwu (2013) to be used for design of machines to process the kernel efficiently.

4.0 CONCLUSIONS

The investigations carried out on some physical properties of African oil bean kernel showed that the result is different from the values obtained for African oil bean seed by various researchers. The major, intermediate and minor diameters of the seeds are in the range of 36.01 – 84.51 mm, 24.75 – 56.90 mm and 8.21 – 19.34 mm, respectively. These values are higher than the principal axes dimensions of the kernel which are in the range of 27.09 – 76.98 mm, 21.40 – 54.40 mm, and 4.56 – 15.10 mm respectively for the major, intermediate and minor diameters. The sphericity of the seed and kernel were found to be 0.53 and 0.51 respectively. These data obtained for these properties are very useful in the design of postharvest machines for the kernel. This will help to eliminate the drudgery involved in manual processing of the African oil bean.

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